# OUTCOMES OF PALATOMETRY THERAPY AS PERCEIVED BY UNTRAINED LISTENERS

by

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# ABSTRACT

The goal of this study was to determine the effectiveness of speech therapy using palatometry on *activity limitation* (World Health Organization [WHO], 1997) for speakers with speech impairments. Prior to this study, three adults and four children received a course of therapy using the palatometer. All of the speakers had previously plateaued in their improvement using traditional speech therapy techniques.

Following approximately 20 sessions using the palatometer, narrow phonetic transcriptions showed notable gains in phonetic accuracy. Post-therapy palatograms showed approximations which were considered closer to normal than pre-therapy productions. The transcriptions and palatograms provide indices of *impairment* (WHO, 1997). Specifically, accuracy of phoneme production is measured. However, the question of whether or not the gains resulting from therapy reduce activity limitation remain unaddressed by such measures. The speakers' own perceptions of improvement were one indication that reduction in activity limitation was an outcome of therapy.

To assess effects on activity limitations, sixteen untrained listeners (who were unfamiliar with disordered speech) were asked to perform two tasks. The first, a judgment task, involved choosing which of two sentences (one pre-therapy and one post-therapy) was "easier to understand."

The second was an identification task with two parts. Listeners orthographically transcribed a set of ten words which contained in total seven to ten phonemes that had been targeted in therapy. They also transcribed three sentences. These tasks were performed by the listeners for each of the seven original speakers.

Word transcription and goal phoneme identification within the word transcription by the untrained listeners improved significantly for five of seven of the speakers involved in therapy. An improvement between 11% and 30% in word identification and goal phoneme identification appeared to result in untrained listeners judging post-therapy samples as "easier to understand" in the judgment task. In general, the untrained listeners were least successful in noting improvement for adults with mild speech disorders. Speakers with mild impairments whose initial intelligibility was high (i.e., 90% or better) seem to require greater improvement than speakers with severe impairments, if gains are to be noticed by the untrained listener.

The perception of untrained listeners in this study indicated that palatometry therapy provided an effective method of reducing limitations on the activity of producing intelligible speech for speakers with a variety of speech disorders.

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# DEDICATION

To my beautiful family, and my wonderful Brett,

for bringing so much love into my life.

# CHAPTER 1

# INTRODUCTION

The current study evaluated the outcomes of a course of palatometry therapy as judged by untrained listeners. Key to this evaluation are the concepts of *activity* (World Health Organization [WHO], 1997), intelligibility and outcomes measurement. The first section of the introduction will describe the WHO's (1997), framework for categorizing human functioning. This framework will be related to the measurement of speech therapy outcomes. Secondly, intelligibility measures will be examined and considered in terms of their relationship to the WHO (1997) model. Finally, a brief overview of palatometry in speech remediation will be given.

## A CLASSIFICATION OF HUMAN FUNCTIONING: IMPAIRMENT, ACTIVITY, AND PARTICIPATION

The World Health Organization (1984) originally proposed an international classification system which focused on three major concepts: impairment, disability, and handicap. In 1997, the original framework was revised in the form of the

*International classification of impairment, disability and handicap - 2 (ICIDH-2).* The concept of *impairment* remained unchanged and is defined as, "a loss or abnormality of body structure or of a physiological or psychological function" (WHO, 1997, p. 2) . However, disability and handicap have been redefined as *activity limitations* and *participation restrictions* respectively. According to the WHO (1997), activity is "the nature and extent of functioning at the level of the person; activities may be limited in nature, duration and quality" (p. 2). Participation is "the nature and extent of a person's involvement in life situations in relation to impairment, activities, health conditions and contextual factors; participation may be restricted in nature, duration and quality" (WHO, 1997, p. 2). The biggest change represented in the concepts of activity limitation and participation restriction is that they are not inherently negative; they contain both a positive and a negative aspect; activity is the positive aspect, while activity limitation is the negative aspect, and, similarly, participation is the positive aspect, while participation restriction is the negative aspect.

The ICIDH-2 also considers *contextual factors* at both the environmental and personal level; these can be features of the physical or social attitudinal world and act positively as facilitators or negatively as barriers. The three levels of disablement (impairment, activity limitation, and participation restriction) do not form a causal chain. Rather they result from interactions between health conditions (disorder or disease) and contextual factors.

These changes represent a movement away from more medically oriented models whose primary goal is to classify disease, to a bio-psycho-social model which examines human functioning at all levels: the body, the whole person, and the person within society and the physical environment (WHO, 1997).

## Application to Speech Therapy

The WHO ICIDH-2 model helps to conceptualize what is being targeted and evaluated over the course of speech therapy, thereby helping the clinician and researcher to consider the person with a speech disorder at all levels of functioning. It is conceivable that, in a course of therapy, all three levels of disablement could be addressed. For example, working on improved placement of articulators targets the loss of function or impairment. Generalization of a treatment target to conversational speech can increase a person's activity level in communication, because those listening to the speaker are more likely to understand what is said, thereby reducing limitations. Caregiver and public education may help to reduce stigma associated with speech impairments, and thereby reducing participation *restrictions.* Considering all levels of disablement will help us formulate more functional and clearly defined outcome measures which address the client's activity and participation levels.

Speech therapy outcome studies often focus on speech measures such as articulation scores, phonetic transcriptions and, in the case of palatometry therapy, palatograms (e.g. Albery & Enderby, 1984; Fletcher, 1989; Michi, Suzuki, Yamashita, & Imai, 1986; Michi, Yamashita, Imai, Suzuki, & Yoshida, 1993). Speech measures evaluate impairment very specifically; they assess speech as a function of the oral motor structures and identify abnormalities in that function. Problems arise from anatomical or motor abnormalities. These types of measures can be compared pre- and post-therapy, and are widely used because of clinicians' and researchers' perceptions that they are more efficient and more easily obtained than other methods of evaluation (Morrison & Shriberg, 1992). Speech measures provide information about specific phonetic segments and word structures; outcome measures assess whether or not a specific phoneme or structure is produced more accurately post-therapy as compared to pre-therapy.

In contrast, the ICIDH-2 emphasizes that impairment measures alone are not reliable predictors of functional outcome. In addition, each person's activity level and social *participation* must be considered. Therefore, speech therapy outcomes should assess *activity* in terms of communication ability, and participation in terms of the nature and scope of social relationships and exchange of relevant information. Further, contextual factors such as confidence in and familiarity with communication situations, communication environments, and communication partners should be addressed at all levels.

# ISSUES IN INTELLIGIBILITY

Intelligibility measures attempt to assesses overall communication rather than just speech as a function. Therefore, they move away from the level of the body towards the level of the person's activities. The *listener-speaker interaction* is integral to intelligibility measures. This section will examine different types of intelligibility measures and their relationships to the WHO (1997) model of human functioning.

## Definition

Schiavetti (1992) defines *intelligibility* as "the match between the intention of the speaker and the response of the listener to the speech passed through the transmission system" (p. 13). Generally, measures of intelligibility are used to determine how well a speaker is understood by a listener. Accordingly, intelligibility is an index at the activity level of the ICIDH-2 (WHO, 1997) framework. The speech disorder interacts with contextual factors such as the listener and the physical environment to determine the level activity limitation for the person with a speech disorder.

Osberger considers intelligibility to be a measure of *communicative effectiveness*, "the ability to use speech to communicate effectively" (Osberger, 1992, p. 234). Intelligibility measures could thus be designed to go beyond activity limitation to include participation restriction if they index, for example, a person's involvement in social situations, or if they include measures of speaker and listener perceptions of the person's social adequacy.

The abilities of both the speaker and the listener play an essential role in the outcomes of intelligibility measures. Consequently, it is important to consider models of language comprehension when examining how listeners come to understand speech.

## Models of Language Comprehension

Intelligibility involves comprehension of the speaker by the listener. In order to comprehend a word a listener must associate phonetic form with lexical meaning. Comprehension models (e.g. Marslen-Wilson, 1987; Carpenter, Miyake, & Just, 1994, 1995) have attempted to account for listeners' differing abilities to understand speech signals, especially when the signal is degraded. These models hold that the semantic and syntactic context of a signal work in parallel to activate a cohort of word forms. This aspect of the model accounts for the ability of listeners to "predict" a word before the necessary acoustic-phonetic information has been presented (Pichora-Fuller, 1996). Word forms within a cohort are activated at different levels. Sensory, lexical, syntactic, semantic and pragmatic levels all contribute information in parallel to activate different word forms to different degrees. Frequency of different word forms also contributes to activation levels. When a word form reaches the threshold of activation, the word is comprehended by the listener. It is clear when examining models of comprehension that any degradation in the sensory, lexical, syntactic, semantic or pragmatic levels could result in the activation of a word form other than the word spoken by the speaker and a misunderstanding could occur. The different types of context that the listener is presented with allow him/her to resolve ambiguities and to choose one word form over another. Therefore, the addition or subtraction of context could greatly affect the listener's ability to comprehend speech.

Further, Carpenter et al. (1994) emphasize the importance of working memory in comprehension. Working memory includes both storage and processing components. In order to use context to decode a speech signal, the listener must use working memory to perform computations such as syntactic parsing, thematic role assignment, comparison, integration of information, inference, and referential assignment. Working memory is used to store current levels of activation and compute changing levels of activation. As the demands of storage or computation increase greater resources are required for comprehension. When this happens one function's capacity may be diminished in order to allocate functions to the other. The result can be slower processing if storage resources are reallocated to processing resources because it takes a greater number of cycles for a form to reach activation. Conversely, if resources from processing components are reallocated to storage components, a form may be forgotten because ambiguity cannot be resolved through increased activation of one form. Exceeding the capacity of working memory can result from ambiguity, syntactic complexity or processing time that is too short. Individual differences in working memory capacity are known to be highly correlated to language comprehension ability. A person with a low working memory span would need to reallocate resources from storage to processing to accomplish comprehension in challenging conditions even though a person with a high working memory span may not need to do so. When the speech input is degraded there is a reduction in storages as listening becomes effortful. Conversely, storage improves when the clarity of the speech signal is enhanced, either auditorally or visually (Pichora-Fuller, 1996). Pichora-Fuller (1996) concluded that the combination of visual and auditory information not only increases perception but secondarily, effectively increases the memory capacity that can be allocated to storage because the uptake of information consumes less processing resources. This is an important consideration in intelligibility measures since intelligible speech provides more context for the listener and decreases the demands on working memory. Conversely, unintelligible speech decreases context (i.e., articulatory, prosodic, etc.) and could increase the demands on working memory, especially for listeners with low working memory capacity.

The following section will outline some of the methods which have been established to measure intelligibility, describing their strengths and weaknesses and presenting research findings relating to different measures.

## Measures of Intelligibility

There is some general agreement among clinicians and researchers about the concept of intelligibility. It has been used widely to rate severity of disorder and monitor progress; however, there is little agreement about how best to measure it. Intelligibility can vary between speakers with similar disorders and even within an individual. Findings by Shriberg, Kwiatkowski, Best, Hengst, and Terselic-Weber (1986) indicated that a Percentage of Consonants Correct score in continuous speech only accounts for 20% of the variance in the intelligibility of children's productions. Such findings have prompted researchers to look more carefully at contextual factors and the nature of the speech disorder when considering intelligibility measures. The variance in intelligibility scores between children has been associated with factors such as utterance length and fluency, word position in the utterance, intelligibility of adjacent words, phonological complexity, grammatical form and syllabic structure (Weston & Shriberg, 1992). Shriberg and Kwiatkowski (1982) found relationships between variability in intelligibility and a child's specific pattern of error types, productive language status and profile of prosody-voice involvement. For dysarthric speakers, variation in intelligibility scores has been attributed to articulatory function (Platt, Andrews, & Howie, 1980), fine motor control (Barlow & Abbs, 1986) and rate of speech (Yorkston & Beukelman, 1981b).

Speaker and listener variables such as level of fatigue and familiarity have also been associated with different levels of intelligibility (Kwiatkowski & Shriberg, 1992). Characteristics of the speech signal and listener variables such as discussed in the above section also affect comprehension. These kinds of variables make intelligibility assessment very difficult and must be kept in mind when considering intelligibility measures.

## Scaling or Judgment Procedures

Scaling procedures involve asking listeners to make a judgment about a speech sample and then to quantify that judgment by placing it on a scale. The *equal-appearing interval scale* is the most widely used in intelligibility testing (Schiavetti, 1992). The listener assigns a number which corresponds to an interval on the scale to each speech sample. Commonly, scales consist of 5, 7, or 9 points, odd numbers being used so that scales contain a beginning, middle, and end point. Schiavetti (1992) reports common endpoint descriptors as "1 = Speech is completely unintelligible" and "5 = Speech is completely intelligible." With this procedure, the intelligibility of each speech sample can be determined as the mean of the ratings given by all the listeners. High test-retest reliability has been reported by some researchers for this type of intelligibility measure (Darley, Aronson, & Brown, 1969; Samar & Metz, 1988; Subtelny, 1977).

Another type of scale which has been used in intelligibility measures is *direct magnitude estimation* (Schiavetti, 1992). This scale procedure is based on ratios; a listener rates one speech sample in comparison to another. The experimenter can assign a rating to a standard speech sample which listeners use for comparison when making their rating, or listeners may make their own rating of an initial standard speech sample and compare following speech samples to it when making subsequent ratings. In the second case, it is necessary to make corrections for variability between listeners' ratings of the standard speech sample before performing any analysis (Schiavetti, 1992).

The major disadvantage of scaling is that speech intelligibility cannot be fit with a linear model. Psychologically, listeners cannot divide a scale into equal intervals. They tend use a more categorical or ordinal method of dividing the scale into units (Schiavetti, 1992). This decreases the construct validity of scaling procedures, because the underlying assumptions are not warranted. In fact, Schiavetti, (1992) states that, "interval scaling is inappropriate for the measurement of speech intelligibility" (p. 24). It has been suggested that interval scaling may not show differences between speakers with intelligibility in the mid-range (20% to 80%) (Samar & Metz, 1988). Direct magnitude estimation does avoid this downfall and, therefore, may be more appropriate for measuring intelligibility. Schiavetti (1992) points out, however, that the major disadvantage of this mode of scaling is its clinical utility. Data are complicated to analyze and to express to other professionals and family members but for research purposes, direct magnitude estimation is the superior of the two scaling methods.

## Identification Tasks

Identification tasks require listeners to listen to speech samples and write down what they hear. The outcome measure for these tasks is the degree of accuracy, i.e., the percentage of correctly identified single words or the percentage of correctly identified words within continuous speech. Schiavetti (1992) argues that, due to their high reliability and validity, identification tasks should be used instead of scaling procedures despite any differences in ease of use. A study by Monsen (1978) examined the relationships between acoustic parameters of speech and word identification tasks and found that predictions of intelligibility from acoustics of speech and word identification tasks were similar. Beukelman and Yorkston (1979) investigated the relationship between information transfer and identification tasks. They asked listeners to answer content questions about a paragraph spoken by a person with dysarthria, as a measure of information transfer. They demonstrated a high correlation between information transfer and word identification in both single words and continuous speech. Shriberg and Kwiatkowski (1982) point out that continuous speech identification measures allow for the use of *Percent Consonants Correct* (*PCC*) to assess severity of involvement. This allows the clinician or researcher to examine speech at the phoneme level while considering all the variables relevant to intelligibility, such as listener familiarity.

There are a number of test formats which can be employed with identification tasks. First, the response options can be from an *open* or *closed* set. Open-set identification requires listeners to write down what think they hear; words can be scored as correct or incorrect to yield a percentage correct score. Alternatively, for word identification in sentences, the words in the sentences can be weighted. For example, function words may be given a lower score than content words due to their high predictability (Monsen, 1978). The *Assessment of Intelligibility of Dysarthric Speech* (*AIDS*) (Yorkston & Beukelman, 1981a) is an open-set identification task which is used clinically. A closed-set identification task involves listener selection of the word he/she thinks he/she has heard from a number of alternatives. The *Speech Intelligibility Evaluation* (*SPINE*) (Monsen, 1981) and the *Speech Pattern Contrast* (*SPAC*) *Test* (Boothroyd, 1985) are both examples of closed-set identification tasks that are used clinically. The *SPINE*, which was developed for speakers with hearing impairments, has been shown to have a correlation of .86 with scores on open-set intelligibility tests, suggesting that closed-set measures can be as useful for determining speech intelligibility levels as open-set measures (Monsen, 1981). Osberger (1992) compared open- and closed-set identification methods for children with hearing impairments and found that closed-set sentence tasks may provide more meaningful information about intelligibility when the speaker's speech production is limited. Presumably context is thus maximized for the extremely unintelligible speaker, giving listeners the "best chance" of identifying the words which are spoken.

A major advantage of a closed-set method is that tasks can be more easily designed to yield descriptive data. For example, initial consonant voicing can be examined by having the speaker say, *ban*, and subsequently having the listener choose between *pan* and *ban*. Their data are quicker and easier to evaluate than individual listener's identifications.

It has been suggested to this point that identification tasks ask a listener to identify a single word or to identify words in a sentence. While the methodological distinction between the two is clear, it is important to consider the consequences of choosing one type of task over the other. Osberger (1992) points out that, in spontaneous speech samples, linguistic competency may affect the intelligibility of speakers with a hearing impairment. If the grammatical features of a sentence conform to those which the listener is accustomed to, it will be easier to identify the words in the sentence. Syntactic errors may decrease the supportive structure available to the listener. Obviously, this source of variation does not exist in single word identification. Carney (1986) found that the intelligibility of children with hearing impairments varied as a function of syntactic ability.

In a study that compared the single word intelligibility scores and sentence intelligibility scores of speakers with different severities of dysarthria, Yorkston and

Beukelman (1981b) found that while sentence intelligibility scores tended to be higher than single word intelligibility scores, ratings of speakers' severity were similar. Yorkston and Beukelman (1981b) go on to point out that speaking rate is accounted for in sentence intelligibility scores, but not in single word scores, when considering communication efficiency. Communication efficiency is the amount of speech which is understood in a given amount of time. For example, a sentence which is 100% intelligible may not be efficient in communication if it takes an exceptionally long time to produce. Between speakers, speaking rate may not be predictive of intelligibility; a person with a very slow speaking rate may be the most or the least intelligible (Yorkston & Beukelman, 1981b). However, within a speaker, intelligibility may vary depending on rate. Also, the interaction between intelligibility and rate determines how much information is conveyed. For example, if decreasing the speech rate results in increased intelligibility, slower speech may by more efficient in communication but if slower speech does not effect intelligibility, faster speech may be more efficient in communication. Communication efficiency can only be measured in sentence level tasks. Yorkston and Beukelman (1981b) also discuss the relationship between the severity of dysarthria and task selection; people with severe dysarthria may be best served by closed-set word identification tasks, because fatigue is an issue and progress may be subtle over time. For people with mild to moderate dysarthria, it may be more informative to choose sentence level tasks or a combination of measures, so that all the factors effecting intelligibility can be examined, and communicative efficiency can be considered.

In sentence identification tasks other suprasegmental factors such as prosody and pitch contribute information in sentence identification tasks that is not as prevalent in word identification tasks. Osberger (1992) states that correlational analyses have shown that excessive, inappropriate pitch changes resulting from poor phonatory control have a strong negative effect on intelligibility. Further, a study by Maassen and Povel (1984) corrected intonation and temporal distortions in the digitized speech of clients with hearing impairments. They found that these corrections resulted in statistically significant improvements in intelligibility.

Greenberg (1997) states that speech recognition systems which identify words through analysis of their underlying phonological constituents have difficulty recognizing speech under real world conditions such as background noise, reverberant acoustic environments and spontaneous, informal conversation. Greenberg (1997) proposed that speech is represented by a number of levels of linguistic abstraction, all of which are necessary for intelligibility in the "real world." According to Greenberg (1997), word frequency, pronunciation variability, syllable frequency and syllable segmentation are all used by listeners when identifying words. These findings support the conclusion that the amount of information other than segmental information available in a speech sample is an important consideration when evaluating intelligibility measures.

Overall, it seems that identification tasks should be chosen very carefully with special consideration for the type of information that will be useful for a given client and what that client is capable of producing. Issues surrounding the severity of the speech disorder, the goals of the clinician, researcher, or client and the purpose of the evaluation are all relevant when choosing the type of identification task to be used.

## Further Consideration of Variables in Intelligibility Measures

A number of variables have been discussed above that affect intelligibility. Here I discuss further issues related to stimuli, phonological and grammatical form, and listener experience.

The selection of stimuli can greatly affect intelligibility scores. Context and linguistic redundancy can be manipulated in speech samples. The general finding has been that the greater the amount of context, the higher the intelligibility scores. This means that sentence identification tasks generally result in higher intelligibility scores than single word identification tasks, because of the increase in context. McGarr (1983) measured intelligibility of speakers with profound hearing loss with both high- and low-predictability sentences. Intelligibility for target words in high predictability sentences was approximately 16% higher than for target words in low predictability sentences. Sitler, Schiavetti and Metz (1983) found that, for the speech of people with hearing impairments, context effects were observed except for the most unintelligible speakers, whose scores for word and sentence intelligibility were both very poor and not significantly different depending on the availability of supportive contest. Presumably, when speech reaches a certain level of unintelligibility, contextual cues are no longer helpful in identification. Context itself may become unintelligible. Another way to increase or decrease context is by manipulating the listeners' access to visual cues. When visual information is available, cues are provided in the speaker's gestures and facial expressions. Osberger (1992) emphasizes the importance of lip reading by the listener. Monsen (1983) found that, when listeners could see a hearing impaired speaker, intelligibility scores improved by approximately 23%.

In a study by Sumby and Pollack (1953), speech intelligibility tests were conducted with and without visual information from the speaker's facial and lip movements. The speech-to-noise ratio and the size of a closed-set vocabulary was varied under both conditions (with and without visual cues). Sumby and Pollack (1953) found that: (1) a smaller closed set of responses resulted in a greater tolerance for noise interference, and (2) in the condition where visual information was present, there was a greater tolerance for noise interference. In terms of language comprehension models, it is possible that a smaller set of vocabulary options aids working memory in eliminating cohorts and limiting the number of computations of activation when the signal is highly degraded. This could allow increased performance under less than ideal acoustical/perceptual conditions. Further, Pichora-Fuller (1996) found that visual information can decrease the resources needed for uptake of information in working memory and thereby allow comprehension of degraded signals which this would be impossible without visual cues. These findings help to explain why closed-set identification tasks can be more sensitive than open-set identification tasks. Further, they emphasize the role of context and the need to consider factors involved in processing speech and language when intelligibility is measured.

Other variables within the stimuli arise from the nature of phonological and syntactic cues. Monsen (1983) found that sentence intelligibility for hearing-impaired children improved by approximately 17% with familiar vocabulary, simple syntax, and a reduced number of consonant clusters and polysyllabic words.

## Listener Variables

A consistent finding within the intelligibility literature is that listeners experienced in listening to disordered speech have higher scores on intelligibility measures (McGarr, 1983; Monsen 1978; Monsen, 1983). Further, Beukelman and Yorkston (1980) found that speech-language pathologists' estimates of intelligibility for mild, moderate, and severe dysarthric clients regularly overestimate intelligibility scores by untrained listeners on word identification tasks for the same samples. These findings are relevant because the intelligibility tests tend to be given, most often, by clinicians who are familiar with disordered speech.

## Summary

Phonological and articulation disorders have traditionally been evaluated using articulation or phonology tests. However, researchers such as Peterson and Marquardt (1981) have argued that, although articulation and speech intelligibility are related, they are not identical. Articulation tests only assess one level of the overall speech disorder, the level of impairment.

However, different contextual factors are present when a person's day to day activity is considered. The most important factors which are relevant to the measurement of intelligibility include listener abilities and experience and contextual cues. Therefore, speech can also be evaluated as part of communication, and listener variables should be considered to be a critical part of the equation. While speech and intelligibility measures are related, they address different levels of functioning. Intelligibility measures can go beyond impairment to evaluate level of activity in daily life. Activity limitation to the speaker may be especially important to consider in outcomes measures, because any relevant therapy should result in a change outside the clinic, in the client's everyday life.

# PALATOMETRY AS A THERAPY APPROACH

Palatometry (electropalatography) is an auditory-visual feedback system which provides an on-line, real-time representation of tongue contact against the hard palate. Clients wear custom-fit acrylic pseudopalates which contain electrodes. The current study used a Kay Elemetrics Palatometer (1996 model), which contains ninety-six electrodes. Electrodes are connected via fine wires to external circuitry. When the tongue touches the area in which electrodes are buried in the pseudopalate, an electronic circuit is completed. The electrodes are represented on a computer screen. These points are highlighted when there is contact in that area. Contact patterns and sound files of the productions can be saved and replayed so that the speaker may compare his/her current performance to previous ones or to the clinician's target. This gives the client both visual and auditory feedback about their production. Palatograms can also be printed from the computer screen so that comparisons and analyses can be made at different points in the course of intervention.

Two major applications of palatometry have been represented in the literature; (1) the description of tongue movement in normal and disordered speech; and (2) the treatment of phonetically and phonologically-based speech disorders. The current study was concerned primarily with therapy applications.

The palatometer has been used successfully as a therapy technique with a number of disorder groups: speakers with repaired cleft palates; (Dent, Gibbon &

Hardcastle, 1992; Michi, Suzuki, Yamashita, & Imai, 1986; Michi, Yamashita, Imai & Ohno, 1990; Michi, Yamashita, Imai, Suzuki, & Yoshida, 1993) and speakers with unrepaired cleft palates (Fletcher, 1985; Gibbon & Hardcastle, 1989; Whitehill, Stokes, & Man, 1996), speakers with hearing impairment (Crawford, 1995; Dagenais, 1992; Fletcher, Dagenais & Critz-Crosby, 1991), speakers with motor speech disorders (Goldstein, Ziegler, Vogel & Hoole, 1994; Howard & Varley, 1995; Morgan, 1992; Morgan, 1995) and people with primarily articulation and phonological speech disorders (Dagenais, 1995; Dagenais, Critz-Crosby & Adams, 1994; Gibbon & Hardcastle, 1987; Gibbon, Dent & Hardcastle, 1993; Dent, Gibbon & Hardcastle, 1995; Gibbon, Hardcastle, Dent & Nixon, 1996; Howard, 1995). In all of these studies the speech disorders were generally considered to be intractable.

In a representative treatment study, Fletcher, Dagenais and Critz-Crosby (1991) conducted palatometry therapy with five profoundly hearing impaired children. Overall, they concluded that, "considering the amount of prior speech treatment subjects had, the gains made in a brief time period (three to four weeks) were remarkable." However, Fletcher et al. (1991) did note that speakers whose intelligibility fell into the mild range improved the least. They suggested that someone with a mild disorder has to make minor phonetic adjustments in long-established habits. This may be more difficult than learning to make new phonological distinctions, as has to be done by speakers with severe disorders. Further, the study found that residual problems such as nasality and voicing were not addressed by palatometry therapy.

This study and others like it have based their outcomes on speech measures such as palatograms and narrow phonetic transcription. In terms of measures of impairment a number studies such as Fletcher et al.'s (1991) indicate that palatometry is a valuable treatment option across a number of disorder types and age groups. However, it is important to consider whether palatometry outcomes generalize to daily life and increase activity levels.

In the following section, the palatometry treatment study on which the current study is based, will be described.

## The Background Palatometry Study

Prior to the present study a speech therapy study was conducted (Bernhardt, Bryer, Haynes, Loyst, & Muir, in preparation). All of the speakers except one had had several years of previous conventional speech therapy outside the university setting, without any recent continuing notable improvement. A stable baseline was confirmed using conventional articulation therapy (6-8 sessions over 4-6 weeks on average). This was then followed by a palatometry treatment program of 20 sessions distributed across 14-16 weeks of contact time. The program had two, four-week blocks of eight sessions each, followed by a one- to three-week treatment break, and then a maintenance phase (four sessions over four to six weeks). The exact time frame of the treatment period varied for each speaker due to personal concerns such as vacation, work, or school commitments, or illness. Also, some speakers waited longer than others to receive a suitable palate, extending the pre-palatometry phase (specifically Delia, Dora, and Dana). In order to evaluate the relative effectiveness of palatometry across ages and disorder types, this project included five adults and four children with a variety of impairments: significant hearing impairment, cleft palate, and/or motor impairment. Clients were seen at the university by one of two certified speech-language pathologists, who worked closely with each other and the principal investigator (Bernhardt). The current investigator was not one of the original project personnel.

Speech measures used for the original study were based on audiotaped samples (pre- and post-treatment), palatograms (pre- and post-treatment), and the speakers' and clinicians' impressions of improvement. Comparison of pre- and post-therapy transcriptions and palatometric data showed observable gains for all speakers (Bernhardt et al., in preparation). Clinicians and speakers reported that they perceived an improvement in speech production over therapy sessions. However, the question remained as to whether or not these gains were relevant to the speakers in their daily lives.

## Speakers

The speakers from the original study who underwent palatometry therapy represented a variety of disorder types and age groups. Three speakers' pre- and/or post-therapy audiotapes were unusable as experimental stimuli for this study, so that only seven speakers' tapes were used. This section outlines each of the seven speakers' history, therapy goals, and progress.

### Speaker: Stan

Stan was born with a cleft lip and palate. He underwent both a lip and palate repair in his first year of life. Subsequent surgeries included: a fistula repair at age 4;3, a columellar lengthening at 7;4, an alveolar graft at age 11, and a maxillary advancement at age 16. A speech assessment report at age 18 from the local cleft palate team indicated that Stan was still exhibiting mild velopharyngeal incompetence, with slight and inconsistently audible nasal emission. Stan's speech sound production was judged to be the most obvious contributor to his speech impairment. The speech assessment report noted the following:

1. Palatalization of /t/, /d/, and /n/
2. Lateralized and palatalized distortions of /s/ and /z/

Stan's intelligibility was judged by the clinician to be 100%, even when the context was unknown, because of the predictability and consistency of his speech sound production errors. Stan did recognize the potential for his speech to improve, and was motivated to continue speech therapy.

For the palatometry project, Stan's pre-therapy tape was made in February, and his post-therapy tape was made in December of the same year (10 months later). He participated in palatometry therapy between May and December when he was 19 years of age.

Speaker: Delia

Delia was born with a cleft palate and she had undergone several surgeries for the treatment thereof. An anterior palatal fistula remains but is considered unsymptomatic for speech or eating by the cleft palate team at the local hospital.

A speech assessment at age 28 by the local cleft palate team, revealed the following:

1. Glottal stop substitutions for /k, t, d/ in word initial position
2. A pharyngeal fricative substitution for initial, medial, and final fricatives
3. Glotto-pharyngeal affricates substituted for palato-alveolar affricates

Many of the consonants in error were produced with simultaneous oral articulations; however, the reporting speech-language pathologist considered that the primary articulation was glottal. When context was unknown, intelligibility was good (90%), due to consistent and predictable errors. Velopharyngeal competency was adequate for speech; minimal hyper- or hypo-nasality was noted in conversation.

Delia's pre-palatometry probe was in April and her post-palatometry probe was in March of the following year (11 months later). Delia participated in palatometry therapy between July and October when she was 29 to 30 years old. She waited four months for her palate to arrive and therefore had a longer no-palate baseline period (8 sessions) and a reduced palatometry period. At the time of referral for palatometry therapy, Delia was perceived to be highly motivated. She was interested in improving her speech and was concerned about others' impressions, especially since she was starting a new business.

Speaker: Dana

Dana was born with a bilateral cleft lip and palate. Her lip was repaired at the age of 4 months, and a palatal repair was done at age 1;10. A pharyngoplasty was performed at age 4;5 and another prior to this study (age 8). Pharyngoplasty narrows the velopharyngeal isthmus in order to improve closure and reduce hypernasality. Due to continued velopharyngeal incompetence, a speech bulb reduction program was initiated at age 6;0. A speech bulb is a bulb-shaped prosthetic which sits in the velopharyngeal port to facilitate closure during the production of oral sounds. Palatal function significantly improved and hypernasality was reduced following speech bulb placement.

A speech assessment at age 8;0 by the local cleft palate team revealed the following errors in speech sound production:

1. Mild palatal distortions of /t/ and /d/
2. Velar distortions of /ʃ/, /r/, and /l/
3. Inconsistent interdental distortions of /s/, /n/, and /l/

Intelligibility was rated by the clinician at 95%; however, speech sound distortions were reported to be conspicuous in connected speech. Speech therapy was recommended for the improvement of these errors.

Dana's pre-palatometry probe was in February and her final one in September (7 months later). She participated in palatometry between May and August. She was 8 to 9 years old at the time of therapy. Dana received a longer pre-palatometry baseline (eight sessions) and only eight sessions (once a week) of palatometry because of a long delay in the making of her palate. Dana was still exhibiting a persistent small velopharyngeal defect which resulted in mild hypernasality and audible nasal turbulence on high pressure sounds with the speech bulb out.

Dana's pre- and post-therapy probes were elicited with her speech bulb both in and out. Because hypernasality is not addressed directly by palatometry, the choice was made to use samples taken with Dana's speech bulb in, to evaluate the effectiveness of her course of palatometry therapy.

Speaker: Devon

Devon experienced a cerebral hemorrhage at the age of 39, two years prior to his participation in the palatometry project. He underwent a craniotomy to evacuate the cerebellar hematoma. It was determined that Devon was born with a brainstem malformation that resulted in the brain hemorrhage. Following his brain injury, Devon was diagnosed with brainstem type spastic quadriparesis and bulbar palsy with associated dysphagia, dysarthria and ataxia. Devon's cognitive skills were minimally affected. However, he had some visual problems ("double vision") and a relatively strong emotional response to his life changes. A speech assessment report at age 40;4 from a local hospital indicates the following speech production errors:

1. Imprecise and/or distorted articulation of vowels and consonants
2. Voicing errors
3. Excess stress on usually unstressed parts of speech
4. Hypernasality
5. Abnormal pitch variations
6. Bursts of loudness

These observations from a previous evaluations represent a number of speech production difficulties at the suprasegmental level. These difficulties were addressed within the course of palatometry therapy, even though they were addressed without the palatometer. On the Assessment of Intelligibility of Dysarthric Speech (AIDS) (Yorkston & Beukelman, 1981a), single words to be intelligible 14% of the time, and sentences to be intelligible 62% percent of the time. It was noted that Devon exhibited poor self-monitoring skills.

Devon's pre-palatometry probe was in December and his final probe in November of the following year (11 months later). He participated in palatometry therapy between May and November.

Speaker: Dora

When Dora was eight months old, it was determined that she had been infected with the cytomegalo virus in utero. She exhibited calcification throughout her brain and a severe to profound hearing loss, with thresholds of 40 to 50 dBHL aided. At age 3;7, Dora lost all residual hearing, with no aided response at the output limits of the audiometer. She received a cochlear implant 4 months after that diagnosis, at age 3;11. Post-implant, Dora presented with thresholds at 250 to 4000 Hz of 30 to 35 dBHL, indicating a mild hearing loss. The implant allowed Dora to detect speech components up to at least 2000 Hz in a quiet background. She was able to identify single words in an open set with 45%, accuracy and did very well in context, identifying 77% of sentences presented. Dora has been enrolled in some form of speech therapy intermittently throughout her life, and uses total communication.

A speech and language progress report at age 7;4 from the school speech-language pathologist states that Dora had excellent sign language and receptive oral

English skills. She was performing well in a classroom for children with hearing impairment. Dora's poor speech intelligibility was identified as an area of weakness, and a report of her speech sound productions revealed the following:

1. /i/ replaced by /m/
2. /n/ replaced by /f/
3. /k/ and /g/ replaced by /t/ and /d/
4. Weak production or omission of /s/
5. Omission of word final sounds
6. Omission of /l/ and /r/

It was suggested that Dora was not using visual information sufficiently to help her form speech sounds. Concerns were also expressed about Dora's social development, because oral communication was so difficult that social opportunities were being avoided.

Dora's pre-palatometry probe was in February and her final probe was in March of the following year (13 months later). Palatometry treatment took place between October and March, approximately four years after receiving her implant. Dora waited a very long time for her custom-fit palate to arrive, so that palatometry therapy could begin. Dora wore a hockey mouth guard for a few minutes a day until her palate arrived. This helped her to get used to having something in her mouth, and decreased her reluctance to wear the custom-fit palate.

Speaker: Sandy

Sandy was born with a bilateral cleft lip and palate; she was diagnosed with Klippel-Feil Syndrome. Klippel-Feil Syndrome is characterized by hearing loss, palatal cleft, and facial asymmetry (Stengelhofen, 1989). She underwent a lip repair at age 4;0, and a palatal repair at age 1;2. Sandy also had bilateral myringotomies and tubes at 9 months, and again at 1;6. Sandy continues to have an anterior palatal fistula, which is occasionally symptomatic for nasal regurgitation of fluid. Her palatal function is considered sufficient for speech production. Sandy has a moderate to severe sensorineural hearing loss and a fluctuating conductive hearing impairment. She wears hearing aids bilaterally.

Sandy was enrolled in a speech therapy program throughout her preschool and school age years. She has a history of dysfluency which she uses strategies to control. In a speech assessment by the local cleft palate team when she was 9 years old, the following general observations were made:

1. Glottal stop and pharyngeal fricative substitutions
2. Assimilation errors
3. Nasal fricative substitutions

It was noted that, while the family noticed some improvement in speech sound production with traditional speech therapy, she had difficulty generalizing gains to conversation.

Sandy's pre-palatometry probe was in March and her post-probe was in December of the same year (9 months later). Sandy participated in palatometry therapy between May and November, when she was 9 years of age.

Speaker: Samantha

Samantha was born with a severe to profound hearing loss and some motor weakness of the oral musculature. It was determined that Samantha's mother had rubella while carrying Samantha. Samantha has some residual hearing in the right ear (low frequencies) and the left ear (high frequencies). Thresholds in her left ear are marginally better than in her right ear. She began wearing hearing aids at the age of 2. Samantha has soft palate paralysis and was fitted with a palatal lift at the age of 15. Her left cheek is weak and droops slightly, but tongue movement and strength are considered generally adequate for speech. Previous speech assessments from local clinicians had revealed difficulties with the following speech sounds:

1. /t/ and /d/
2. /k/ and /g/
3. /r/
4. /j/

Samantha lip-read and signed in Cantonese until the age of 9, when she began to learn English.

Samantha's pre-palatometry probe was in May and her post-palatometry probe was in January of the following year (8 months later). She participated in palatometry therapy between May and December. Samantha was 18 years old at the time of palatometry therapy.

## Pre-Therapy Severity

Many of the speakers in the original study had both segmental and suprasegmental speech disturbances. In order to quantify the severity of the speaker's speech impairment pre-therapy, each speaker was evaluated along a number of speech parameters: the greater the number of areas affected, the more severe the speech impairment. Ratings were determined by the experimenter, who was very familiar with the pre-therapy speech samples, and a transcriber from the original project. Table 1.1 outlines the speakers' severity ratings.

TABLE 1.1: Areas of difficulty before palatometry therapy.

| Speakers | Segmental | | | Suprasegmental | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Phonological | | | | | | | | | |
| | Phonetic Place | Consistent Substitutions | Omissions | Rate | Fluency | Volume | Voice | Intonation | Syllable Timing |
| Stan | × | | | | | | | | |
| Delia | × | × | | | | × | | | |
| Dana | × | × | | | | | × | | |
| Devon | × | | | × | | × | ×* | | × |
| Dora | × | × | × | | | × | | | |
| Sandy | × | × | × | | × | × | × | | |
| Samantha | × | × | × | × | × | | × | × | × |

Note: Where × occurs, this variable was a negative influence on speech production. Nasality was an issue for all speakers.

* Strained quality.

## FOCUS OF THE CURRENT STUDY

The discussion in this chapter emphasizes the importance of evaluating outcomes beyond the level of impairment when determining the overall effect of a therapy approach on the client. Palatometry has been seen as an effective tool in reducing impairment. However, very little work has been done on its effect on activity limitations. The relationship of therapy outcomes to activity and participation is perhaps the most relevant consideration for clients. The question addressed by the current study was whether or not palatometry therapy was able to reduce a set of speakers' activity limitations. Research hypotheses were generated to address this question.

## RESEARCH QUESTIONS AND HYPOTHESES

This study used the perceptions of untrained listeners to investigate the effectiveness of palatometry in speech therapy and the relationship of these effects to *activity limitations* (World Health Organization [WHO], 1997) for individuals with moderate to severe speech impairment.

Research questions and their associated hypotheses were as follows:

1. Do untrained listeners judge post-therapy speech samples to be easier to understand than pre-therapy speech samples?

   *Null Hypothesis 1:* There will be no reliable ratings of paired sentences according to whether they were produced pre- or post-treatment within or between speakers or listeners.

2. Are post-therapy gains significant enough to improve the accuracy of identification of words and sentences by untrained listeners?

   *Null Hypothesis 2:* There will be no difference in accuracy of identification across the pre- and post-treatment samples, either within or between speakers or listeners.

3. Is there an improvement post-therapy in the accuracy of identification of phonemes which were goals in therapy?

   *Null Hypothesis 3:* There will be no improvement in the identification of goal phonemes from pre- to post-therapy.

# CHAPTER 2

# METHOD

The goal of the current study was to determine the outcomes of a previous palatometry therapy study as perceived by untrained listeners. This section briefly describes the speakers from the original study who participated in palatometry therapy and goes on to consider the methods used evaluate outcomes for this current study.

## Summary of speakers

Table 2.1 presents a summary of the speakers, including age, history, and severity of speech disorder. Each speakers' goals for the palatometry project are also listed in the order they were addressed in palatometry therapy.

TABLE 2.1: Summary of speakers and their palatometry goals.

| Speaker | Age[a] | History | Goals | Severity of Speech Disorder |
|---|---|---|---|---|
| Stan | 19 | Cleft lip and palate | /s, ʃ, dʒ, t & st/ | Mild |
| Delia | 29 to 30 | Cleft palate | /t, d, k, g, θ, s & z/ | Mild |
| Dana | 8 to 9 | Cleft lip and palate | /t, d, s & l/ | Mild |
| Devon | 40 to 41 | Cerebral hemorrhage: dysarthria & ataxia | /t, d, k, g, s, ʃ/ Final clusters Control of pitch & loudness | Moderate |
| Dora | 8 to 9 | Profound hearing loss; cochlear implant | /g, s, d, ʃ, tʃ, r blends, & dʒ/ | Severe |
| Sandy | 9 | Cleft lip and palate; moderate hearing loss | /g, k, s, & θ/ | Severe |
| Samantha | 18 | Profound hearing loss; mild motor impairment | /r, k, ʃ & s/ | Severe |

(a) Represents age while participating in palatometry therapy.

# LISTENERS

Sixteen listeners, eight males and eight females, were recruited for this study. Listeners were required to have completed high school, be between 17 and 40 years of age, have normal hearing and speak English as a first language. Further, all listeners had no prior experience of disordered speech; they did not work with people with speech impairments, and did not have any close family members with disordered speech. The mean age of listeners was 25 (range of 17 to 32 years of age). Hearing tests were conducted on each listener including pure tone, speech discrimination, and speech recognition testing. In order to pass the eligibility criteria for the experiment, listeners had to have pure tone thresholds at or below 20dBHL at 500, 1000, 2000, 4000 and 6000 Hz, have a speech recognition threshold at or below 20dBHz, and a speech discrimination score over 88%. All listeners met these criteria; all had hearing within normal limits.

Listeners signed a consent form outlining the objectives and requirements of the study and were compensated with fifteen dollars for each hour of participation. They were required to attend two separate, one-hour sessions with the sessions being a minimum of two to three days apart. Table 2.2 outlines the specific characteristics of the listeners involved.

TABLE 2.2: Characteristics of listeners.

| Speaker Code | Age (17+) | Education (grade 11+) | Occupation | Gender |
|---|---|---|---|---|
| L1 | 29 | B.A. | Support work | Female |
| L2 | 32 | High School | Computer | Male |
| L3 | 30 | B.A. | Law student | Male |
| L4 | 25 | Diploma | Sales | Male |
| L5 | 24 | B.A. | Law student | Female |
| L6 | 24 | B.Sc. | M.A. student | Female |
| L7 | 20 | High School | Graphics | Male |
| L8 | 26 | B.Sc. | Researcher | Male |
| L9 | 20 | Diploma | Autobody | Male |
| L10 | 22 | B.A. | Law Student | Female |
| L11 | 25 | Diploma | Audio | Male |
| L12 | 29 | B.F.A. & B.A. | Artist | Male |
| L13 | 17 | Grade 11 | High school Student | Female |
| L14 | 26 | Diploma | Legal secretary | Female |
| L15 | 23 | Diploma | Student | Female |
| L16 | 25 | B.Sc. | Student | Female |

# EXPERIMENTAL SET-UP

Stimuli were chosen from audiotapes recorded during pre- and post-therapy assessments. Recordings were made under field conditions; an effort was made to keep the room as quiet as possible but natural background noise was present. Stimuli were recorded with a Marantz tape recorder and a PZM 33-1090B microphone. Pre- and post-therapy probes came from a list of 164 single words (Bernhardt, 1990), the Assessment of Intelligibility for Dysarthric Speakers (AIDS) (Yorkston & Beukelman, 1981a), the Rainbow passage and story retells focusing on targeted phonemes from C-PAC (1981). Appendix A lists the stimuli produced by each speaker.

All stimuli were digitized using the Computerized Speech Research Environment 45 (CSRE45) software (1995) and the Tucker Davis Technologies (TDT) hardware (1994). The Marantz tape recorder was connected to the TDT hardware system. The output of the tape recorder was connected to the input of the DD1, digital recording device, of the TDT which recorded directly into the Ecoscon program of the CSRE45 software, at a sampling rate of 20 kHz. Sound files could be edited and analyzed in the Ecoscon program. Sound files were stored on a 1 Gigabyte Jaz disk.

Once the sound files had been edited and saved, the Ecosgen program in CSRE45 was used to set up the experimental protocol. This program organizes sound files into blocks to be presented in random order with sound files within blocks also presented in random order. Corresponding pre- and post-therapy sound files could be paired for presentation within Ecosgen. The response interface for the listener was also specified within Ecosgen.

Stimuli were presented to the listeners using Ecoscon via the TDT (see Appendix B for set up of Tucker Davis Technologies modules). Participants listened through Madsen TDH 39P 10W headphones. Due to the different recording levels of the original audiotapes, sound files were attenuated or amplified during pre-processing so that pairs of stimuli were presented at similar levels as determined by the experimenter. Appendix C lists RMS values and voltages for all of the sound files. All stimuli were presented within comfortable listening levels in a sound-attenuating, double-walled Industrial Acoustical Company (IAC) booth.

## Judgment Task

A judgment task was designed to address the first null hypothesis. The goal of the task was to investigate whether untrained listeners found the speakers easier to understand post-therapy as compared to pre-therapy.

Stimuli for the judgment task consisted of ten pairs of sentences for each speaker from the AIDS, the rainbow passage and the story retells. Each sentence pair consisted of one pre-therapy (T1) sentence and one post-therapy sentence (T2). The ten pairs were presented in two orders; T1-T2 and T2-T1. Accordingly, twenty pairs of sentences for each speaker were presented to the listeners. In total, 280 sentences, or 140 pre-post pairs and 140 post-pre pairs, were used for this task. The selection of sentences was limited by the probes that were done pre- and post-therapy. Also, twenty pairs of sentences per speaker was the maximum that could reasonably be presented in an hour and a half. Whenever possible, the same sentence was chosen pre- and post-therapy to make up a pair. When the probes used pre- and post-therapy were not identical, sentences were matched as closely as possible for length, semantic content, and phonological complexity, thereby allowing listeners to make choices based on qualitative production differences between pre- and post-therapy samples with minimal influence of sentence complexity. Four of the seven speakers had sentence pairs which were not matched identically: Dana and Sandy both had twelve (of twenty) sentence pairs which were not identical, Stan had ten (of twenty) sentence pairs which were not matched identically; Devon had no identical pre- and post-sentences. For a list of all of the stimuli, see Appendix A.

Seven blocks (one per speaker) were presented to listeners; each block consisted of twenty pairs of T1 and T2 sentences from one speaker. The blocks were randomized along with the pairs within each block. Each listener heard four randomly selected blocks in the first one-hour session; the remaining three blocks were randomly presented in the second one-hour session. The randomized order prevented a systematic practice effect. For example, L1 might have heard Devon last when she was most experienced at listening to disordered speech, but L2 might have heard Devon first, when he was least experienced at listening to disordered speech.

The order of speakers presented to each listener was different, so that practice effects should not have had any systematic effect on the averaged results for each speaker.

During this task, listeners faced a computer screen which displayed two large squares marked 'A' and 'B.' After each pair of sentences, they were asked to make a two-alternative forced choice by selecting which sentence was easier to understand, sentence A or sentence B (see Appendix D for exact instructions). The wording of the instruction to listeners "to choose the sentence that was easier to understand" was intended to be general enough to provide little guidance to listeners, but sufficient to help them to focus on intelligibility rather than speech. They could make their selection by using the mouse to click on one of the squares. The next sentence pair would not be played until the listener had made a choice; however, the listener could not replay the sentences. A special notice came up on the screen telling listeners that they would be hearing a new speaker.

Afterwards, listeners were asked to write down what they thought they were basing their decisions on, and they were asked to rate the level of difficulty that they had in making this judgment for each speaker.

## Word Identification Task

In this task, listeners were asked to identify in writing 20 words for each speaker; 10 words from T1 and 10 words from T2. The same 10 words were chosen from T1 and T2 tapes. Words came from a list of 164 single words (Bernhardt, 1990). Since a number of speakers' tapes did not have all 164 full words lists pre- and post-therapy, ten words was the maximum that could be assigned to each speaker without exhausting the stimuli. The word list was randomized using a spreadsheet program. A list of ten words including between seven and ten of the phonemes targeted in therapy was constructed for each speaker. Substitutions were made to the list when the word chosen was not recorded at both T1 and T2. By including seven to ten goal phonemes, some words contained goal phonemes and some did not.

Fourteen blocks were designed using Ecosgen, seven blocks containing the pre-therapy words for each speaker and seven blocks containing the corresponding post-therapy words for each speaker. The pre-therapy words were presented to listeners during the first one-hour session and the post-therapy words were presented during the second one-hour session. The two sessions were a minimum of two to three days apart in an attempt to minimize any practice effects. Listeners completed the judgment task before starting the identification task so that they had some exposure to disordered speech when they began the identification task. Within each session, the blocks were randomized as was the presentation of the words within the blocks. Again, randomization was used to minimize practice effects.

During this task, listeners again faced the computer screen. The screen contained one large square labeled 'NEXT.' The listeners were asked to write down what they heard on a piece of paper and to click on the 'NEXT' button with the mouse when they were ready to hear the next stimulus (see Appendix D for exact instructions). As such, the time spent on each stimuli was determined by the listener;

however, they could not replay the stimuli. A special message was displayed to notify listeners when they would be listening to a new speaker.

## Sentence Identification Task

Three sentences from T1 and T2 were chosen from productions elicited using the AIDS (Yorkston & Beukelman, 1981a), the rainbow passage, and the story retells. Different sentences were selected for the pre- and post-therapy tasks. The procedure for the task was otherwise the same as for word identification.

# CHAPTER 3

# RESULTS

The current study used intelligibility measures to assess the effects of palatometry therapy on *activity limitation* (World Health Organization [WHO], 1997) as perceived by untrained listeners. Listeners completed judgment, and word and sentence identification tasks to assess the intelligibility of speakers with a variety of disorders who had completed palatometry therapy. This section outlines the research questions which motivated the listeners' tasks and the experimental results of each task.

1. Do untrained listeners perceive post-therapy speech samples as easier to understand when compared to pre-therapy speech samples?

*Null Hypothesis 1:* There will be no reliable ratings of the paired sentences according to whether they were produced pre- or post-treatment within or between speakers or listeners.

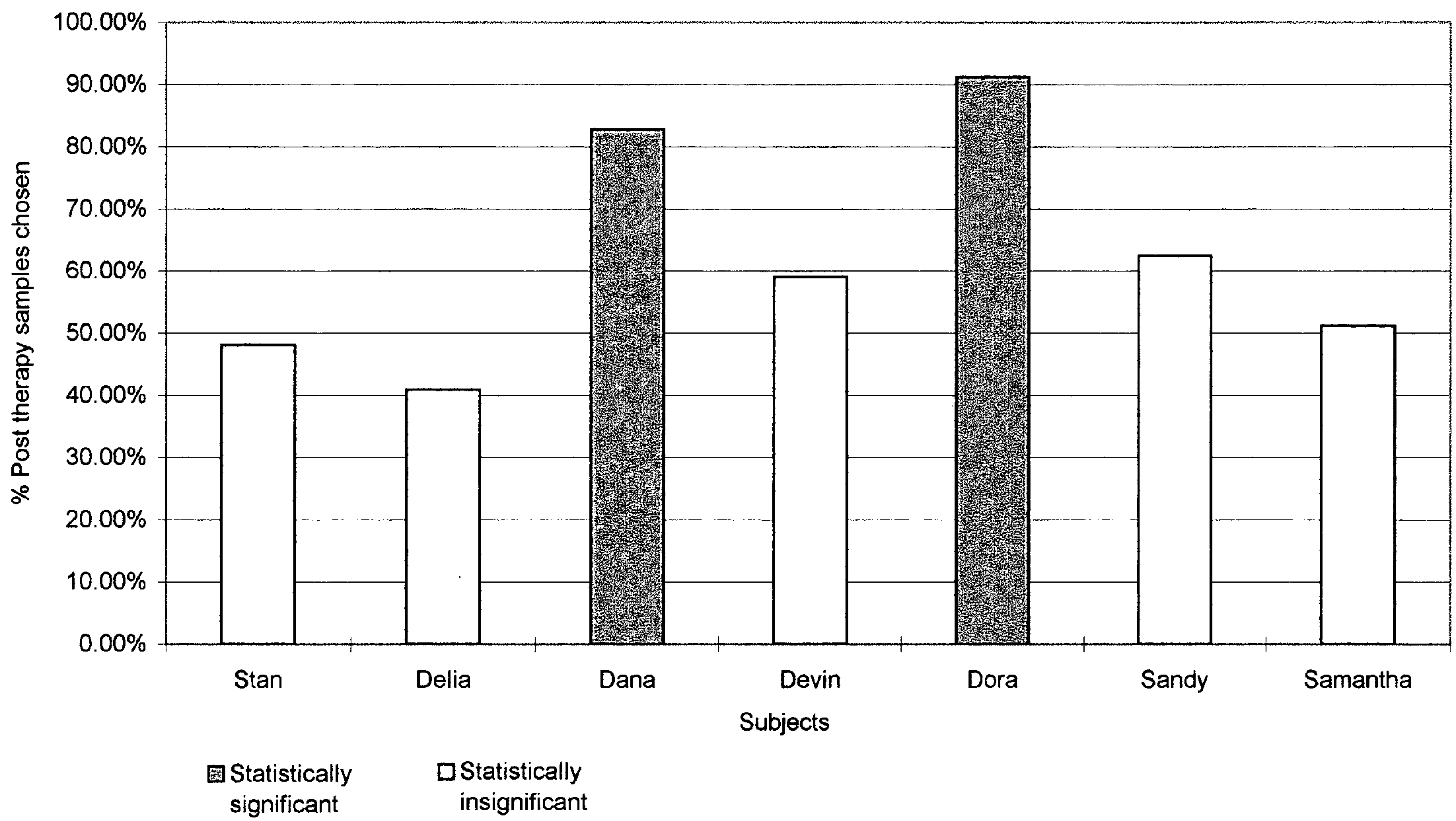
This null hypothesis was addressed in the judgment task where listeners chose which was easier to understand, the pre- or post-therapy sentence. The computer program recorded listener responses, marking a response correct if the T2 sentence was chosen and incorrect if T1 sentence was chosen. A percentage of the post-therapy samples chosen for each speaker by each listener was provided. Table 3.1 summarizes the listeners' scores for this task.

TABLE 3.1: Percentage of post-therapy sentences chosen as easier to understand in the judgment task

| Listeners | Speakers | | | | | | | Listener data distribution | |
|---|---|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha | Average | SD |
| L1 | 45% | 30% | 85% | 55% | 90% | 65% | 75% | 64% | 20.12 |
| L2 | 40% | 45% | 75% | 55% | 95% | 70% | 45% | 61% | 18.60 |
| L3 | 30% | 0% | 80% | 35% | 90% | 65% | 55% | 51% | 28.96 |
| L4 | 80% | 95% | 95% | 60% | 75% | 45% | 25% | 68% | 24.19 |
| L5 | 60% | 45% | 90% | 80% | 95% | 70% | 45% | 69% | 18.79 |
| L6 | 20% | 5% | 80% | 65% | 95% | 70% | 85% | 60% | 32.73 |
| L7 | 65% | 20% | 70% | 70% | 85% | 70% | 30% | 59% | 21.75 |
| L8 | 55% | 5% | 80% | 50% | 80% | 80% | 50% | 57% | 25.06 |
| L9 | 60% | 45% | 80% | 65% | 100% | 55% | 55% | 66% | 17.20 |
| L10 | 50% | 50% | 70% | 55% | 95% | 65% | 45% | 61% | 15.97 |
| L11 | 60% | 40% | 75% | 70% | 95% | 60% | 30% | 61% | 20.12 |
| L12 | 35% | 85% | 85% | 65% | 95% | 50% | 55% | 67% | 20.32 |
| L13 | 45% | 25% | 90% | 45% | 100% | 60% | 65% | 61% | 24.45 |
| L14 | 50% | 60% | 85% | 50% | 90% | 55% | 40% | 61% | 16.09 |
| L15 | 40% | 30% | 85% | 70% | 100% | 60% | 55% | 63% | 21.56 |
| L16 | 35% | 75% | 100% | 55% | 80% | 60% | 65% | 67% | 15.43 |
| Average | 48.13% | 40.94% | 82.81% | 59.06% | 91.25% | 62.50% | 51.25% | 62.27% | 17.12 |

The statistical analysis used for this task was binomial probability. (Data met the assumptions of a normal distribution.) Each of the seven speakers' set of data was examined individually across the 16 untrained listeners. The listeners' percentages of post-therapy sentences chosen over twenty forced choice trials (i.e., two possible outcomes; A or B), (*n=20*) were averaged for each of the seven speakers. This data pooling was legitimate because listener variance was minimal (see Table 3.1). The number of post-therapy sentences chosen had to exceed 14/20 to be significant at the $p \leq 0.05$ to support the conclusion that post-therapy utterances were significantly easier to understand. Conversely, the number of post-therapy sentences chosen had to be less than 4/20 to be significant at the $p \geq 0.95$ to support the conclusion that pre-therapy utterances were significantly easier to understand. It follows that an average percentage between 20% and 70% would indicate random variation in choice between pre- and post-therapy alternatives. For speakers Dana and Dora all listeners chose post-therapy samples more than 14 of 20 trials, clearly indicating that untrained listeners chose post-therapy samples as easier to understand significantly more often than pre-therapy samples. It is important to note that for both of these speakers all 16 listeners chose the post-therapy sentence more than 70% of the time, so that the difference was detected by 100% of listeners. The remainder of the speakers showed average percentages which fell into the random choice range, indicating no significant preference for pre- or post-therapy samples by untrained listeners. However, 5 of the 16 listeners chose the post- therapy sentence more than 70% of the time for Sandy. Further, 4 of 16 individual listeners chose the post-therapy sample for Devon more than 70% of the time. As such, both Sandy and Devon showed a difference post-therapy which was detectable by a portion of the untrained listeners. The average score of the untrained listeners did not indicate a preference for pre-therapy samples for any of the speakers. Their data are summarized in Figure 3.1.

Figure 3.1: Average percentage of post-therapy sentences chosen across listeners



## Qualitative Comments by Listeners

After listening to each speaker in the judgment task, listeners were asked to indicate how difficult it was to decide which sample was easier to understand. Listeners circled "not difficult," "moderately difficult," or "very difficult." Further, listeners were asked to write down what they based their decision on. Table 3.2 summarizes the listeners' responses to these questions.

TABLE 3.2: Listeners' responses to qualitative questions following each speaker in the judgment task

| Speaker | Difficulty* | Basis for choices between paired samples* |
|---|---|---|
| Stan | Not difficult (7)<br>Moderately difficult (9) | • "Pronunciation/clarity" (3)<br>-'s' production (2)<br>• Number of words understood (2)<br>• Preferred less "slurring" (2)<br>• Guessed (2)<br>• Preferred faster "cadence" (1)<br>• Preferred slower sample (1)<br>• "Confidence of voice" (1)<br>• Preferred less sibilance (1)<br>• Preferred more fluidity (1) |
| Delia | Not difficult (10)<br>Moderately difficult (5)<br>Very difficult (1) | • Preferred faster sample (found it more pleasant, less distracting) (8)<br>• Preferred slower sample (found it clearer and 's' was better/less lisp) (7)<br>• "Confidence of voice" (1) |
| Dana | Not difficult (11)<br>Moderately (5) | • Pronunciation (9)<br>-'h', 'l', 'w' production (1)<br>-'s' production (1)<br>-'r' production (1)<br>• Number of words understood (2)<br>• "Confidence of voice" (1)<br>• Preferred "energy and enthusiasm" (1) |
| Devon | Not difficult (1)<br>Moderately difficult (8)<br>Very difficult (7) | • Number of words understood (8)<br>• Pronunciation (5)<br>• Less "dips and valleys in tone" (1)<br>• Guessing (1)<br>• Comment: Speaker sounded drunk (3) |
| Dora | Not difficult (2)<br>Moderately difficult (6)<br>Very difficult (9) | • Number of words understood (11)<br>• Pronunciation (2)<br>-Production of 'b' and 'd'/'m' (2)<br>• Guessing (1)<br>• Comment: Speaker a young male child (1) |
| Sandy | Very difficult (12)<br>Moderately difficult (4) | • Number of words understood (13)<br>• Guessing (2) |
| Samantha | Very difficult (15)<br>Moderately difficult (1) | • Recognizable words (9)<br>• Pronunciation (4)<br>• "Which sounded like English" (1)<br>• "Breaks between words and sentences" (1)<br>• Guessing (1)<br>• Comment: Speaker "disturbing" to listen to (1) |

*Listeners' perspective
( n ) Number of listeners out of sixteen which gave a particular answer

2. Are post-therapy gains significant enough to improve the identification of words and sentences by untrained listeners?

*Null Hypothesis 2:* There will be no difference in accuracy of identification between the pre- and post-samples, either within or between speakers or listeners.

The orthographic transcriptions of the listeners were collected, and for the word identification task, words were simply marked right if they were correctly identified and wrong if they were not, yielding a percentage correct out of ten, pre- and post-therapy. The scores for word identification, pre- and post-therapy, are summarized in Tables 3.3 to 3.5.

TABLE 3.3: Percentage of words correctly identified pre-therapy in the word identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 70% | 60% | 60% | 40% | 10% | 50% | 10% |
| L2 | 70% | 80% | 70% | 60% | 10% | 20% | 0% |
| L3 | 70% | 60% | 40% | 70% | 10% | 10% | 0% |
| L4 | 60% | 60% | 50% | 70% | 20% | 40% | 10% |
| L5 | 70% | 70% | 90% | 80% | 20% | 40% | 10% |
| L6 | 70% | 70% | 70% | 60% | 20% | 10% | 10% |
| L7 | 70% | 80% | 30% | 60% | 10% | 20% | 0% |
| L8 | 70% | 80% | 50% | 40% | 10% | 20% | 0% |
| L9 | 50% | 80% | 70% | 60% | 0% | 10% | 0% |
| L10 | 70% | 90% | 80% | 70% | 10% | 20% | 0% |
| L11 | 80% | 70% | 60% | 70% | 10% | 40% | 0% |
| L12 | 50% | 80% | 70% | 60% | 10% | 30% | 10% |
| L13 | 60% | 90% | 80% | 80% | 10% | 10% | 10% |
| L14 | 80% | 80% | 60% | 80% | 10% | 30% | 0% |
| L15 | 50% | 70% | 90% | 80% | 10% | 20% | 0% |
| L16 | 70% | 70% | 70% | 80% | 0% | 20% | 0% |
| Average | 66.25% | 74.38% | 65.00% | 66.25% | 10.63% | 25.00% | 3.75% |

TABLE 3.4: Percentage of words correctly identified post-therapy in the word identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 70% | 80% | 90% | 70% | 50% | 30% | 0% |
| L2 | 80% | 80% | 100% | 80% | 70% | 30% | 10% |
| L3 | 50% | 80% | 90% | 70% | 50% | 20% | 0% |
| L4 | 90% | 70% | 100% | 70% | 60% | 50% | 10% |
| L5 | 70% | 70% | 90% | 90% | 70% | 40% | 10% |
| L6 | 60% | 80% | 90% | 90% | 50% | 30% | 10% |
| L7 | 60% | 80% | 100% | 90% | 50% | 60% | 10% |
| L8 | 80% | 70% | 90% | 60% | 40% | 20% | 0% |
| L9 | 90% | 80% | 100% | 60% | 30% | 30% | 20% |
| L10 | 80% | 80% | 90% | 90% | 60% | 30% | 20% |
| L11 | 30% | 80% | 100% | 60% | 60% | 30% | 10% |
| L12 | 60% | 80% | 90% | 70% | 40% | 40% | 0% |
| L13 | 70% | 80% | 100% | 80% | 60% | 30% | 10% |
| L14 | 90% | 80% | 90% | 70% | 60% | 60% | 0% |
| L15 | 60% | 90% | 90% | 60% | 70% | 30% | 0% |
| L16 | 70% | 80% | 100% | 80% | 50% | 50% | 10% |
| Average | 69.38% | 78.75% | 94.38% | 74.38% | 54.38% | 38.25% | 7.50% |

TABLE 3.5: Difference between the percentage of words correctly identified pre- and post-therapy in the word identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 0% | 20% | 30% | 30% | 40% | -20% | -10% |
| L2 | 10% | 0% | 30% | 20% | 60% | 10% | 10% |
| L3 | -20% | 20% | 50% | 0% | 40% | 10% | 0% |
| L4 | 30% | 10% | 50% | 0% | 40% | 10% | 0% |
| L5 | 0% | 0% | 0% | 10% | 50% | 0% | 0% |
| L6 | -10% | 10% | 20% | 30% | 30% | 20% | 0% |
| L7 | -10% | 0% | 70% | 30% | 40% | 40% | 10% |
| L8 | 10% | -10% | 40% | 20% | 30% | 0% | 0% |
| L9 | 40% | 0% | 30% | 0% | 30% | 20% | 20% |
| L10 | 10% | -10% | 10% | 20% | 50% | 10% | 20% |
| L11 | -50% | 10% | 40% | -10% | 50% | -10% | 10% |
| L12 | 10% | 0% | 20% | 10% | 30% | 10% | -10% |
| L13 | 10% | -10% | 20% | 0% | 50% | 20% | 0% |
| L14 | 10% | 0% | 30% | -10% | 50% | 30% | 0% |
| L15 | 10% | 20% | 0% | -20% | 60% | 10% | 0% |
| L16 | 0% | 10% | 30% | 0% | 50% | 30% | 10% |
| Average | 3.13% | 4.38% | 29.38% | 8.13% | 43.75% | 11.62% | 3.75% |

In analysis of the sentence identification task, the number of words correctly identified was calculated for each sentence. When the pre- and post-therapy sentences were compared, they were matched as closely as possible for length, semantic complexity and phonological complexity. Scores for words identified per sentence pre- and post-therapy are summarized in Tables 3.6 to 3.8.

TABLE 3.6: Percentage of words per sentence correctly identified pre-therapy in the sentence identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 100% | 95% | 95% | 63% | 18% | 63% | 0% |
| L2 | 100% | 100% | 100% | 87% | 20% | 80% | 0% |
| L3 | 100% | 96% | 100% | 50% | 11% | 53% | 0% |
| L4 | 100% | 91% | 100% | 94% | 10% | 41% | 0% |
| L5 | 100% | 100% | 95% | 56% | 0% | 71% | 0% |
| L6 | 100% | 96% | 100% | 75% | 14% | 53% | 0% |
| L7 | 100% | 100% | 100% | 81% | 0% | 47% | 6% |
| L8 | 100% | 100% | 95% | 47% | 0% | 29% | 0% |
| L9 | 100% | 100% | 100% | 69% | 15% | 56% | 0% |
| L10 | 100% | 83% | 100% | 69% | 21% | 6% | 6% |
| L11 | 100% | 100% | 95% | 81% | 4% | 53% | 6% |
| L12 | 100% | 87% | 90% | 75% | 29% | 56% | 6% |
| L13 | 100% | 100% | 95% | 75% | 14% | 65% | 6% |
| L14 | 100% | 91% | 95% | 81% | 11% | 53% | 0% |
| L15 | 100% | 91% | 90% | 50% | 11% | 71% | 17% |
| L16 | 100% | 95% | 95% | 75% | 14% | 47% | 0% |
| Average | 100% | 95.31% | 96.56% | 70.50% | 12.00% | 52.75% | 2.94% |

TABLE 3.7: Percentage of words per sentence correctly identified post-therapy in the sentence identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 100% | 100% | 44% | 70% | 64% | 88% | 21% |
| L2 | 88% | 100% | 53% | 100% | 46% | 88% | 16% |
| L3 | 76% | 95% | 76% | 65% | 25% | 44% | 0% |
| L4 | 100% | 96% | 53% | 100% | 44% | 76% | 21% |
| L5 | 71% | 100% | 61% | 60% | 61% | 63% | 32% |
| L6 | 100% | 100% | 76% | 80% | 67% | 56% | 16% |
| L7 | 88% | 100% | 76% | 80% | 30% | 69% | 35% |
| L8 | 100% | 100% | 59% | 30% | 50% | 69% | 5% |
| L9 | 100% | 91% | 71% | 75% | 27% | 43% | 29% |
| L10 | 100% | 83% | 65% | 75% | 39% | 69% | 13% |
| L11 | 100% | 83% | 71% | 87% | 61% | 75% | 5% |
| L12 | 88% | 100% | 50% | 70% | 45% | 69% | 39% |
| L13 | 88% | 96% | 76% | 70% | 64% | 63% | 21% |
| L14 | 100% | 100% | 76% | 45% | 76% | 88% | 21% |
| L15 | 94% | 100% | 47% | 65% | 54% | 63% | 26% |
| L16 | 76% | 83% | 76% | 65% | 77% | 69% | 10% |
| Average | 91.81% | 95.44% | 64.38% | 71.06% | 51.88% | 68.25% | 19.38% |

TABLE 3.8: Difference between the percentage of words per sentence correctly identified pre- and post-therapy in the sentence identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 0% | 5% | -51% | 7% | 46% | 25% | 21% |
| L2 | -12% | 0% | -47% | 13% | 26% | 8% | 16% |
| L3 | -24% | -1% | -24% | 15% | 14% | -9% | 0% |
| L4 | 0% | 5% | -47% | 6% | 34% | 35% | 21% |
| L5 | -29% | 0% | -34% | 4% | 61% | -8% | 32% |
| L6 | 0% | 4% | -24% | 5% | 53% | 3% | 16% |
| L7 | -12% | 0% | -24% | -1% | 30% | 22% | 29% |
| L8 | 0% | 0% | -38% | -17% | 50% | 40% | 5% |
| L9 | 0% | -9% | -29% | 6% | 12% | -13% | 29% |
| L10 | 0% | 0% | -35% | 6% | 18% | 63% | 7% |
| L11 | 0% | -17% | -24% | 6% | 57% | 22% | -1% |
| L12 | -12% | 13% | -40% | -5% | 16% | 13% | 33% |
| L13 | -12% | -4% | -19% | -5% | 50% | -2% | 15% |
| L14 | 0% | 9% | -19% | -36% | 65% | 35% | 21% |
| L15 | -6% | 9% | -43% | 15% | 43% | -8% | 9% |
| L16 | -24% | -12% | -19% | -10% | 63% | 22% | 10% |
| Average | -8.19% | 0.13% | -32.18% | 0.56% | 39.88% | 15.50% | 16.44% |

The statistical analysis used for the identification task was the *t*-test for paired differences between pre- and post-therapy identifications. (Data met the assumptions of a normal distribution.) Each of the seven speakers' data across the sixteen untrained listeners was averaged. Again, data pooling was legitimate because listener variation was minimal. (Similar to that evidenced in Table 3.1). The difference between pre- and post-therapy accuracy of identification (i.e., score out of 10 for each listener) was calculated. If there was no true difference between pre- and post-therapy scores the difference would equal zero. A *t*-test was used to determine if the difference between accuracy of identification between pre- and post-therapy samples was significantly greater than zero. A *t*-value greater than 1.753 ($p \leq 0.05$) or less than -1.753 ($p \geq 0.95$) for 15 degrees of freedom ($n=16$) was considered statistically significant. A negative value indicates that identification accuracy was greater pre-therapy then post-therapy and, therefore, contrary to what was expected. Tables 3.9 and 3.10 summarize the standard deviations and *t*-values for the identification tasks.

TABLE 3.9: Standard deviations and *t*-values for the word identification task

| Speakers | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
|---|---|---|---|---|---|---|---|
| Standard Deviation | 13.25 | 7.68 | 12.37 | 12.34 | 9.1 | 12.66 | 5.99 |
| *t*-value | 0.67 | 1.61 | 6.71* | 1.86* | 13.59* | 2.59* | 1.77* |

*$p \leq 0.05$

TABLE 3.10: Standard deviations and *t*-values for the sentence identification task

| Speakers | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
|---|---|---|---|---|---|---|---|
| Standard Deviation | 7.14 | 6.05 | 8.77 | 14.15 | 12.95 | 15.68 | 8.41 |
| *t*-value | -3.24* | 0.06 | -10.38* | 0.11 | 8.71* | 2.79* | 5.52* |

*$p \leq 0.05$

For the word identification task, average accuracy of word identification by untrained listeners increased post-therapy for all of the speakers; change was in the positive direction for 100% of the palatometry speakers as transcribed by untrained listeners. According to the more stringent criterion of *t*-values, untrained listeners identified words significantly more accurately post-therapy for all of the speakers except Stan and Delia, whose scores showed no significant difference in word identification accuracy pre- or post-therapy. In sentence identification, average accuracy of word identification in sentences by untrained listeners increased for five of the seven speakers post-therapy. *t*-values indicate that untrained listeners identified the words in a sentence significantly more accurately post-therapy for Dora, Sandy, and Samantha. Devon's and Delia's scores showed no change in the accuracy of word identification in sentences pre- or post-therapy. Finally, Stan's and Dana's scores indicate that word identification in sentences was significantly more accurate for the pre-therapy samples. Figures 3.2 and 3.3 summarize these results.

Figure 3.2: Average difference in word identification between pre- and post-therapy across listeners

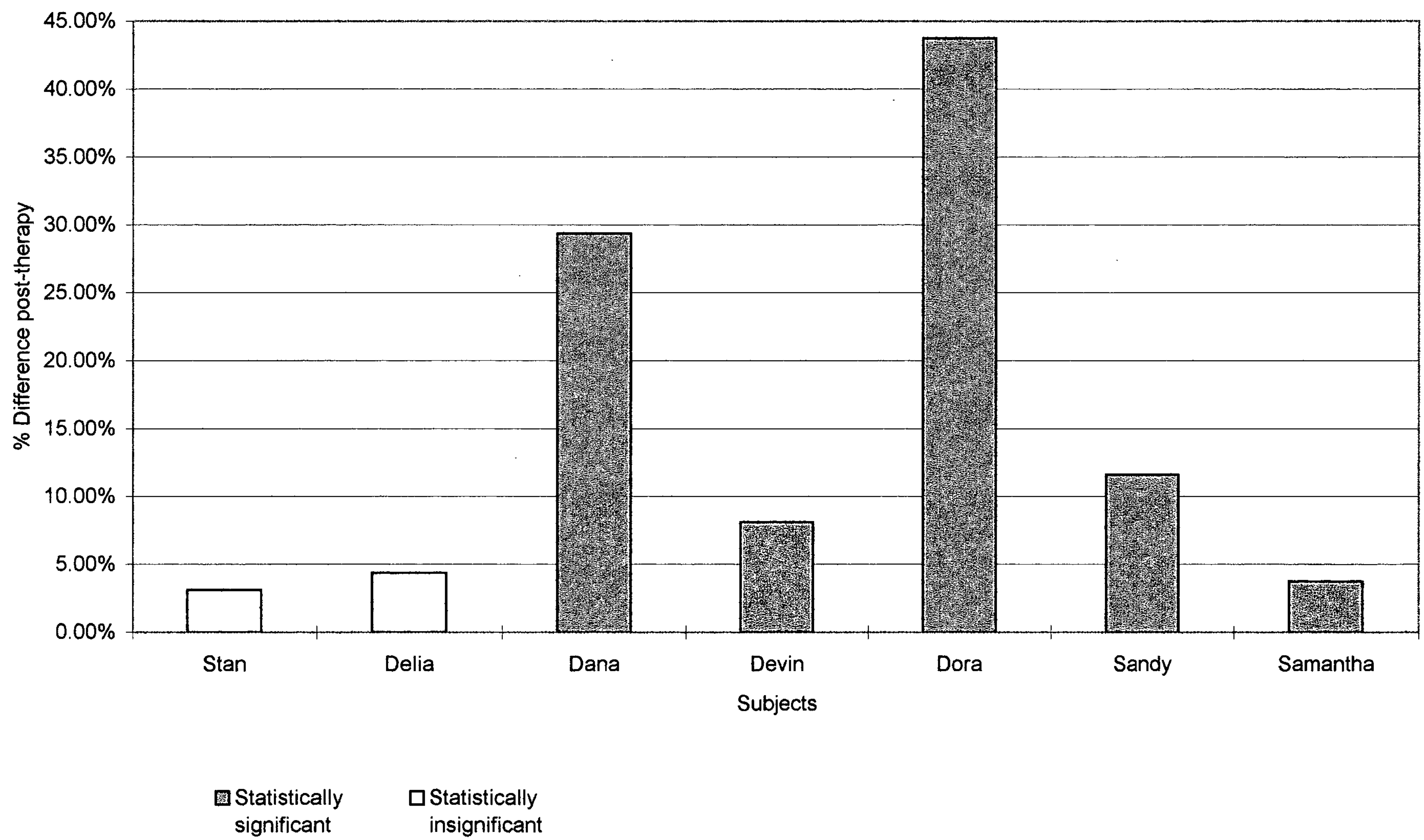
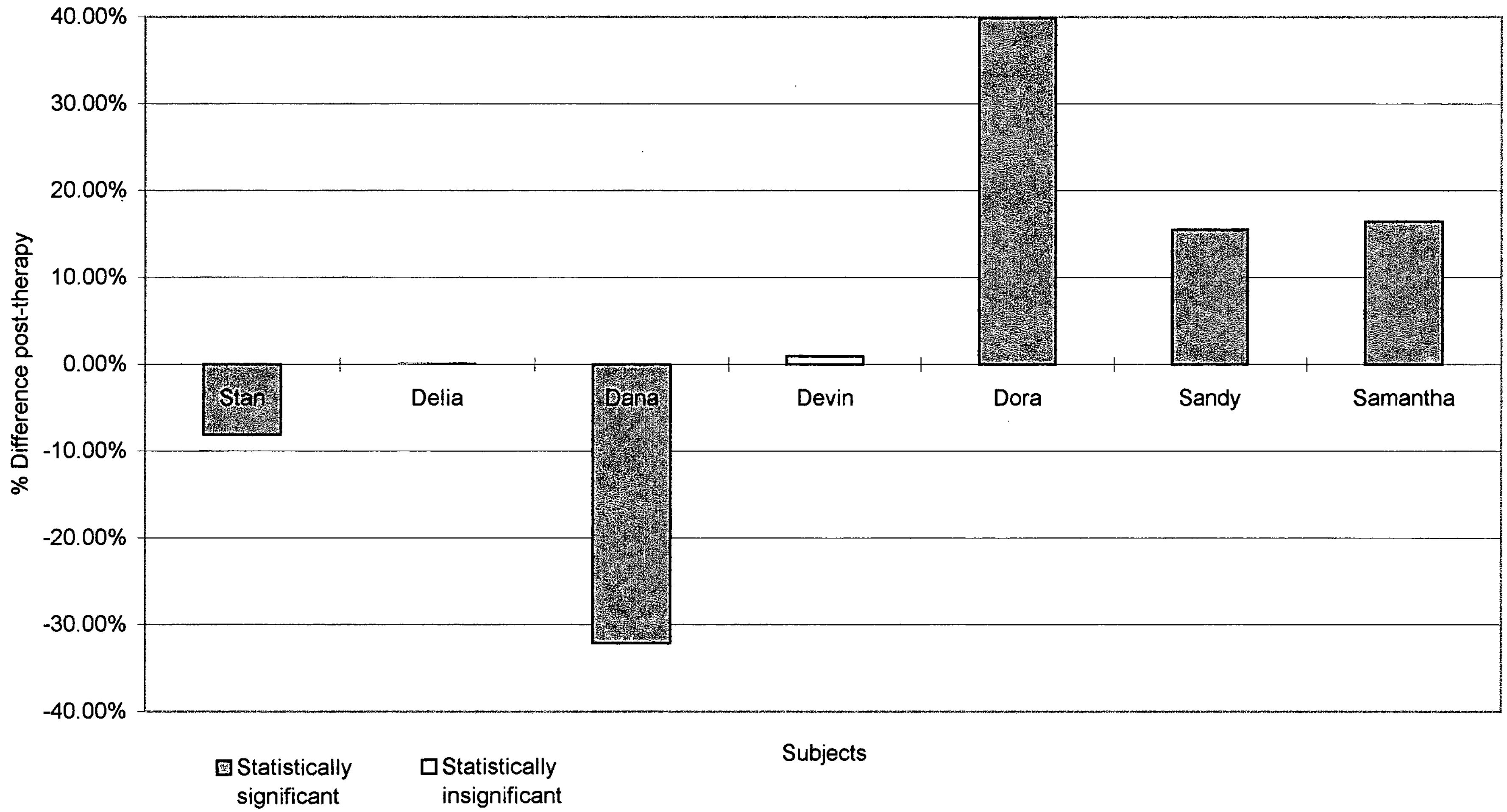


Figure 3.3: Average difference in word identifcation in sentence transcription between pre- and post-therapy across listeners



3. Is there an improvement post-therapy in the identification of phonemes which were goals in therapy?

*Null Hypothesis 3:* There will be no improvement in the identification of goal phonemes comparing pre- to post-therapy.

The number of therapy target phonemes that were correctly identified in word and sentence identification was calculated at T1 and T2. The percentages of goal phoneme identification across the 16 listeners in words and sentences pre- and post-therapy are summarized in Tables 3.11 to 3.16.

TABLE 3.11: Percentage of goal phonemes correctly identified pre-therapy in the word identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 82% | 75% | 78% | 63% | 0% | 38% | 11% |
| L2 | 91% | 90% | 100% | 88% | 20% | 10% | 0% |
| L3 | 70% | 75% | 60% | 88% | 0% | 0% | 0% |
| L4 | 91% | 75% | 70% | 75% | 30% | 44% | 11% |
| L5 | 82% | 75% | 100% | 100% | 30% | 13% | 11% |
| L6 | 82% | 75% | 80% | 75% | 10% | 0% | 13% |
| L7 | 91% | 75% | 40% | 88% | 0% | 0% | 0% |
| L8 | 82% | 80% | 80% | 50% | 0% | 0% | 0% |
| L9 | 70% | 80% | 60% | 67% | 0% | 10% | 0% |
| L10 | 91% | 75% | 100% | 88% | 0% | 22% | 11% |
| L11 | 82% | 75% | 100% | 75% | 0% | 25% | 11% |
| L12 | 82% | 88% | 90% | 88% | 0% | 25% | 22% |
| L13 | 91% | 88% | 100% | 88% | 10% | 13% | 22% |
| L14 | 88% | 88% | 80% | 88% | 0% | 38% | 11% |
| L15 | 82% | 75% | 100% | 88% | 0% | 13% | 11% |
| L16 | 82% | 75% | 80% | 75% | 0% | 13% | 11% |
| Average | 83.69% | 79.01% | 82.38% | 80.25% | 6.25% | 16.50% | 9.06% |

TABLE 3.12: Percentage of goal phonemes correctly identified post-therapy in the word identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 91% | 75% | 100% | 100% | 40% | 38% | 0% |
| L2 | 91% | 75% | 100% | 75% | 80% | 38% | 22% |
| L3 | 73% | 75% | 100% | 75% | 40% | 25% | 0% |
| L4 | 91% | 75% | 100% | 100% | 80% | 56% | 22% |
| L5 | 91% | 63% | 100% | 88% | 60% | 38% | 33% |
| L6 | 91% | 75% | 90% | 100% | 60% | 38% | 33% |
| L7 | 82% | 75% | 100% | 100% | 70% | 38% | 33% |
| L8 | 91% | 50% | 90% | 50% | 40% | 50% | 0% |
| L9 | 100% | 75% | 100% | 88% | 60% | 38% | 22% |
| L10 | 91% | 75% | 90% | 88% | 60% | 13% | 33% |
| L11 | 82% | 75% | 100% | 75% | 60% | 38% | 22% |
| L12 | 91% | 75% | 100% | 100% | 50% | 50% | 22% |
| L13 | 91% | 100% | 100% | 100% | 60% | 50% | 11% |
| L14 | 91% | 75% | 100% | 75% | 60% | 63% | 33% |
| L15 | 82% | 88% | 100% | 100% | 70% | 38% | 22% |
| L16 | 91% | 75% | 100% | 88% | 60% | 50% | 33% |
| Average | 88.75% | 75.06% | 98.13% | 87.63% | 59.38% | 41.31% | 21.31% |

TABLE 3.13: Difference between the percentage of goal phonemes correctly identified pre- and post-therapy in the word identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 9% | 0% | 22% | 37% | 40% | 0% | -11% |
| L2 | 0% | -15% | 0% | -13% | 60% | 28% | 22% |
| L3 | 3% | 0% | 40% | -13% | 40% | 25% | 0% |
| L4 | 0% | 0% | 30% | 25% | 50% | 12% | 11% |
| L5 | 9% | -12% | 0% | -12% | 30% | 25% | 22% |
| L6 | 9% | 0% | 10% | 25% | 50% | 38% | 20% |
| L7 | -9% | 0% | 60% | 12% | 70% | 38% | 33% |
| L8 | 9% | -30% | 10% | 0% | 40% | 50% | 0% |
| L9 | 30% | -5% | 40% | 21% | 60% | 28% | 22% |
| L10 | 0% | 0% | -10% | 0% | 60% | -9% | 22% |
| L11 | 0% | 0% | 0% | 0% | 60% | 13% | 11% |
| L12 | 9% | -13% | 10% | 12% | 50% | 25% | 0% |
| L13 | 0% | 12% | 0% | 12% | 50% | 37% | -11% |
| L14 | 3% | -13% | 20% | -13% | 60% | 25% | 22% |
| L15 | 0% | 13% | 0% | 12% | 70% | 25% | 11% |
| L16 | 9% | 0% | 20% | 13% | 60% | 37% | 22% |
| Average | 5.06% | -3.95% | 15.75% | 7.38% | 53.13% | 24.81% | 12.25% |

TABLE 3.14: Percentage of goal phonemes correctly identified pre-therapy in the sentence identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 100% | 87% | 100% | 73% | 0% | 33% | 0% |
| L2 | 100% | 100% | 100% | 73% | 0% | 66% | 0% |
| L3 | 100% | 93% | 100% | 73% | 0% | 33% | 0% |
| L4 | 100% | 93% | 100% | 73% | 0% | 33% | 0% |
| L5 | 100% | 87% | 80% | 82% | 0% | 66% | 0% |
| L6 | 100% | 93% | 100% | 36% | 0% | 0% | 0% |
| L7 | 100% | 93% | 100% | 73% | 0% | 33% | 0% |
| L8 | 100% | 100% | 100% | 45% | 0% | 66% | 0% |
| L9 | 100% | 100% | 100% | 64% | 0% | 33% | 0% |
| L10 | 100% | 87% | 100% | 27% | 0% | 0% | 0% |
| L11 | 100% | 100% | 100% | 73% | 0% | 33% | 0% |
| L12 | 100% | 100% | 87% | 73% | 0% | 33% | 0% |
| L13 | 100% | 87% | 100% | 64% | 0% | 0% | 0% |
| L14 | 100% | 100% | 100% | 73% | 0% | 67% | 7% |
| L15 | 100% | 93% | 100% | 73% | 20% | 33% | 0% |
| L16 | 100% | 93% | 100% | 100% | 0% | 38% | 0% |
| Average | 100% | 93.25% | 97.94% | 67.18% | 1.25% | 35.44% | 0.44% |

TABLE 3.15: Percentage of goal phonemes correctly identified post-therapy in the sentence identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 100% | 100% | 100% | 38% | 38% | 50% | 22% |
| L2 | 100% | 100% | 80% | 46% | 54% | 83% | 11% |
| L3 | 100% | 100% | 60% | 38% | 46% | 83% | 22% |
| L4 | 63% | 75% | 100% | 38% | 38% | 67% | 11% |
| L5 | 100% | 93% | 47% | 46% | 31% | 33% | 22% |
| L6 | 100% | 100% | 100% | 46% | 75% | 33% | 0% |
| L7 | 100% | 100% | 100% | 77% | 62% | 50% | 33% |
| L8 | 63% | 100% | 100% | 77% | 38% | 33% | 33% |
| L9 | 100% | 93% | 70% | 77% | 23% | 33% | 44% |
| L10 | 100% | 100% | 80% | 23% | 46% | 50% | 11% |
| L11 | 100% | 100% | 80% | 54% | 15% | 50% | 11% |
| L12 | 100% | 93% | 100% | 69% | 31% | 83% | 11% |
| L13 | 100% | 80% | 70% | 77% | 23% | 50% | 22% |
| L14 | 100% | 100% | 100% | 62% | 46% | 33% | 26% |
| L15 | 100% | 100% | 70% | 38% | 23% | 50% | 67% |
| L16 | 100% | 100% | 80% | 46% | 31% | 50% | 13% |
| Average | 95.38% | 95.88% | 83.56% | 53.25% | 38.75% | 51.94% | 22.44% |

TABLE 3.16: Difference between the percentage of goal phonemes correctly identified pre- and post-therapy in the sentence identification task

| Listeners | Speakers | | | | | | |
|---|---|---|---|---|---|---|---|
| | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
| L1 | 0% | 13% | 0% | -35% | 38% | 17% | 22% |
| L2 | 0% | 0% | -20% | -27% | 54% | 17% | 11% |
| L3 | 0% | 7% | -40% | -35% | 46% | 50% | 22% |
| L4 | -37% | -18% | 0% | -35% | 38% | 34% | 11% |
| L5 | 0% | 6% | -33% | -36% | 31% | -33% | 22% |
| L6 | 0% | 7% | 0% | 10% | 75% | 33% | 0% |
| L7 | 0% | 7% | 0% | 4% | 62% | 17% | 33% |
| L8 | -37% | 0% | 0% | 32% | 38% | -33% | 33% |
| L9 | 0% | -7% | -30% | 13% | 23% | 0% | 44% |
| L10 | 0% | 13% | -20% | -4% | 46% | 50% | 11% |
| L11 | 0% | 0% | -20% | -19% | 15% | 17% | 11% |
| L12 | 0% | -7% | 13% | -4% | 31% | 50% | 11% |
| L13 | 0% | 7% | -30% | 13% | 23% | 50% | 22% |
| L14 | 0% | 0% | 0% | -11% | 46% | -34% | 26% |
| L15 | 0% | 7% | -30% | -35% | 3% | 17% | 67% |
| L16 | 0% | 7% | -20% | -54% | 31% | 12% | 13% |
| Average | -4.63% | 2.63% | -14.38% | -13.94% | 37.5% | 16.50% | 22.44% |

Statistical analysis of the identification of goal phonemes utilized *t*-tests of paired differences. The analysis was identical to the one used to test the previous hypothesis. Tables 3.17 and 3.18 summarize the standard deviations and *t*-values for percentage of goal phonemes identified pre- and post-therapy in the identification tasks.

TABLE 3.17: Standard deviations and *t*-values for goal phoneme identification in the word identification task

| Speakers | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
|---|---|---|---|---|---|---|---|
| Standard Deviation | 6.15 | 8.34 | 13.11 | 13.53 | 12.95 | 13.2 | 10.14 |
| *t*-value | 2.32* | 1.34 | 3.39* | 1.54 | 8.71* | 5.31* | 3.41* |

*$p \leq 0.05$

TABLE 3.18: Standard deviations and *t*-values for goal phoneme identification in sentence identification

| Speakers | Stan | Delia | Dana | Devon | Dora | Sandy | Samantha |
|---|---|---|---|---|---|---|---|
| Standard Deviation | 8.9 | 7.53 | 12.76 | 17.64 | 11.7 | 20.46 | 11.66 |
| *t*-value | 1.47 | 0.99 | -3.18* | -2.24* | 9.06* | 2.28* | 5.43* |

*$p \leq 0.05$

For the word identification task, untrained listeners showed a statistically significant improvement in the identification of goal phonemes post-therapy for all speakers except Delia and Devon, whose scores showed no statistical difference in accuracy of goal phoneme identification pre- or post-therapy. Devon's results did show that listeners' post-therapy identifications were better on average although not statistically significant. In sentence identification, *t*-values indicate that untrained listeners showed a statistically significant improvement in accuracy of goal phoneme identification post-therapy for Dora's, Sandy's and Samantha's speech samples. Stan's and Delia's scores showed no statistically significant difference in goal phoneme identification pre- or post therapy by untrained listeners, while Devon's and Dana's scores indicate increased accuracy in goal phoneme identification by untrained listeners for pre-therapy samples. Figures 3.4 and 3.5 summarize these results.

Figure 3.4: Average difference in goal phoneme identification between pre- and post-therapy in the word transcription task

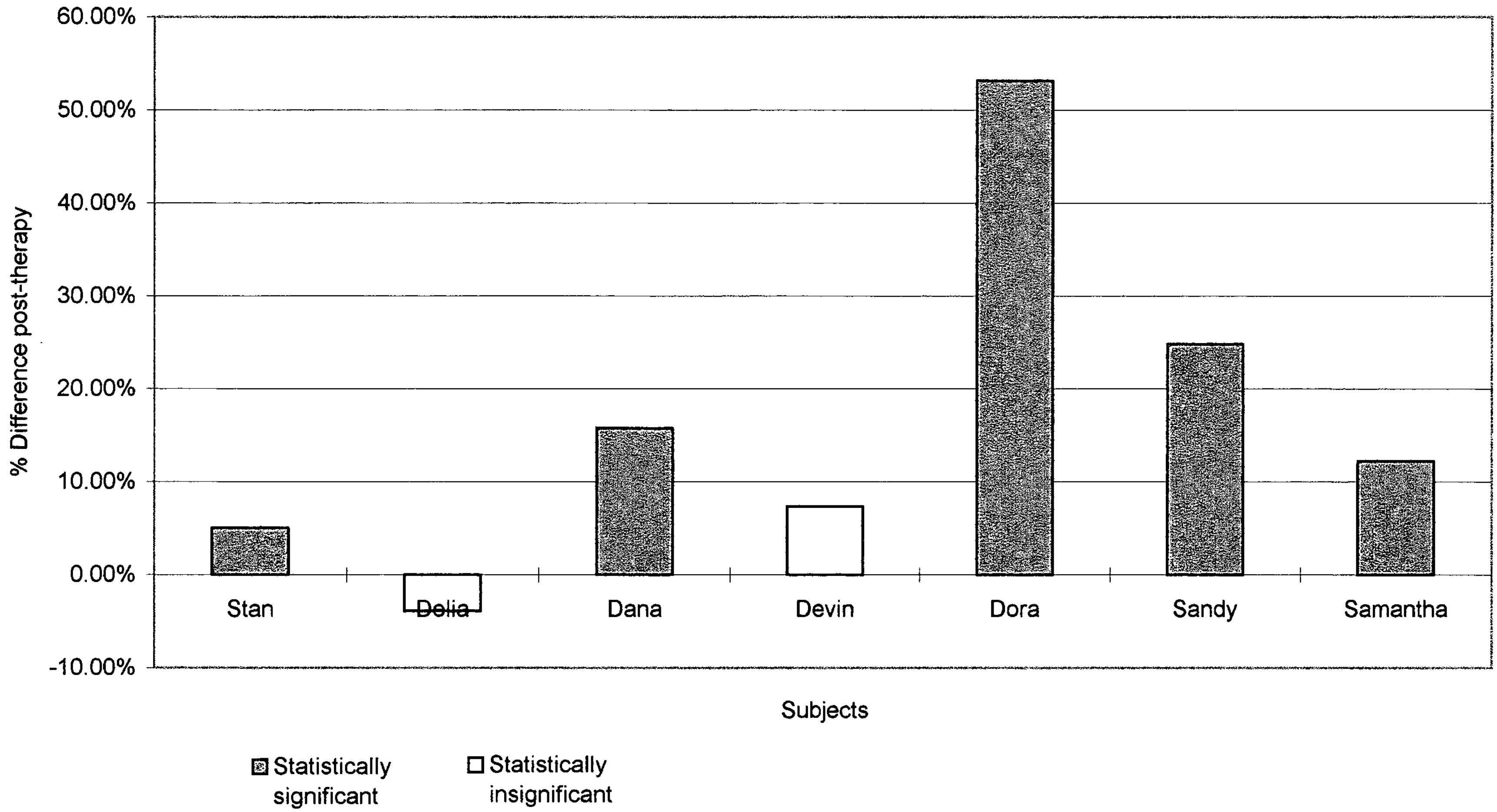
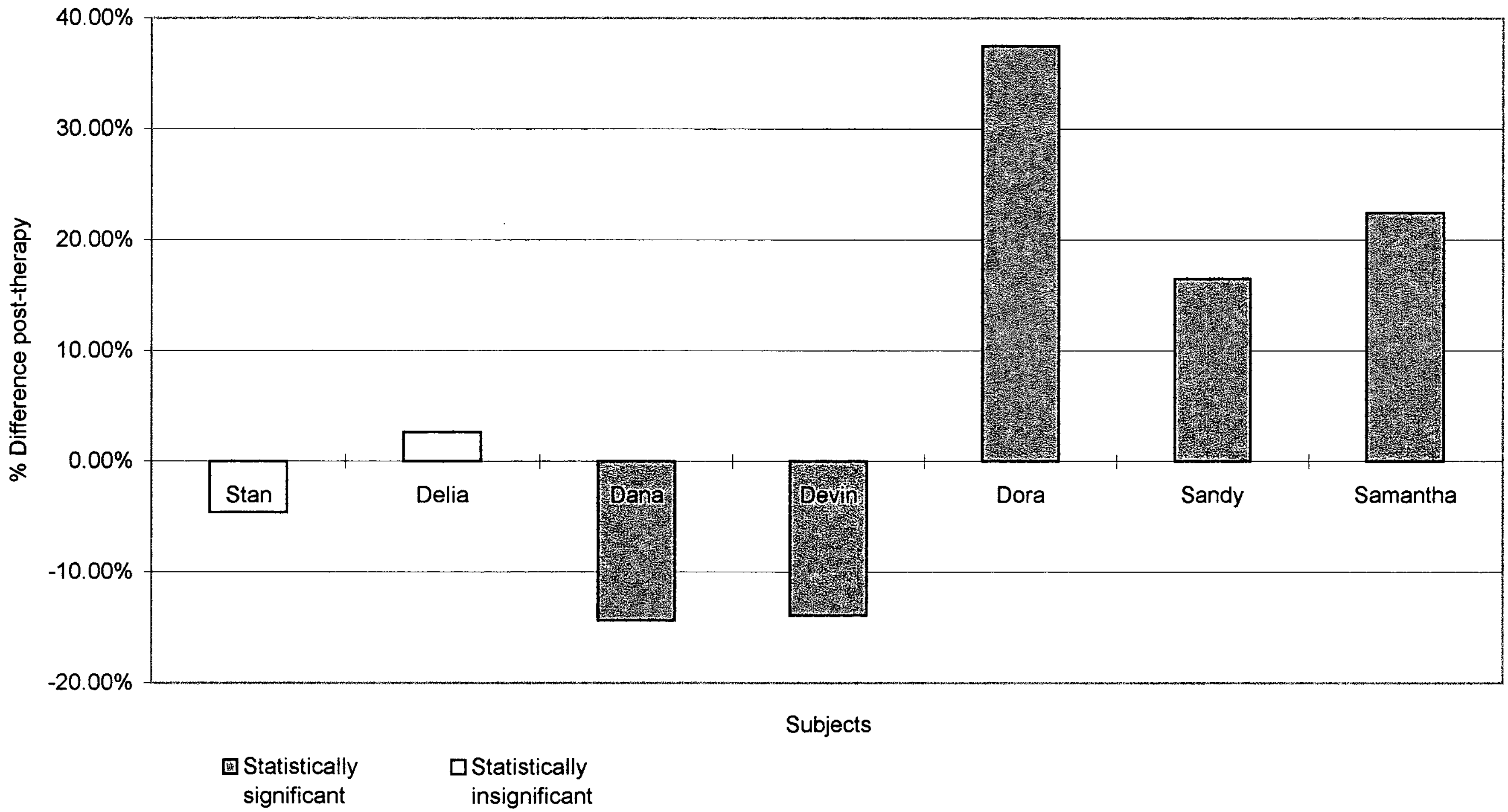


Figure 3.5: Average difference in goal phoneme identification between pre- and post-therapy in the sentence transcription task



# CONCLUSION

Overall, the intelligibility ratings of untrained listeners improved for all speakers on one or all of the tasks. However, speakers presented different profiles of improvement post-therapy. The following chapter will discuss each speaker's results in terms of the tasks, speaker variables, and the World Health Organization's (1997) model of human functioning.

# CHAPTER 4

# DISCUSSION

The main goal of this study was to evaluate the effectiveness of a course of palatometry as perceived by untrained listeners. In this chapter, the results of the judgment and identification tasks will be compared and contrasted. The results of the word and sentence identification tasks will also be discussed. In addition, the relationship of goal phoneme identification to word and sentence identification will be examined. Then, the results will be considered in terms of speakers' age, severity, and disorder. In addition, the findings of this study will be related to the World Health Organization's (1997) model of impairment, activity, and participation. Finally, the clinical implications of this study, its limitations, and directions for further research will be discussed.

## TASK RESULTS ACROSS LISTENERS

Two types of intelligibility measures were used in this study: judgment and identification. Word and sentence identification tasks were administered and goal phoneme identification was calculated within words and sentences. In this section, results obtained using word and sentence identification tasks will be considered in relation to each other and to previous research. The results of the identification tasks and the judgment task will also be compared and contrasted.

## Word and Sentence Identification Tasks

Previous studies (e.g., Yorkston & Beukelman, 1981b) have indicated that intelligibility scores for sentence identification tasks tend to be higher than intelligibility scores for word identification tasks. Sentences provide more context, making identification easier for the listener. A comparison of pre-therapy identification of single words (Table 3.2) and pre-therapy identification of words in sentences (Table 3.5) indicates that this was the case for all speakers except Samantha. Word identification improved in sentences anywhere from 2% to 30% depending on the speaker. The same comparison can be made between post-therapy identification of single words (Table 3.3) and post-therapy identification of words in sentences (Table 3.6). Word identification in sentences post-therapy was better than single word identification for all speakers except Dana, Devon and Dora. The range of improvement was between 13% and 30% for post-therapy word identification in sentences compared to words in isolation. This suggests that for the majority of speakers, listeners found contextual information helpful when trying to identify words, resulting in higher intelligibility ratings. All of the speakers whose intelligibility scores did not improve when the listeners were given sentence context had a speech impairment that fell into the severe range according to Table 2.1, except Dana. The speakers with more severe impairments often showed little difference in intelligibility ratings between single word identification and word identification in sentences. For example, Devon and Dora's results only show a 3% improvement in accuracy of word identification in sentences when compared to single word identification. This finding agrees with Sitler, Schiavetti, and Metz (1983) who observed that when speech reaches a certain level of unintelligibility, contextual cues may no longer be helpful in identification.

A study by Yorkston and Beukelman (1981b) found that while sentence intelligibility scores tend to be higher, word and sentence intelligibility measures both rate speakers' severity similarly. This finding suggests that therapy outcomes should be similar when measured by sentence or word identification tasks. Although intelligibility ratings may be higher for sentence identification, they should be equally better pre- and post-therapy for sentence identification over word identification. This means that the difference between pre- and post-therapy intelligibility scores should be similar for word and sentence identification. This only generally true for some of the speakers. Dora, Sandy and Samantha all showed improvements in accuracy post-therapy, which were significant for both word and sentence identification. Delia showed no statistically significant change in accuracy pre- or post-therapy for word or sentence identification. However, Stan, Dana and Devon all showed discrepancies between the outcomes of word identification and sentence identification tasks. To explain these discrepancies both the original stimuli and the speaker's speech disorder were examined more closely.

Stan's results showed no significant change in single word identification accuracy pre- or post-therapy; however, sentence identification was significantly more accurate pre-therapy. One possibility is that with only three sentences being evaluated, a "mistake" or misarticulation in one or two of the sentences could have resulted in a post-therapy score that was consistently less than 100% post-therapy across listeners. For example, approximately 38% of the listeners misidentified "stagecoach" as "scapegoat." Listeners use content words to decipher the remainder of the sentence. For example, the accurate identification of a noun helps to limit verb selection to the few forms which may co-occur with that noun. It appears that listeners who were unable to identify "stagecoach" in Stan's samples often made misidentifications in the rest of the sentence. For example, one listener identified "You can ride a stagecoach" as "He can ride on skates." Further, Stan's post-therapy sentences contained significantly more polysyllabic words (29%) than the pre-therapy sentences (6%). According to Monsen (1983), the number of polysyllabic words in a sentence is one variable that can make a significant difference in accuracy of word identification. In fact, 13% of listeners misidentified the three syllable word "attitude" in one sentence Stan produced. Stan's pre-therapy sentences had no three syllable words.

Dana's intelligibility improved significantly on all measurements of speech intelligibility except for sentence identification, where accuracy of word identification was significantly better pre-therapy. A closer look at the data reveals that all listeners made misidentifications at the beginnings of the post-therapy sentences, accounting for nearly 100% of the errors made. The three sentences in the post-therapy sample started with "Oh well.. ," "They...," and "There..." and the three sentences in the pre-therapy sample started with "You...," "You...," and "Mom...". The interdental fricative /θ/ is a later developing sound than the approximate /j/ and the bilabial stop /m/. In addition, it may be that listeners are not expecting a connective, social phrase like "Oh well" to start a sentence when they are instructed to listen for understanding, and when it occurs out of the context of a conversation. Another possibility is that acoustic information was clipped off the beginning of the post-therapy samples during editing, giving the listener a distinct disadvantage in identification post-therapy. Finally, it is possible that Dana's speech samples are simply clearer pre-therapy. Whatever the reason, it is significant that nearly all the errors in post-therapy sentence identification occurred at the beginning of the sentence, because listeners would not have the ability to use preceding context to interpret the remainder of the sentence. If listeners are not able to understand the beginning of the sentence, it is difficult for them interpret the rest, and predictability is compromised. McGarr's (1983) study found that high probability sentences have higher intelligibility than low probability sentences. Therefore, for Dana's sentences, listeners may have had more contextual cues available to support comprehension in pre-therapy samples than in post-therapy samples.

Devon's results show that while he appeared to have made significant improvement in accuracy of single word production post-therapy, he made no significant change in sentence production pre- or post-therapy, according to listener word identification. The misidentifications made in Devon's sentences appear to be less informative than in the previous two cases. They are more random and less predictable. Devon's severe dysarthria and ataxia may have been very relevant here. First, people with dysarthria often fatigue when asked to produce longer utterances, and muscle weakness can affect articulation to a greater degree when they are fatigued (Yorkston & Beukelman, 1981b). Accordingly, Devon may have been able to pronounce a single word with more accuracy than an entire sentence. Also, Devon's ataxia resulted in erratic pitch and loudness fluctuations, and these may have been more obvious and deleterious in sentences. These difficulties may not have been present to a noticeable extent in single words for which he likely had better control over a shorter duration.

In summary, the comparison of word and sentence identification results suggests that, overall, the results of the word identification task may be a more easily interpretable measure of intelligibility in this study. Difficulties in matching sentence complexity and the small sample may have confounded the results of the sentence identification task for some speakers.

Goal Phoneme Identification in Word and Sentence Identification Tasks

The phonemes that were targeted in therapy should be the primary source of change in word and sentence identification tasks following palatometry therapy because palatometry focuses specifically on tongue placement. Accordingly, speakers should show similar patterns of outcomes when goal phoneme identification and word and sentence identification are measured. The following section examines the relationship between goal phoneme identification and word and sentence identification.

For goal phoneme identification in the word identification task, Dana's, Dora's, Sandy's and Samantha's samples all resulted in significant improvements just as they had for word identification. Delia's sample showed no significant difference in goal phoneme or word identification accuracy pre- or post-therapy. These results indicate that improvements in word identification, or lack thereof, were at least partially due to meeting the goals of therapy.

Stan's sample showed no significant change in accuracy of listener word identification pre- or post-therapy; however, his samples did show a significant improvement in accuracy of goal phoneme identification. This could simply indicate that the improvements in accuracy of phoneme production were not enough to improve overall word identification. For example, one listener identified "mud" pre-therapy and "trudge" post-therapy for the word "judge" (two goal phonemes: /dʒ/). In neither case did the listener identify the word correctly but post-therapy, one goal phoneme was accurately transcribed. Further, one listener was able to make no identification for the word “soap” pre-therapy but wrote “soak” post-therapy for “soap” (goal phoneme: /s/). The goal phoneme, but not the word, was again correctly identified.

Devon’s results showed a significant increase in accuracy of listener word identification post-therapy but no significant difference in goal phoneme identification in words pre- or post-therapy. This could indicate that Devon’s improvements post-therapy resulted more from control over pitch and loudness breaks than from accuracy of phoneme production. Control of pitch and loudness was targeted in therapy separate from palatometry goals.

All speakers except Stan showed the same listener results pre- and post-therapy, or lack thereof, in sentence identification and goal phoneme identification in sentences. Stan’s results showed a significant improvement in listener accuracy of sentence identification pre-therapy, but no significant change in accuracy of phoneme identification pre- or post-therapy. Goal phoneme identification in sentences did appear to be better pre-therapy, but not significantly better. This is consistent with the possibility that the pre-therapy sentences were “easier” to articulate. If this is the case, Stan may have made a few more speech errors in the post-therapy samples which resulted in misidentifications and misinterpretations of the sentence. The word with the speech error may have been misidentified resulting in misidentification of other words in trying to make the sentence “make sense.”

In summary, the goal phoneme identification in words and sentences showed generally that changes following palatometry therapy were probably due to greater accuracy in the production of the phonemes targeted in therapy. Devon was the only speaker where the data suggested that improvements in areas other than speech sound production may have been more salient.

## Judgment Task and Identification Tasks

The judgment task and identification tasks represent two different measures of intelligibility. For the judgment task, the listener compares one speech sample to another and selects one as better than the other. Identification tasks simply ask the listener to write down what they hear. While identification tasks and judgment tasks claim to measure the similar things, studies (e.g. Samar & Metz, 1988) have found that they often give different results. This section will compare the results for the two tasks for the current study.

Changes for more speakers were detected using the identification tasks than the judgment task. The judgment task only detected changes for Dana and Dora. The identification tasks detected that all speakers improved post-therapy in either word identification (Figure 3.2), goal phoneme identification in words (Figure 3.3), sentence identification (Figure 3.4) or goal phoneme identification in sentences (Figure 3.5).

It seems that listeners were able to increase accuracy of identification post-therapy but judged improvements post-therapy more conservatively. An improvement in post-therapy accuracy of single word identification somewhere between 11% (Sandy) and 29% (Dana) appeared to be necessary for an accurate global judgment. Sandy's results showed an improvement in accuracy of single word identification of 11% but the judgment task did not reach significance for designation of post-therapy samples as easier to understand. However, Dana's results show an improvement in accuracy of single word identification of 29%, and the judgment task indicated a significant designation of post-therapy samples as easier to understand. It is possible that with a larger number of speakers a cut-off may have been determined between 11% and 29% improvement in single word identification, where a change in word intelligibility was enough for listeners to designate post-therapy samples as easier to understand.

## SPEAKER VARIABLES

The speakers in this study included adults and children with speech disorders including cleft palate, hearing impairment and/or motor impairment. Further, speech impairments ranged from mild to severe (Table 2.2). In this section, the effect of speaker variables on the results observed in different tasks will be examined. A variety of disorders and ages within a small sample of speakers (seven) necessitates that much of this discussion be speculative.

## Age and Severity

*Adult* was defined as anyone 18 years old or older for the purposes of this study. Dana, Dora and Sandy were children at the time of the study and Stan, Delia, Devon and Samantha were all adults. Estimates of severity were made in Table 2.2 which outlines areas of difficulty for each speaker.

No real trends were obvious in the data when examining age and severity individually in such a small sample of speakers. However, Stan and Delia were the speakers who improved the least in this study and they were both adults with mild speech disorders. Further, they were the only adults with mild speech disorders in this study. A number of explanations are suggested by this result.

First, Fletcher, Dagenais and Critz-Crosby (1991) postulated that new learning was easier than changing established articulation patterns when accounting for their results, i.e., that speakers who fell into the mild intelligibility range improved the least following palatometry. This explanation could also apply to the current study. Stan and Delia had to adjust the phones they were already making to be more accurate while a speakers such as Samatha had to learn new phones because her phonological repertoire was very limited. In fact, Table 2.2 describes Stan and Delia's primary area of difficulty as phonetic. All the other speakers had phonologically based speech disorders. Fletcher, Dagenais and Critz-Crosby (1991) suggests that the minor "adjustments" which Stan and Delia had to make may have been more difficult than learning entirely new phones. However, Dana, who also had a mild disorder did show significant improvement on almost every measure of speech intelligibility. It is possible to take Fletcher et al.'s (1991) argument one step further and consider that adults have had more time to establish articulatory patterns. Dana, a child, may have had less established articulatory patterns which were more open to change.

Alternatively, listener bias may have resulted in an underestimation of Stan and Delia's improvements post-therapy. Stan and Delia were both very intelligible pre-therapy. In evaluations previous to palatometry it had been determined that when context was unknown, Stan's sentence intelligibility was measured at 100% and Delia's was 90%. Qualitative comments on the judgment task suggest that, when speakers were highly intelligible, listeners stopped paying attention to what they could understand and based their choices between pre- and post-therapy samples on personal preference. For more severe speakers such as Samantha, Dora, Sandy and Devon, listeners indicated that they made judgments about whether pre- or post-therapy were easier to understand based on the number of words they could understand and the "pronunciation" of words and consonants. However, for Delia, almost 100% of listeners said they made their decisions about which sample was easier to understand based on speaking rate. Further, every listener who said they preferred a faster speaking rate chose the pre-therapy sample more often than post-therapy sample, and every listener who said they preferred a slower speaking rate chose the post-therapy sample more often than the pre-therapy sample. In the post-therapy speech samples Delia was using a therapy strategy of slowing down her speech. Two listeners indicated that they noticed "less lisp" when she spoke more slowly, but they found faster speech less distracting, and thus they chose pre-therapy samples almost exclusively. For Stan, listeners mentioned a number of nonspecific qualities they preferred such as "fast cadence," "sibilance," "lack of slurring," "confidence," and "fluidity." In these cases listeners disregarded the instructions to "choose the one that is easier to understand" and made decisions about which sample they would rather listen to. In Stan and Delia's case listeners were able to understand them very well pre- and post-therapy, and so listeners turned to personal preference to make a choice. In the more severe cases this luxury was not available. Listeners had to attend to and compare the pieces of speech they could understand. However, Stan and Delia also showed little improvement in the identification tasks in which speech characteristics such as rate and fluidity were less likely to have an effect on intelligibility scores. It is possible that for these tasks Stan and Delia's high intelligibility also played a confounding role. It may be that when a speaker's pre-therapy intelligibility is close to 100%, small changes may have less of an effect on the overall intelligibility rating. For a speaker like Samantha, who had a severe speech disorder, a number of listeners commented that they listened for the sample which "sounded more like English." This could mean that, post-therapy, her /r/ was more identifiable; it would give listeners a more reliable cue as to what she was saying. However, for Stan and Delia, if the result of therapy was that an /s/ became more accurate, listeners could have identified the word or sentence they were presented with or without this increase in precision. The argument follows from the fact that improvements in speech intelligibility are not linear (Schiavetti, 1992). A small gain may show up more dramatically in speech intelligibility measures for speakers with poor intelligibility than for those with relatively good intelligibility.

Related to severity, listeners appeared to make more potentially stigmatizing comments about the speakers with severe speech disorders. In daily life this could restrict participation (WHO, 1997) in society and result in diminished social roles. One listener commented that she found hearing Samantha's voice "disturbing." Another listener guessed that Dora was a "young male child." A number of listeners noted that Devon sounded "drunk." These comments were made on the comments section of a qualitative questionnaire, and were not prompted by the experimenter. Listeners were never asked how they perceived the speaker. This may indicate that speakers with severe intelligibility disorders face a greater degree of discrimination when communicating with untrained listeners.

## Disorder

The seven speakers in this study presented with various disorders. Even though speakers cannot be grouped easily based on disorder, because of the variation in ages and etiologies amongst listeners, some interesting results for individual speakers may be related to disorder type.

Dora was the speaker who showed the most improvement on all measures of intelligibility, and she was the only speaker with a hearing impairment and a cochlear implant. Dora had had her implant for four years at the time she received palatometry therapy. Most studies (e.g. Osberger, Maso & Sam, 1993) indicate that changes in speech intelligibility, which are primarily due to the effects of the cochlear implant, usually have occurred by four years post-implant. Dora's progress reports, described in Chapter 2, indicate that her clinician felt she was not using visual information in the face and lips to help her form sounds. The visual input from palatometry could have been what Dora needed to help her make use of her improved auditory ability. The two sources of bio-feedback may have reinforced one another, resulting in better sound production.

Speakers with cleft palates appear to have shown the least improvement in speech intelligibility in this study. However, two of the speakers with cleft palates had mild speech intelligibility disorders and were adults, so it is likely that severity and age, and not disorder, account for the lack of improvement by these speakers. This is supported by the finding that the two children with cleft palates, Sandy and Dana, made significant improvements in speech intelligibility post-therapy.

# RELEVANCE OF FINDINGS TO THE WORLD HEALTH ORGANIZATION (1997) MODEL

Following palatometry therapy, all of the speakers made improvements at the level of impairment. Impairment measures look specifically at speech as a function of the oral motor structures. Palatograms showed that all speakers were able to make sound approximations which were closer to "normal." Consistent with the palatogram finding, phonetic identifications indicated that transcribers could better identify the phonemes in the speaker's speech. These measures show that the oral structures were able to produce certain speech sounds more accurately in the context of therapy. As such, before the current study began, it was known that palatography was successful at the impairment level. However, impairment is only one level of functioning. Other contextual factors are present when we consider a speaker's activity and participation. Most importantly, the listener is present in any communication interaction. Therefore, it was crucial to investigate the effects of palatometry at levels of functioning beyond impairment, to achieve a more complete evaluation of outcomes.

Untrained listeners participated in the current study to mimic the contextual factors a speaker may encounter in day to day activity. For example, a clerk at a store or a telephone operator may not have had any exposure to disordered speech. Further, intelligibility measures were used, because they assess what is understood by the listener. If information transfer within a communication situations is increased post-therapy, activity limitation will be decreased. For example, if an improvement in the production of /s/-clusters results in the speaker being better able to communicate that he/she needs "stamps" to the postal clerk, therapy has made it easier for the speaker to accomplish a day to day activity. If /s/-clusters are produced more accurately only in the therapy context, the speaker may see no real effect of his/her speech improvement in everyday life. Intelligibility in our study was measured in the most stringent context. No visual cues were present, as they would be in everyday life. Further, contextual cues, such as topic, that would be present in conversation, did not exist in the isolated words and sentences used as stimuli.

In the current study, nearly all speakers showed some improvement in intelligibility measures by untrained listeners post-therapy. This means that listeners untrained with disordered speech were better able to understand all the speakers at some level following palatometry therapy. Palatometry therapy not only improved speech production at the oral motor level, but at the level of communication. Activity limitation was reduced post-therapy. Most speakers were able to use the skills they had acquired in therapy to make themselves better understood in everyday communication.

Impairment and activity measures agreed that all speakers showed improvement post-therapy, indicating changes at two different levels of functioning post-therapy. Improvements at the level of activity mean that the speaker was better understood by listeners other than clinicians, who are trained to understand disordered speech and to recognize changes post-therapy. Also, important findings have been discussed throughout this chapter which indicates that while all speakers demonstrated a positive result, their outcomes were varied. For example, in Devon's case it was apparent that with his particular motor impairment, areas of difficulty at the suprasegmental level such as pitch and loudness fluctuations may had more influence on listeners than his phonological or phonetic impairments. In the word identification task, listeners were better able to identify his words post-therapy even though they showed no improvement in identification of goal phonemes. This could mean that therapy which addressed his pitch and loudness fluctuations (therapy beyond palatometry) may have been the most beneficial to his everyday communication. For speakers such as Dora, Dana, Sandy, and Samantha there was improvement on a majority of the intelligibility measures and there appeared to be little doubt that palatometry was the primary factor in their improvement. Increased intelligibility in sentence and word identification, and for some, in judgment, indicate that untrained listeners were able to understand more of the information they were transmitting through their speech. If the average person in the public is able to better understand a speaker it is likely that interactions on a daily basis will be more successful. These kinds of results are very important for both the clinician and the client to understand. They not only indicate whether communication has improved but why it has improved. For some of the clients the results of these outcome measures could be used to guide further therapy. Understanding how and why a client improved is key to determining relevant therapy goals and to evaluating the success of these goals..

The adults in this study with a mild disorder (Stan and Delia) are interesting when considering speech therapy and the WHO (1997) model. Stan and Delia showed little change in intelligibility measures post-therapy. However, it should not be assumed that there was no change in the level of activity limitation post-therapy. Because Stan and Delia were very intelligible pre-therapy, changes in activity level post-therapy may have been very subtle. They may seldom have trouble getting a store clerk to understand them, but when a misunderstanding would occur post-therapy, they might then have new techniques to make themselves understood in a shorter time period. Furthermore, Stan's productions showed no change in listener accuracy of word identification post-therapy but did show an increase in listener accuracy of goal phoneme identification post-therapy. This could indicate that Stan's improvement at the activity level would primarily be that he could give his listener more cues to a word that may have been misunderstood. For example, post-therapy, Stan might be able to produce the first sound of a word accurately that would have been completely unintelligible pre-therapy. Such increases in the information conveyed to the untrained listener increase the chances of a successful communicative interaction between speaker and listener. Further, this result emphasizes the role of context in Stan's speech, since he was very intelligible in sentences although listeners had significant difficulty with words pronounced in isolation.

The self-reports of speakers that they feel better about their speech are also relevant. If speakers feel better about their speech and more confident about their ability to make themselves understood, then everyday communication should be easier and activity less limited.

Finally, it is important to consider the negative comments, discussed in the previous section, made by listeners about speakers with severe speech disorders. These perceptions of untrained listeners have the potential to be stigmatizing and to affect the speakers' roles in society. For example, if an employer feels Devon is drunk, he may be unfairly labelled as irresponsible, or he may even be fired. As such, negative perceptions of listeners could result in participation restrictions to the speaker with a speech disorder.

## LIMITATIONS OF THIS STUDY AND DIRECTIONS FOR FUTURE RESEARCH

Outcomes studies are not prevalent in speech therapy. Studies in the area of phonological therapy have primarily addressed impairment measures as outcomes. The current study highlights the importance of measuring effects of therapy outside of the clinic. The following section outlines limitations of this study, such as sample size and stimuli selection which have been alluded to throughout this chapter. Directions for future research will also be presented.

Outcome studies require reliable samples of speech pre- and post-therapy, collected ahead of time with a view to future possible studies. Preparation of stimuli for the current (retrospective) study was extremely difficult because pre- and post-therapy probes in the original study did not necessarily consist of similar material. In order to have a sufficient sample to chose from, it is important to ensure that the same probes for words, sentences and connected speech are used pre- and post-therapy. In the current study, difficulty matching samples pre- and post-therapy resulted in stimuli that were often less than ideal, especially for the tasks involving sentences. Care should be taken to consider the phonological and semantic complexity as well as the lengths of sentences collected pre- and post-therapy. It may also be best to consider length in terms of syllables rather than words, to avoid difficulties like those found in Stan's data earlier in the chapter. Further, it is important to have audiotaped samples which are not contaminated by difference in background noise. If one of the samples contains more noise than the other, listeners' judgments about intelligibility can be compromised. Because the world is often noisy and judgments in quiet conditions therefore potentially misleading, it is permissible to allow a natural level of background noise, but noise levels must be the same pre- and post-therapy. These considerations are relevant when planning research on outcomes of therapy.

Further, the current study had a very small number of speakers (seven). If the number of speakers were increased in a future study then the effects of speaker variables such as age, disorder, and severity and intelligibility could be analyzed.

Additionally, this study used only untrained listeners. It would be informative to compare the results of untrained and trained listeners. This would help to determine the importance of using untrained listeners when measuring activity and participation. It may be that trained listeners cannot provide adequate measures of activity and participation outside the clinic. Further, it is possible that, without the input of untrained listeners, clinicians could set inappropriate goals.

Next, the current study could be further quantified by comparing palatogram changes and phonetic transcriptions and listeners' evaluation of intelligibility ratings.

Finally, the qualitative results gathered in this study suggest that a systematic study of speakers' and listeners' perceptions pre- and post-therapy may provide a way to measure outcomes at the level of participation restriction, an area which has rarely been investigated in regard to phonological therapy.

## CLINICAL IMPLICATIONS

The results of the current study indicate a number of clinical implications for both intelligibility measures, and palatometry as a form of therapy. This section will discuss these implications.

First, it is possible that untrained listeners provide the best measures of changes in activity limitations post-therapy. Communication involves a person untrained with disordered speech for much of the clients' everyday interactions. Therefore, the most functional measure of change may be obtained from untrained listeners who are not invested in the therapy process and who cannot rely on other sources of information to compensate for difficulty perceiving disordered speech productions.

Next, word identification may be the most practical measure of intelligibility for clinical use. An improvement in accuracy of word identification from pre- to post-therapy somewhere between 11% and 30% may be sufficient for untrained listeners to notice a difference in ease of understanding. If a more specific cut-off percentage can be determined, it may be possible to use improvement in word identification as a discharge criterion. Judgment tasks are a somewhat less practical way to measure improvement for the majority of clients. Sentence or continuous speech identification could also be sensitive enough for clinical use if it is possible to collect well-matched pre- and post-therapy sentences.

Finally, palatometry was found to be a useful therapy tool for a variety of disorders and age groups. Improvements at the activity level were noticeable to untrained listeners for all speakers in this study.

# CONCLUSION

With increased pressure both in clinical and research settings to provide therapy which is relevant and cost-effective, it is important to consider changes post-therapy at all levels of functioning (WHO, 1997). To ensure client satisfaction, we must use therapy techniques which result in changes that are relevant to the client, and not just the clinician. The clinician should not have to tell the clients that they have made improvement. The clients themselves should see increases in activity and participation. In terms of activity, the clients should be able to communicate more often and more easily. In terms of participation, the client should face less stigma and social isolation because of their speech disorder. As researchers and clinicians, we cannot ensure such outcomes unless we find a way to measure activity and participation. This study used the functional index of intelligibility to measure changes in activity limitations. It found that palatometry produced effects that stemmed beyond the impairment level, and reduced activity limitation. As such, gains made in palatometry therapy were able to move outside the clinic and became relevant to speakers' day to day lives. Further, qualitative data suggested that speakers may have experienced participation restrictions. More study is needed to determine if general listener perceptions about the speakers changed from pre- to post-therapy. It is undeniable that a decrease in the negative perceptions of speakers by listeners from pre- to post-therapy would be a positive effect of therapy and likely result in improved social participation by the speaker. The final conclusion of this study is that to be responsible to clients, all forms of therapy should evaluate, target and measure goals in the areas of activity limitation and participation restriction. Addressing levels of functioning beyond impairment is the only way to ensure clinicians and researchers are "making a difference."

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# APPENDIX A

# EXPERIMENTAL STIMULI

## Stimuli for the Judgment Task

1. Speaker: Stan

Sentences from the Rainbow Passage at T1

a. When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow.

b. The rainbow is a division of white light into many beautiful colors.

c. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

d. There is, according to legend, a boiling pot of gold at one end.

e. People look, but no one ever finds it.

Sentences from the AIDS at T1

f. She picked a bouquet of wildflowers. (6.65)

g. Both injuries were to the same leg. (7.6)

h. You'll also have to buy the gas. (7.67)

i. I told her I only had nine minutes. (8.98)

j. Salt is the only special ingredient you need. (8.64)

Sentences from the Rainbow Passage at T2

a. When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow.

b. The rainbow is a division of white light into many beautiful colors.

c. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

d. There is, according to legend, a boiling pot of gold at one end.

e. People look, but no one ever finds it.

Sentences from the AIDS at T2

f. How many melons would you like? (6.55)

g. Handle it anyway you have to. (7.32)

h. He ignores them concentrating on his work. (7.81)

i. You'd be better off taking a cold shower. (8.1)

j. Do you know what the yards look like? (8.41)

2. Speaker: Delia

Sentences from the Rainbow Passage at T1

a. When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow.

b. Raindrops in the air.

c. The rainbow is a division of light into many beautiful colors.

d. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

e. These take the shape of a long round arch.

f. There is, according to legend, a boiling pot of gold at one end.

g. No one ever finds it.

h. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

i. His friends say he is looking for a pot of gold at the end of the rainbow.

j. A boiling pot of gold at one end.

Sentences from the Rainbow Passage at T2

a. When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow.

b. Raindrops in the air.

c. The rainbow is a division of light into many beautiful colors.

d. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

e. These take the shape of a long round arch.

f. There is, according to legend, a boiling pot of gold at one end.

g. No one ever finds it.

h. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

i. His friends say he is looking for a pot of gold at the end of the rainbow.

j. A boiling pot of gold at one end.

3. Speaker: Dana

Sentences from the Rainbow Passage at T1

a. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

b. People look, but no one ever finds it.

c. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Sentences from Story Retells at T1

d. Sam and Lucy were walking on their way to school.

e. They stopped to play on the swings.

f. I can swing higher then you.

g. A nice policeman came along.

h. Hurry up kids or else you will miss your bus.

i. They got there right on time to see their bus leaving.

j. I forget his name.

Sentences from the Rainbow Passage at T2

a. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

b. People look, but no one ever finds it.

c. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Sentences from Story Retells at T2

d. One day, Sam and Lucy were on their way to catch the bus.

e. They saw the swings.

f. I can swing higher then you.

g. Then a policeman came.

h. You better hurry and get to the bus.

i. They saw the bus drive away without them.

j. They went to the corner.

4. Speaker: Devon

Sentences from Story Retells at T1

a. Sheila and Todd went to the ocean on vacation.
b. Sheila liked the water, splash, splash, splash.
c. Todd caught a bunch of fish.
d. The next day, they, Sheila and Todd got a bunch of shells.
e. Sam and Lucy are a couple of kids on the way to get the bus.
f. They're getting high-jacked by a swing.
g. A cop comes by and tells them they better watch the time.
h. He knows he got to get the bus.
i. They're just in time to watch the bus leave.
j. Julie has all her friends over.

Sentences from Story Retells at T2

a. Sheila and Todd went to the ocean for their vacation.
b. Sheila went splish, splash with their shoes and socks off.
c. Todd went fishing.
d. Together they collected shells.
e. Sam and Lucy were going towards the bus for school.
f. They came upon some swings.
g. A very nice policeman came along.
h. You'll miss your bus.
i. They got on and missed the bus.
j. Tony did a couple pieces of toast.

5. Speaker: Dora

Sentences from the Rainbow Passage at T1

a. The sunlight strikes raindrops in the air.
b. They act like a prism and form a rainbow.
c. The rainbow is a division of white light into many beautiful colors.
d. These take the shape of a long round arch.
e. Two ends apparently beyond the horizon.
f. Boiling pot of gold at one end.
g. People look, but no one ever finds it.
h. No one ever finds it.
i. A man looks for something beyond his reach.
j. His friends say he is looking for a pot of gold at the end of the rainbow.

Sentences from the Rainbow Passage at T2

a. The sunlight strikes raindrops in the air.
b. They act like a prism and from a rainbow.
c. The rainbow is a division of white light into many beautiful colors.
d. These take the shape of a long round arch.
e. Two ends apparently below the horizon.
f. Boiling pot of gold at one end.
g. People look, but no one ever finds it.
h. No one ever finds it.
i. A man looks for something beyond his reach.
j. His friends say he is looking for a pot of gold at the end of the rainbow.

6. Speaker: Sandy

Sentences from the Rainbow Passage at T1

a. The rainbow is a division of white light into many beautiful colors.

b. These take the shape of a long round arch, with its path high above, and its two ends apparently beyond the horizon.

c. There is, according to legend, a boiling pot of gold at one end.

d. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Sentences from the AIDS at T1

e. We gathered shells on the beach. (6.1)

f. I hadn't even read for the part. (7.88)

g. I saw him a few weeks later. (7.38)

h. The lovable man is not a mama's boy. (8.65)

i. Dreaming it, I moaned suddenly in my sleep. (8.69)

j. That's not the word to describe it at all. (9.41)

Sentences from the Rainbow Passage at T2

a. The rainbow is a division of white light into many beautiful colors.

b. These take the shape of a long round arch, with its path high above, and its tow ends apparently beyond the horizon.

c. There is, according to legend, a boiling pot of gold at one end.

d. When a man looks for something beyond his reach, his friends say he is looking for the pot of gold at the end of the rainbow.

Sentences from the AIDS at T2

e. For bird lovers they're very special. (6.93)

f. He is definitely a notch above us. (7.11)

g. No one can quarrel with the aim. (7.49)

h. I didn't know where they were coming from. (8.16)

i. After that nature should do it for you. (8.55)

j. Why is yours the greatest choir in the world? (9.56)

7. Speaker: Samantha

Sentences from the AIDS at T1

a. Enjoy the fair weather while in the tropics. (8.76)

b. There are two basic ways to fasten concrete securely. (9.89)

c. I have no reason to believe he is a candidate. (10.15)

d. Spending time with the family is really my favorite activity. (10.6)

e. I haven't got time to go on listening to tapes. (11.84)

f. He said to remind me when I grade you. (11.5)

g. A cat raised by other cats will be forever fearful of people. (12.13)

h. Overall, the mail has become more erratic and on the average slower. (12.92)

i. Last night, we all went to a music festival they had downtown. (13.53)

j. You'd better enjoy it because you may get another chance to see one. (14.34)

Sentences from the AIDS at T2

a. Enjoy the fair weather while in the tropics. (8.76)

b. There are two basic ways to fasten concrete securely. (9.89)

c. I have no reason to believe he is a candidate. (10.15)

d. Spending time with the family is really my favorite activity. (10.6)

e. I haven't got time to go on listening to tapes. (11.84)

f. Some of the new farm guides are full of exciting discoveries. (11.45)

g. A cat raised by other cats will be forever fearful of people. (12.13)

h. Overall, the mail has become more erratic and on the average slower. (12.92)

i. Last night, we all went to a music festival they had downtown. (13.53)

j. You'd better enjoy it because you may get another chance to see one. (14.34)

Stimuli for Word Identification Task

1. Speaker: Stan

| | |
|---|---|
| sewing machine | soap |
| television | judge |
| present | sleep |
| pages | cooking |
| dress | van |

**Number of phonemes in sample which were targeted in therapy: 10**

2. Speaker: Delia

| | |
|---|---|
| music | thumb |
| zipper | horse |
| chicken | jumping |
| wagon | hang |
| star | read |

**Number of phonemes in sample which were targeted in therapy: 8**

3. Speaker: Dana

| | |
|---|---|
| Santa Claus | red |
| tubby | see |
| dolly | gum |
| diving | me |
| laugh | mom |

**Number of phonemes in sample which were targeted in therapy: 10**

4. Speaker: Devon

| | |
|---|---|
| dollhouse | shoe |
| sunny | flower |
| combing | off |
| quarter | bee |
| cage | church |

**Number of phonemes in sample which were targeted in therapy:: 8**

5. Speaker: Dora

| | |
|---|---|
| screw**dr**iver | **frog** |
| mou**th**y | noisy |
| **gl**asses | boot |
| snow | bib |
| **truck** | on |

**Number of phonemes in sample which were targeted in therapy: 10**

6. Speaker: Sandy

| | |
|---|---|
| ice **c**ube | **gr**een |
| **c**alling | **s**un |
| too**th**y | pie |
| hu**gg**ing | nine |
| **k**ey | plum |

**Number of phonemes in sample which were targeted in therapy: 8**

7. Speaker: Samantha

| | |
|---|---|
| sunglasses | ice |
| finge**r** | **r**ow |
| **c**andle | you |
| pou**r**ing | dad |
| b**rush** | eat |

**Number of phonemes in sample which were targeted in therapy: 9**

Stimuli for Sentence Identification Task

1. Speaker: Stan

   T1

   a. We have a big house. (5.22)
   b. My work is here too. (5.78)
   c. We gathered shells on the beach. (6.1)

   T2

   a. You can ride a stage coach. (5.15)
   b. Many have adopted this attitude. (5.92)
   c. I was conscious all the time. (6.5)

2. Speaker: Delia

   T1

   a. People look but no one ever finds it.
   b. They act like a prism and form a rainbow.
   c. Two ends apparently beyond the horizon.

T2

a. A man looks for something beyond his reach.
b. The sunlight strikes raindrops in the air.
c. The rainbow is a division of white light.

3. Speaker: Dana

T1

a. Mom, what are these little spots on my face?
b. You can not go outside today.
c. You can have anything you want.

T2

a. Oh well, we have lots of time.
b. They went in the store.
c. There was only one left.

4. Speaker: Devon

T1

a. She was turning ten.
b. I can't remember.
c. Her mom said, look out the window.

T2

a. She put a flower on the tray.
b. Todd went fishing.
c. Breakfast was for the mother.

5. Speaker: Dora

T1

a. Saw a zebra at the zoo.
b. He was very happy with his real nose, wet paint.
c. She looked out the window and she looked out at the park.

T2

a. They stopped to play with swings.
b. I can swing higher then you Lucy, Sam said.
c. A police officer came and said hurry up or you'll miss your bus.

6. Speaker: Sandy

T1

a. My husband drives too fast. (5.77)
b. It was not a joke. (5.73)
c. She picked a bouquet of wild flowers. (6.65)

T2

a. He took heart and played. (5.35)

b. Its the way it was. (5.80)

c. We all sat down and relaxed. (6.26)

7. Speaker: Samantha

T1

a. Every newspaper reported the story. (5.63)

b. The robber escaped with the diamonds. (6.52)

c. The plot is laced with mysterious incidences. (7.3)

T2

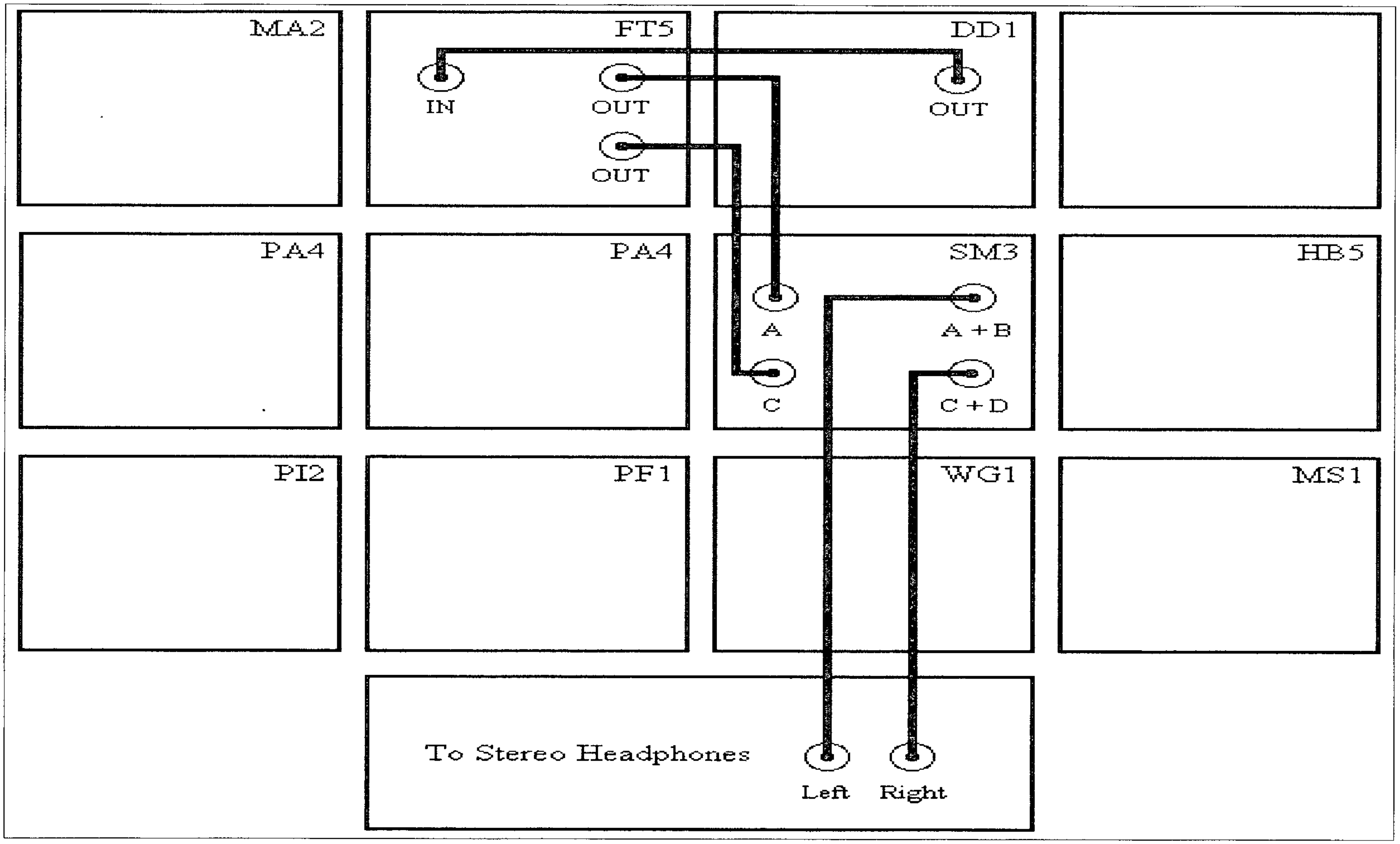
a. Its not a bright outlook. (5.51)

b. There is a treehouse up above. (6.7)

c. There is enough oil here for all. (7.94)

# APPENDIX B

## TUCKER-DAVIS MODULES SET-UP



# APPENDIX C

## VOLTAGE AND ROOT MEANS SQUARE (RMS) VALUES FOR SOUND FILES

1. Speaker: Stan

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RWSDS1PE | 250 | 0.0763 | 0.0803 | 263 | RWSDS1PS |
| RWSDS2PE | 226 | 0.0692 | 0.0803 | 263 | RWSDS2PE |
| RWSDS3PE | 286 | 0.0875 | 0.0966 | 316 | RWSDS3PS |
| RWSDS4PE | 366 | 0.1119 | 0.0984 | 322 | RWSDS4PS |
| RWSDS5PE | 299 | 0.0915 | 0.1087 | 356 | RWSDS5PS |
| RSDS10PE | 294 | 0.0898 | 0.0.0731 | 239 | RSDS10PO |
| RSDS11PE | 338 | 0.1034 | 0.0900 | 294 | RSDS11PO |
| RSDS12PE | 406 | 0.1240 | 0.0935 | 306 | RSDS12PO |
| RSDS13PE | 384 | 0.1174 | 0.1158 | 379 | RSDS13PO |
| RSDS14PE | 395 | 0.1206 | 0.1230 | 403 | RSDS14PO |
| Word Identification Task | | | | | |
| RSDW1PR | 283 | 0.0864 | 0.0714 | 233 | RSDW1PS |
| RSDW2PR | 221 | 0.0675 | 0.0713 | 233 | RSDW2PS |
| RSDW3PR | 246 | 0.0754 | 0.0820 | 268 | RSDW3PS |
| RSDW4PE | 302 | 0.0923 | 0.0834 | 273 | RSDW4PS |
| RSDW5PE | 209 | 0.0639 | 0.0865 | 283 | RSDW5PS |
| RSDW6PR | 409 | 0.1250 | 0.1118 | 366 | RSDW6PS |
| RSDW7PE | 210 | 0.0642 | 0.0705 | 231 | RSDW7PS |
| RSDW8PE | 205 | 0.0629 | 0.0732 | 239 | RSDW8PS |
| RSDW9PE | 270 | 0.0826 | 0.0885 | 290 | RSDW9PS |
| RSDW10PE | 175 | 0.0534 | 0.0547 | 179 | RSDW10PS |
| Sentence Identification Task | | | | | |
| RWSDS7PE | 258 | 0.0789 | 0.0790 | 258 | RWSDS7PS |
| RWSDS8PE | 324 | 0.0991 | 0.0662 | 216 | RWSDS8PO |
| RWSDS9PE | 307 | 0.0938 | 0.0826 | 270 | RWSDS9PO |

2. Speaker: Delia

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RWDLS3PE | 305 | 0.0934 | 0.0940 | 380 | RWDLS3PO |
| RWDLS4PE | 320 | 0.0978 | 0.0935 | 306 | RWDLS4PO |
| RWDLS5PE | 318 | 0.0972 | 0.0995 | 325 | RWDLS5PO |
| RWDLS7PE | 312 | 0.0953 | 0.0869 | 284 | RWDLS7PO |
| RWDLS8PE | 324 | 0.0992 | 0.0930 | 304 | RWDLS8PO |
| RDLS10PE | 336 | 0.1026 | 0.1030 | 337 | RWDLS10PO |
| RDLS13PE | 339 | 0.1037 | 0.0884 | 289 | RDLS13PO |
| RDLS14PE | 334 | 0.1020 | 0.0977 | 320 | RDLS14PO |
| RDLS16PS | 314 | 0.0961 | 0.0895 | 243 | RDLS16PO |
| RDLS15PE | 354 | 0.1082 | 0.1058 | 346 | RDLS15PO |
| Word Identification Task | | | | | |
| RDLW1PE | 112 | 0.0343 | 0.0345 | 113 | RDLW1PS |
| RDLW2PE | 125 | 0.0383 | 0.0526 | 172 | RDLW2PS |
| RDLW3PE | 130 | 0.0397 | 0.0466 | 152 | RDLW3PS |
| RDLW4PE | 116 | 0.0356 | 0.0396 | 129 | RDLW4PS |
| RDLW5PR | 177 | 0.0542 | 0.0474 | 155 | RDLW5PS |
| RDLW6PR | 210 | 0.0643 | 0.0542 | 177 | RDLW6PS |
| RDLW7PE | 149 | 0.0457 | 0.0555 | 181 | RDLW7PS |
| RDLW8PE | 187 | 0.0571 | 0.0760 | 251 | RDLW8PS |
| RDLW9PE | 152 | 0.0466 | 0.0418 | 136 | RDLW9PS |
| RDLW10PE | 186 | 0.0571 | 0.0333 | 109 | RDLW10PS |
| Sentence Identification Task | | | | | |
| RDLS12PE | 340 | 0.1040 | 0.0960 | 314 | RDLS11PO |
| RWDLS2PE | 159 | 0.0486 | 0.0458 | 149 | RWDLS1PS |
| RWDLS9PE | 316 | 0.0966 | 0.0964 | 315 | RWDLS6PO |

3. Speaker: Dana

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RWDAS2PE | 354 | 0.1081 | 0.1209 | 396 | RWDAS1PS |
| RWDAS4PE | 351 | 0.1073 | 0.1248 | 408 | RWDAS2PS |
| RWDAS5PE | 304 | 0.0929 | 0.1329 | 435 | RWDAS3PS |
| RWDAS6PE | 382 | 0.1168 | 0.0962 | 315 | RWDAS4PS |
| RWDAS7PE | 309 | 0.0944 | 0.0858 | 281 | RWDAS5PS |
| RWDAS8PE | 397 | 0.1213 | 0.0800 | 262 | RWDAS9PS |
| RWDAS9PE | 362 | 0.1105 | 0.0820 | 268 | RDAS10PS |
| RDAS10PE | 273 | 0.0835 | 0.0933 | 305 | RDAS11PS |
| RDAS12PE | 390 | 0.1191 | 0.1061 | 347 | RDAS13PS |
| RDAS13PE | 206 | 0.0629 | 0.0847 | 277 | RDAS12PS |
| Word Identification Task | | | | | |
| RDAW1PE | 234 | 0.0714 | 0.1008 | 330 | RDAW1PS |
| RDAW2PE | 311 | 0.0951 | 0.1198 | 392 | RDAW2PS |
| RDAW3PE | 206 | 0.0629 | 0.0581 | 190 | RDAW3PS |
| RDAW4PE | 349 | 0.1067 | 0.0754 | 247 | RDAW4PS |
| RDAW5PE | 282 | 0.0861 | 0.0726 | 238 | RDAW5PO |
| RDAW6PR | 276 | 0.0843 | 0.1032 | 338 | RDAW6PS |
| RDAW7PE | 251 | 0.0767 | 0.0614 | 201 | RDAW7PS |
| RDAW8PE | 269 | 0.0822 | 0.1025 | 336 | RDAW8PS |
| RDAW9PE | 422 | 0.1290 | 0.0958 | 314 | RDAW9PS |
| RDAW10PE | 381 | 0.1166 | 0.0914 | 299 | RDAW10PS |
| Sentence Identification Task | | | | | |
| RDAS15PE | 380 | 0.1160 | 0.0959 | 314 | RWDAS7PS |
| RDAS16PS | 272 | 0.0833 | 0.0777 | 254 | RDAS15PS |
| RDAS17PE | 387 | 0.1184 | 0.1117 | 366 | RDAS16PS |

4. Speaker: Devon

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RWDDS1PR | 668 | 0.2040 | 0.2096 | 686 | RWDDS7PS |
| RWDDS2PR | 596 | 0.1820 | 0.1930 | 632 | RWDDS8PS |
| RWDDS4PR | 563 | 0.1719 | 0.1945 | 637 | RWDDS9PS |
| RWDDS5PR | 637 | 0.1946 | 0.1866 | 611 | RDDS10PS |
| RWDDS6PR | 609 | 0.1861 | 0.2092 | 685 | RWDDS1PS |
| RWDDS7PR | 669 | 0.2044 | 0.2030 | 665 | RWDDS2PS |
| RWDDS8PR | 694 | 0.2119 | 0.2287 | 749 | RWDDS5PS |
| RDDS10PR | 682 | 0.2082 | 0.2398 | 785 | RWDDS6PS |
| RDDS11PR | 618 | 0.1887 | 0.2172 | 711 | RWDDS3PS |
| RDDS12PR | 708 | 0.2163 | 0.2063 | 675 | RDDS12PS |
| Word Identification Task | | | | | |
| RDDW1PR | 737 | 0.2251 | 0.2325 | 761 | RDDW1PS |
| RDDW2PR | 495 | 0.1511 | 0.1280 | 419 | RDDW2PS |
| RDDW3PR | 456 | 0.1393 | 0.1589 | 520 | RDDW3PS |
| RDDW4PR | 541 | 0.1654 | 0.1568 | 513 | RDDW4PS |
| RDDW5PR | 401 | 0.1225 | 0.1246 | 408 | RDDW5PS |
| RDDW6PR | 604 | 0.1844 | 0.1783 | 584 | RDDW6PS |
| RDDW7PR | 587 | 01764 | 0.1866 | 611 | RDDW7PS |
| RDDW8PR | 633 | 0.1934 | 0.2053 | 672 | RDDW8PS |
| RDDW9PR | 534 | 0.1631 | 0.1626 | 532 | RDDW9PS |
| RDDW10PR | 539 | 0.1647 | 0.1454 | 476 | RDDW10PS |
| Sentence Identification Task | | | | | |
| RDDS13PR | 623 | 0.1904 | 0.2162 | 708 | RDDS11PS |
| RDDS3PR | 649 | 0.1904 | 0.2172 | 711 | RWDDS3PS |
| RDDS15PE | 862 | 0.2632 | 0.2437 | 798 | RDDS13PS |

5. Speaker: Dora

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RWDRS1PR | 448 | 0.1308 | 0.1364 | 446 | RWDRS1PO |
| RWDRS2PR | 449 | 0.1373 | 0.1489 | 487 | RWDRS2PO |
| RWDRS3PR | 402 | 0.1228 | 0.0964 | 315 | RWDRS3PO |
| RWDRS4PR | 494 | 0.1508 | 0.0742 | 253 | RWDRS4PO |
| RWDRS5PR | 419 | 0.1281 | 0.1133 | 371 | RWDRS5PO |
| RWDRS6PR | 391 | 0.1196 | 0.1274 | 417 | RWDS6PO |
| RWDRS7PR | 440 | 0.1343 | 0.0984 | 322 | RWDRS7PO |
| RWDRS8PR | 405 | 0.1239 | 0.0898 | 294 | RWDRS8PO |
| RWDRS9PR | 435 | 0.1330 | 0.0913 | 299 | RWDRS9PO |
| RDRS10PR | 469 | 0.1434 | 0.1020 | 334 | RDRS10PO |
| Word Identification Task | | | | | |
| RDRW1PR | 438 | 0.1339 | 0.1238 | 405 | RDRW1PS |
| RDRW2PR | 376 | 0.1149 | 0.1158 | 379 | RDRW2PS |
| RDRW3PR | 380 | 0.1163 | 0.0829 | 271 | RDRW3PS |
| RDRW4PR | 356 | 0.1088 | 0.0948 | 310 | RDRW4PS |
| RDRW5PR | 392 | 0.1197 | 0.1028 | 336 | RDRW5PS |
| RDRW6PR | 429 | 0.1310 | 0.1277 | 418 | RDRW6PS |
| RDRW7PE | 532 | 0.1627 | 0.1319 | 432 | RDRW7PS |
| RDRW8PR | 448 | 0.1369 | 0.1271 | 416 | RDRW8PS |
| RDRW9PR | 383 | 0.1169 | 0.1369 | 448 | RDRW9PO |
| RDRW10PR | 424 | 0.1295 | 0.1295 | 424 | RDRW10PS |
| Sentence Identification Task | | | | | |
| RDRS11PR | 369 | 0.1120 | 0.1109 | 363 | RDRS13PS |
| RDRS12PR | 486 | 0.1485 | 0.1367 | 448 | RDRS12PS |
| RDRS13PE | 444 | 0.1358 | 0.1494 | 489 | RDRS11PS |

6. Speaker: Sandy

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RSAS12PE | 318 | 0.0972 | 0.1024 | 335 | RSAS12PO |
| RSAS13PE | 359 | 0.1097 | 0.0965 | 316 | RSAS13PO |
| RSAS14PE | 275 | 0.0840 | 0.0845 | 276 | RSAS14PO |
| RSAS15PE | 288 | 0.0880 | 0.1029 | 337 | RSAS15PO |
| RWSAS4PE | 418 | 0.1277 | 0.1277 | 418 | RWSAS4PO |
| RWSAS5PE | 407 | 0.1245 | 0.1276 | 418 | RWSAS5PS |
| RWSAS6PE | 357 | 0.1091 | 0.1117 | 336 | RWSAS6PO |
| RWSAS7PE | 249 | 0.0763 | 0.0840 | 275 | RWSAS7PO |
| RWSAS8PE | 253 | 0.0775 | 0.0967 | 316 | RWSAS8PO |
| RWSAS9PE | 297 | 0.0907 | 0.0911 | 298 | RWSAS9PO |
| Word Identification Task | | | | | |
| RSAW1PE | 400 | 0.1224 | 0.1008 | 330 | RSAW1PO |
| RSAW2PR | 237 | 0.0725 | 0.0687 | 225 | RSAW2PO |
| RSAW3PE | 215 | 0.0657 | 0.0.0770 | 252 | RSAW3PO |
| RSAW4PE | 270 | 0.0825 | 0.0768 | 251 | RSAW4PO |
| RSAW5PE | 319 | 0.0975 | 0.0894 | 292 | RSAW5PO |
| RSAW6PE | 512 | 0.1066 | 0.1009 | 330 | RSAW6PO |
| RSAW7PR | 280 | 0.0857 | 0.1121 | 367 | RSAW7PO |
| RSAW8PE | 326 | 0.0996 | 0.0880 | 288 | RSAW8PO |
| RSAW9PE | 516 | 0.1576 | 0.1476 | 483 | RSAW9PS |
| RSAW10PR | 337 | 0.1029 | 0.1072 | 350 | RSAW10PO |
| Sentence Identification Task | | | | | |
| RWSAS1PE | 567 | 0.1732 | 0.1571 | 514 | RWSAS1PS |
| RWSAS2PR | 491 | 0.1500 | 0.1486 | 486 | RWSAS2PS |
| RWSAS3PE | 355 | 0.1084 | 0.1358 | 444 | RWSAS3PO |

7. Speaker: Samantha

| T1 | | | T2 | | |
|---|---|---|---|---|---|
| Filename | RMS | Voltage | Voltage | RMS | Filename |
| Judgment Task | | | | | |
| RWSMS7PE | 231 | 0.0706 | 0.0853 | 279 | RWSMS7PS |
| RWSMS8PE | 227 | 0.0694 | 0.0648 | 212 | RWSMS8PS |
| RWSMS9PE | 224 | 0.700 | 0.0774 | 253 | RWSMS9PS |
| RSMS10PE | 221 | 0.0676 | 0.0716 | 234 | RSMS10PS |
| RSMS11PE | 225 | 0.0689 | 0.0725 | 237 | RSMS11PS |
| RSMS12PE | 202 | 0.0618 | 0.0752 | 246 | RSMS12PS |
| RSMS13PE | 228 | 0.0698 | 0.0810 | 265 | RSMS13PS |
| RSMS14PE | 240 | 0.0735 | 0.0737 | 241 | RSMS14PS |
| RSMS15PE | 258 | 0.0789 | 0.0798 | 261 | RSMS15PS |
| RSMS17PE | 270 | 0.0825 | 0.0829 | 271 | RSMS17PS |
| Word Identification Task | | | | | |
| RSMW1PE | 260 | 0.0795 | 0.0769 | 252 | RSMW1PS |
| RSMW2PE | 191 | 0.0584 | 0.0778 | 254 | RSMW2PS |
| RSMW3PE | 138 | 0.0422 | 0.0739 | 242 | RSMW3PS |
| RSMW4PE | 259 | 0.0791 | 0.0652 | 213 | RSMW4PS |
| RSMW5PE | 156 | 0.0478 | 0.0648 | 212 | RSMW5PS |
| RSMW6PE | 144 | 0.0440 | 0.0562 | 104 | RSMW6PS |
| RSMW7PE | 179 | 0.0547 | 0.0527 | 172 | RSMW7PS |
| RSMW8PE | 266 | 0.0815 | 0.1120 | 366 | RSMW8PS |
| RSMW9PE | 121 | 0.0369 | 0.0488 | 159 | RSMW9PS |
| RSMW10PE | 248 | 0.0758 | 0.0693 | 227 | RSMW10PS |
| Sentence Identification Task | | | | | |
| RWSMS1PE | 216 | 0.0660 | 0.0812 | 265 | RWSMS2PS |
| RWSMS4PE | 229 | 0.0699 | 0.0771 | 252 | RWSMS3PS |
| RWSMS5PE | 250 | 0.0764 | 0.0743 | 243 | RWSMS6PS |

# APPENDIX D

# INSTRUCTIONS

## Judgment Task

In this task you will be asked to judge which of two sentences is easier to understand. You will be presented with two sentences in a row. The first one is sentence 'A' and the second is sentence 'B.' You will make a choice between the two based on which one is easier to understand by clicking the mouse on the 'A' or 'B' box. The computer will not let you make a choice until both sentences have been played in their entirety. If you are not sure which sentence is easier to understand it is important that you guess. The next stimulus will not play until you have made a choice.

The sentences in this experiment are taken from audiotape, so sometimes there may be noise in the background. You need to ignore the noise and pay attention to the speech.

After you finish one block a notice will come on the screen and you will need to click on 'OK' to start the next block. A sentence will be played as soon as you hit the 'OK' button so you should be ready to listen as soon as you hit it. In each block the sentences will be spoken by the same speaker. Before you start the next block, fill out the questions I am giving you now about that portion of the experiment. If you need a break at any point simply leave the 'OK' screen up when you leave the booth. The computer will wait until you hit 'OK' to begin the next portion of the experiment. Do you understand?

Transcription Task

In this task you will be asked to write down what you hear. Again, if you are not sure it's very important that you make a guess.

The first block will consist of ten words and the next block will contain three sentences. These will all be spoken by the same speaker and this cycle will repeat itself four/eight times. You will only hear the word/sentence once, so listen carefully. Again, a notice will come on the screen at the end of each block and you will need to hit 'OK' to begin a new block. Don't forget that stimuli will be played right after you hit 'OK', so be ready to listen. Just like in the last task, you may take a break between blocks if you feel the need.

Once you have heard one stimulus, a word or a sentence, the next will not play until you hit the 'NEXT' button, so you will want to write down what you hear and then hit the 'NEXT' button with the mouse so that you can hear the next item.

After you have written down the sentences, circle the words which you are certain you heard correctly. If you feel you have heard the entire sentence correctly circle the sentence number. For the words simply circle the word number if you are certain you heard it correctly.

At this point, I will read you all the possible words you may hear (I will not be reading the sentences). You just need to listen to them so that you are familiar with the possibilities. Feel free to write specific comments about the words and sentences you hear directly on the sheet next to them. Do you understand?