EFFECT OF ALPHABET BOARD SUPPLEMENTATION AND STIMULUS PRESENTATION MODE ON INTELLIGIBILITY OF DYSARTHRIC SPEECH

THESIS

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ABSTRACT

EFFECT OF ALPHABET BOARD SUPPLEMENTATION AND STIMULUS PRESENTATION MODE ON INTELLIGIBILITY OF DYSARTHRIC SPEECH

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Reduced intelligibility is a frequent and universal consequence of dysarthria. Intelligibility scores reflect the cumulative effects of all levels of speech production on the output produced by a speaker and provide an overall index of the severity. Several investigators have reported that the use of aided devices, such as an alphabet board may I increase intelligibility for dysarthric speakers. Improvements may result from decreased speaking rate, increased prosodic characteristics, or improved articulatory precision. It is not known if stimulus presentation mode influences these results.

This study provided a means for examining the differences in single word intelligibility scores during aided and unaided conditions and the differences between stimulus presentation modes for single word production. Data were collected from selected individuals with dysarthria. Intelligibility scores were obtained from a group of 16 listeners. Results for these subjects indicated improved intelligibility across one subject during the aided task. No differences in intelligibility scores were found across the three stimulus presentation modes.

CHAPTER I

INTRODUCTION

Reduced intelligibility is a frequent and universal consequence of dysarthria (Darley, Aronson, & Brown, 1979; Duffy, 1995; Yorkston & Beukelman, 1981). Intelligibility scores reflect the cumulative effects of all speech components (i.e., respiration, phonation, articulation, resonance, and prosody) on the output produced by a speaker. These scores provide valuable information concerning the overall index of the severity of the individual's speech, and may include the nature and the extent of the speech impairment (Kent, Weismer, Kent, & Rosenbek, 1989). Intelligibility scores convey how speakers function across various communication settings and provide a simple means of conveying to others, the speaker's communicative abilities. Finally, the scores obtained through intelligibility testing may aid in quantifying treatment efficacy.

According to communication engineering and signal processing theory, intelligibility scores provide an index of the accuracy and efficiency by which information is transmitted from a speaker to a listener (Hawley, 1977). The intelligibility score obtained is a result of several factors. These include the acoustic signal produced by a speaker, the medium through which the signal is transmitted, and the integrity or abilities of the listener (Weismer & Martin, 1992). In communication disorders, it is assumed that the medium or transmission system through which the acoustic signal

travels is adequate. Reduced intelligibility results when there is impairment at either the level of speech production or the level of the speech reception/perception mechanism. As a result, intelligibility has been applied not only in the area of dysarthria (Darley, Aronson, & Brown, 1975; Tikofsky, 1964, 1970; Yorkston & Beukelman, 1978), but also in assessing the degree of hearing impairment (Monson, 1978, 1983; Osberger, 1992). In dysarthria assessment, one assumes that the listener's perceptual abilities are within normal limits. Therefore, reduced intelligibility is attributed to impaired speech production abilities of the speaker.

Although the intelligibility factors of speaker, transmission system, and listener are all considered to be signal dependent (i.e., the information conveyed is directly dependent on the acoustic signal), other non-acoustic information is conveyed while communicating. Additional information or communicative cues contribute to how well a message is understood by a listener. Yorkston, Strand, and Kennedy (1996) refer to this as comprehensibility. Comprehensibility relies not only on the acoustic signal produced by the speaker, but also on "the extent to which a listener understands utterances produced by a speaker in a communication context" (Yorkston et al., 1996, p. 55). Comprehensibility also incorporates signal-independent information such as syntax, semantics, and physical context produced by the speaker, in combination with any additional cues (Yorkston et al., 1996). Therefore, although intelligibility is an index of how the acoustic signal is produced and received, comprehensibility is not exclusively dependent on the adequacy of the acoustic signal produced by the speakers.

Several investigators have reported that the use of aided devices, such as an alphabet board, may increase intelligibility for dysarthric speakers (Yorkston &

Beukelman, 1977; Crow & Enderby, 1989). Generally, the procedure involves having speakers point to the first letter of each word on a printed board as they are speaking. This procedure has several effects on communication. First, if the alphabet board is visible to the listeners, the orthographic visual cues provide them with additional information through another modality. This procedure alone could improve comprehensibility. Secondly, even when visual cues from the alphabet board are not available to the listeners, significant changes occur in the speakers' prosodic characteristics while pointing to each letter. This is evident in the acoustic signal produced by the speakers. The additional cognitive and motor activity of this action may result in a reduced speaking rate and improved intonation, which in many cases, will result in improved intelligibility. Although reduced speaking rate in dysarthric subjects using an alphabet board has been shown to improve overall articulatory precision (Beukelman & Yorkston, 1977), it is not known if use of a letter board improves articulatory precision in single words when the stimulus presentation mode varies.

Improved intelligibility using an alphabet board

Beukelman and Yorkston (1977) studied the effects of an alphabet board on two severely dysarthric speakers, with normal language skills. Prior to the study, both subjects used an alphabet board to spell out their entire message, word by word. For the purposes of the investigation, the subjects were instructed to point only to the first letter of each word they wanted to produce. This procedure was deemed the aided condition for the study. The purpose of the study was to determine the listener's perception of the subject's rate and intelligibility of speech while aided and unaided speech tasks were

implemented. Each subject was videotaped while saying 20 single words and 6 unrelated sentences. The examiner produced single words and sentences and the subjects were instructed to imitate those words and sentences. The subjects' speech samples were presented to the listeners via videotape during three conditions:

1. Unaided- subjects spoke without the aid of the spelling board.
2. Aided- subjects pointed to the initial letter of each word on the board as they spoke with the letters being visible to the listeners.
3. Aided and concealed- the speech samples recorded for the aided conditions were presented to the judges, however, the portion of the video monitor showing the spelling board was concealed.

The listeners analyzed the speaker's speech sample by watching the videotape presented to them. However, there were no reports in the study about how the listeners viewed the subjects. If the listeners viewed the subjects' facial areas as well as the alphabet board, this may result in present increased intelligibility versus if the listeners only viewed the alphabet board. If the listeners were able to observe the subjects' faces and the alphabet board, this would increase the communication cues received, resulting in increased comprehensibility. However, if the listeners only viewed the alphabet board and not the subjects' faces, then comprehensibility would still be increased; however, perhaps to a lesser degree due to lesser communication cues. The results of the study revealed that the percentage of intelligibility scored by the listeners was greatest during the aided speaking tasks for both words and sentences. Intelligibility of single words during the aided task was consistently lower than the intelligibility of sentences. The increased percentage of intelligibility for sentences may be attributed to the surrounding contextual information

that therefore increased comprehensibility. Also, the additional visual or orthographic cues increased comprehensibility. This allowed the listeners to implement additional top-down processing strategies as speakers produced each word. Beukelman and Yorkston (1977) attributed the increased intelligibility to two factors. First, the increased information provided by identifying the initial letter of each word supplied the listeners with additional cues through another modality (i.e., reading). Secondly, use of an aided task acted as a pacing procedure, which decreased the overall speaking rate.

Crow and Enderby (1989) also investigated the effects of using an alphabet chart on the speaking rate and intelligibility of speakers with dysarthria. Their study included 6 dysarthric subjects of varying etiologies and severity. Three of the subjects had motor neuron disease, one had cerebellar degeneration, one had Parkinson's disease, and one subject had experienced bilateral strokes. The subjects' severity levels ranged from mild to severe, as judged by a speech-language pathologist, and the subjects had no history of other speech and language difficulties. The procedure used for classifying the severity of the dysarthria was not presented. The following three speaking tasks were used in their study: a single-word task, predictable picture description task, and a conversational task. The single-word task required the subjects to produce 20 words that were represented with simple pictures, shapes, and colors. The predictable picture description task required the subjects to produce a sentence from a picture card. The pictures, which were visible to the listeners, resulted in highly predictable sentences. Finally, the subjects were required to participate in a conversation task. The conversational task required spontaneous speech productions that were less predictable. The subjects were required to describe pictures in their own words, or they were asked to respond to some simple

questions about themselves, their families, their home, or things familiar to them. The mode of stimulus presentation for the three speaking tasks was via picture cards. The subjects were to produce the words or sentences depicted on each card. Crow and Enderby revealed that when the subjects used the alphabet board, their percentage of intelligibility was greater with the alphabet board than it was without. The accuracy of articulation of the sounds increased when the board was implemented as when compared to the unaided speaking tasks. The subjects correctly produced twice as many of the targeted sounds when the board was used versus when the board was not used. In addition to intelligibility, Crow and Enderby found that with the alphabet board the mean speaking rate was 35.2 words per minute, when compared to the mean speaking rate of 101.7 when the alphabet board was not used. Therefore speaking rate decreased when the alphabet board was used. A decrease in the subjects' speaking rate would be expected with the alphabet board due to the additional motor act of pointing to the first letter of each word.

Intelligibility tests and stimulus presentation mode

As described above, the use of an alphabet board has proven to be successful for increasing the intelligibility of speakers with dysarthria. However, another factor that may influence intelligibility in dysarthria is the stimulus presentation mode. The mode of stimulus presentation can be placed on a continuum from spontaneous productions to direct imitation of the stimulus. The examiner must select the assessment instrument with the appropriate stimulus presentation mode, depending on whether the intent of the assessment is to obtain a representative sample of the subject's speech or to determine

stimulability of the subjects' speech. Specific intelligibility tests that assess dysarthric speech as well as tests that assess children's articulation abilities, use continuum of presentation modes to elicit responses including direct imitation, delayed imitation, elicited naming through either picture or printed word stimuli, and completion tasks.

Because standardized articulation tests for children employ many different stimulus presentation modes, several investigations have focused on the effects of those modes on articulation. Not only does the mode of stimulus presentation affect intelligibility, but according to Bernthal and Bankson (1998), " the interpersonal dynamics present during a client-examiner interaction may influence the test results and different examiners may elicit different reactions from different client." (p. 166). During testing, the examiner must be cognizant that responses elicited may mirror what the examiner is doing, more than what the client usually does (Bernthal and Bankson, 1998).

Dubois and Bernthal (1978) compared the productions of phonemes in words and elicited them through differing speaking tasks. The tasks consisted of story retelling, delayed imitation, and spontaneous picture-naming tasks. The results indicated that there was a small but significant difference among the stimulus presentation modes. Also, Snow and Milisen's (1954) study of 1st, 2nd, 7th, and 8th grade children revealed that the imitative method consistently resulted in higher levels of articulatory performance.

Spontaneous productions require that the individuals rely on their own representations of the words. However, when an imitative method is used, the individuals' production is based on the models provided by the clinician. There are advantages and disadvantages for both methods. An advantage for having individuals produce words through spontaneous naming is that the utterances may be more

representative of those produced in a natural, non-test setting. However, a disadvantage for using this method is that it is difficult to elicit some targeted words or phonemes using pictures. Likewise, the imitative method also has advantages and disadvantages. An advantage is that data collection may require less time, because productions are less affected by the client's unfamiliarity with the target words. A disadvantage, however, is that the results that are obtained from this method are less likely to be representative of the individuals' spontaneous speech patterns.

Single word testing

When assessing a patient's articulation abilities, one of the fastest ways of obtaining the data is by giving a test that uses single words. Single word testing allows the examiner to more easily identify the aspect of production (i.e., manner, place, or voicing) that is incorrect. Ease of transcription of single-words results in the widespread usage of this procedure, however, single word testing does not permit an extensive evaluation of the effects of context on speech sound productions. Single word testing is often preferred for those patients exhibiting severely impaired intelligibility. Although prior knowledge of the target word may result in inflated intelligibility scores, it may also permit a more thorough analysis of the impaired articulatory productions (Yorkston & Beukelman, 1981).

Intelligibility tests in dysarthria

Several commercially available tests and published procedures are available for assessing intelligibility in dysarthria. Several standardized tests are available to identify

and quantify the severity of intelligibility in dysarthria. These tests include the Assessment of Intelligibility of Dysarthric Speech (AIDS) (Yorkston & Beukelman, 1981), the Sentence Intelligibility Test (SIT) (Yorkston & Beukelman, 1996), the Frenchay Dysarthria Assessment (Enderby, 1983) and Kent's intelligibility test procedures (Kent, Weismer, Kent, & Rosenbek, 1989).

One of the most widely used standardized measures for assessing intelligibility, speaking rate, and communication efficiency in dysarthria, the Assessment of Intelligibility of Dysarthric Speech (AIDS) (Yorkston & Beukelman, 1981). This test assesses intelligibility of single words and sentences, and the rate of intelligible words per minute in sentences. The mode of stimulus presentation for the AIDS test requires that clients either imitate or read 50 randomly selected words or 22 sentences chosen by the clinician from the test booklet. Using the imitation mode, productions are modeled by the clinician, thereby providing maximal cues. Using the reading mode of elicitation fewer cues are provided. The information collected by the AIDS test provides clinicians with an index of severity of the patient's speech. The index of severity also allows for clinicians to rank-order large groups of different speakers with dysarthria along a particular dimension. The scores obtained provide an overall percentage of intelligibility in single words and sentence tasks. By establishing baseline scores, they give the clinician a starting point for therapy. When determining if the subjects' intelligibility has increase or decreased, the clinician has the baseline scores to compare the current scores allowing her to monitor of change over time.

A computer version of the AIDS test is the Sentence Intelligibility Test (SIT) (Yorkston & Beukelman, 1996). This test incorporates the same type of stimuli as used

in the original version of the AIDS test. Randomized sentences vary from five to fifteen words in length. The examiner may choose to administer either a long version (i.e., 22 sentences) or a shortened version (i.e., 11 sentences). Therefore, total number of words produced is dependent on the version selected. The sentences appear on the screen and the clients then read the sentences. Depending on the client's visual acuity, the font size can be altered for ease of reading. After the sentences are recorded on audiotape, a listener, other than the test examiner listens to the tape and transcribes verbatim what was heard. Once the sentences are transcribed, the computer program scores the sample, computes the intelligibility score and rate of speech, and provides a report. The information provided by the SIT gives the same diagnostic information as the AIDS.

Another standardized test of intelligibility is the Frenchay Dysarthria Assessment (Enderby, 1983). This test assesses single words, sentences, and conversation intelligibility. For the first two tasks, 10 randomly selected words and 10 randomly selected sentences unknown by the examiner are drawn and read by the client. The words and sentences are presented to the client on 6" x 4" index cards. The examiner, unaware of the word that the client is to produce, uses a 5-point scale to rate the client's performance. The rating scale used for the single word and sentence tasks ranges from easily intelligible speech to two or less words interpreted correctly. For the conversational assessment, the examiner engages the subject in conversation for five minutes and then rates the subject's speech on a 5-point scale, ranging from no abnormality to subject was totally unintelligible. The Frenchay Dysarthria Assessment provides a means for the clinician to determine the severity of a subject's intelligibility

deficit, and to then direct treatment at the appropriate level where speech is most impaired.

Another means of evaluating intelligibility is by using the procedures developed by Kent, Weismer, Kent, and Rosenbek (1989). Although not yet standardized or commercially available, this single word intelligibility procedure not only assesses the accuracy of the production, but also assesses the types of errors that are contributing to the client's reduced speech intelligibility. There are two formats for scoring this test- a multiple choice and a paired-word intelligibility format. The multiple-choice test has a target word that is followed by three foils. The words for the multiple-choice test represent 19 phonetic contrasts. The target word is presented to a subject on individual index cards. The subject then produces the target word, and the listener then selects the word from the foils. The single-word test is used for subjects with severe dysarthria. For this test the examiner presents both words to the subject on index cards and has them produce both words as distinctly as possible. This is an attempt to optimize the production of the phonetic contrasts by showing both words to the subject. Both the multiple-choice and the paired-contrast word tests allow the clinician to gather information during the assessment about the specific errors that the subject is producing as well as provide a severity index. Therefore, with this information, the clinician can begin treating those phonetic contrasts that most affect that person's intelligibility.

Statement of the problem and experimental questions

Many research studies have measured the increase of intelligibility from the listener's perspective when the dysarthric speaker uses different types of aided devices

for speaking tasks (i.e. alphabet board) (Crow & Enderby, 1989; Beukelman & Yorkston, 1977). However, research has not explored the possibility that the use of an alphabet board may in fact increase the speaker's articulation precision when these extra cues are provided across different stimulus presentation modes.

The purpose of this study was to determine if alphabet board supplementation (i.e., pointing to the first letter of the target words) affected speech intelligibility for individuals with dysarthria when stimulus presentation mode (i.e., imitation, picture, and printed word) was varied. This investigation involved collecting audio tape recordings from individuals with dysarthria under several experimental conditions. The speech samples were then presented to a group of listeners to determine speech intelligibility. As a result, changes in intelligibility were attributed to changes in the acoustic signal produced by the speakers.

Based on the available literature and known characteristics of dysarthria, the following questions were posed:

1. Does pointing to the first letter of a word in a single word task increase speech intelligibility in individuals with dysarthria?

2. Does the stimulus presentation mode affect the single word intelligibility of dysarthric speakers?

CHAPTER II

METHODS

Brief Overview

The purpose of this study was to determine if modifying the stimulus presentation mode and adding an aided production condition (i.e., letter pointing) affects speech intelligibility for individuals with dysarthria. This investigation involved collecting audio tape recordings from individuals with dysarthria under several experimental conditions, then presenting those speech samples to a group of listeners to assess speech intelligibility.

Subjects

This study involved two subject groups. The first group provided the various speech samples that were recorded; the other served as listeners for the perceptual judgement phase of this study. Eleven potential subjects, all diagnosed with dysarthria resulting from a traumatic brain injury, were identified for this study. All subjects were recruited from current patients at Tangram Premier Rehabilitation Network, San Marcos, Texas. All individuals were native English speakers who have passed a pure-tone, air-conduction, hearing screening in at least one ear at 500, 1000, 2000, and 4000 Hz at 35 dB HL (ANSI, 1996). Hearing testing was conducted using a GSI-10 audiometer in a

quiet environment, with no more than 25 dB ambient noise. All subjects were required to demonstrate at least Level V performance according to the Rancho Los Amigos Scale of Cognitive Levels (RLA) scale (Hagen & Malkmus, 1979). This level has been shown to be sufficient for attending to and following directions during tasks similar to those of this study. Subjects selected for this study ranged from Level V to Level VIII. Since the experimental task involved a pointing response, subjects' motoric abilities were also evaluated as part of the selection criteria. To participate in this study, subjects were required to point to printed letters on an alphabet board with either hand within a five second period, for 18 out of 20 trials. All subjects met this criterion. The Sentence Intelligibility Test (SIT) (Yorkston, Beukelman, & Traynor, 1996) was then administered to the speakers prior to the experiment. The SIT recordings were made and subsequently transcribed by an uninformed listener as required by test protocol. The listener was graduate student who worked with dysarthric speakers during off-campus placements and she had taken graduate level courses on motor speech disorders. The intelligibility scores of the potential subjects selected for this study ranged from 25% to 100%. Four of the eleven subjects scored 100% on the SIT, indicating no reduced intelligibility. Therefore, they were excluded from this study. Six subjects, whose speech intelligibility ranged from mild to severe and met all selection criteria, were included in the experiment. Subjects consisted of 5 males and 1 female. They ranged in age from 20 to 57 years; TBI months post onset ranged from 28 to 149. All testing was conducted at that facility. A summary of subject biographic data is provided in Appendix A.

A second group of subjects participated in the listening task of this experiment. These subjects were 16 undergraduate students in the Department of Communication

Disorders who have had minimal clinical exposure to dysarthric speakers. All were between 20 and 30 years old and their primary language was English. All participants for the listening task passed a pure-tone, air-conduction, hearing screening in at least one ear at 500, 1000, 2000, and 4000 Hz at 35 dB HL (ANSI, 1996), which was conducted in a sound-treated audiometric booth using a GSI-10 audiometer. A copy of the consent forms used for both subject groups are provided in Appendix B.

Stimuli Development

Twenty single-syllable words were used as stimuli for this experiment and were selected from an intelligibility procedure developed by Kent et al (1989). All words were common nouns and are listed in Appendix C. Words were printed on individual 3" x 5" index cards which were shown to the subjects during one condition. Also, simple picture cards depicting those same words were shown during another testing condition. Finally, a printed alphabet board was constructed. It was 11" x 17", with 2" uppercase letters printed in four rows in alphabetical order. Subjects used the alphabet board to point to the first letter of the target words in half of the testing conditions. The layout of the alphabet board is included in Appendix D.

Testing and Recording procedures

Upon completion of the selection criteria and testing, speech samples were obtained from the 6 dysarthric speakers. Subjects were seated at a table in a quiet room with no more than 40 dB ambient noise as measured by a sound level meter. An Optimus electret ultra-miniature omni-directional microphone (model 33-3013) was used for

recording the speech samples. That particular microphone was selected due to its wide frequency response (70 – 16,000 Hz.). The microphone was attached to an adjustable head-band with boom. This apparatus assured a constant mouth-to-microphone distance of approximately 5 cm., which provided an optimal S/N ratio. Analog audio recordings were obtained using a high quality Denon (DR-M34HR) cassette tape deck onto Sony Type-I normal bias cassette tapes. No noise reduction settings were used, therefore, the acoustic signals could be analyzed later in their original format.

The subjects produced the twenty target words under the following speaking conditions:

1. Imitation Unaided (IU)- subjects repeated the target word produced by the examiner. The examiner used the carrier phrase "Say _____."
2. Imitation Aided (IA)- subjects repeated the target word produced by the examiner in addition to pointing to the first letter of word on the alphabet board. Again, the examiner used the carrier phrase "Say _____."
3. Written Unaided (WU)- subjects were presented the written target words and then produced each target word.
4. Written Aided (WA)- subjects were presented the written target words and pointed to the first letter of the word on the alphabet board and then produced the word.
5. Picture Unaided (PU)- subjects were presented the illustrated target words and then produced each target word.
6. Picture Aided (PA)- subjects were presented the illustrated target words and pointed to the first letter of the word on the alphabet board and then produced the word.

During trials when subjects were required to use the alphabet board, they were instructed to point to the initial letter prior to producing the target words. The intent was to assure that any extraneous sounds made during the pointing task would not interfere with the audio recording. One production of each target word under the six conditions was obtained, which resulted in 120 words per subject. Condition and word order were randomized across speakers.

Digital editing

Once the audio recordings were obtained, the samples were converted to digital data files by playing the recordings from the Denon (DR-M34HR) cassette deck directly to the line input of the Computerized Speech Lab (CSL; Kay Elemetrics Corp.) signal analysis program. All target words were digitized with a sampling rate of 40KHz using a 300 MHz computer. A silent interval of approximately 500 ms was included at the beginning and end of each target word as an acoustic ramp, which eliminated the abrupt noise onset and offset. Each target word was then coded and digitally stored on the computer's fixed disk and backed up onto individual 100 MB Zip disks. These digitally edited files were then available for presentation during the listening task phase of this experiment.

Listening task

Sixteen undergraduate student volunteers from the Department of Communication Disorders passing the selection criteria participated as listeners for this study. These judges were unfamiliar with these subjects and had minimal exposure to dysarthric

speakers, thereby promoting unbiased judgements. The listening task was completed as a group during one session. All listeners were seated at a table in a quiet room (i.e., less than 40 dB ambient noise). The target words were randomized across speakers, words, and conditions. The list of randomized stimuli is presented in Appendix E. The digitized target words were presented via computer via a pentium III 360 MHz computer. Stimuli were played through a pair of JBL Media 200 speakers positioned no more than four meters from each subject. Therefore, the stimuli were presented at no less than 80dB as measured by a hand held sound level meter (Radio Shack #33-2055) positioned at ear level to the listeners. Stimuli were presented at a rate of approximately one per five seconds. This presentation allowed sufficient time for the judges to listen to each target word and indicate on a written form which of five words was produced. Word choices were primarily those foils used in the intelligibility procedure published by Kent et al (1989) and are listed in Appendix C. The listening task was divided into 6 sections. Each section had 120 words resulting in 720 total words. The listeners were instructed to listen to the words presented and circle the word they heard. A brief listening break of approximately one minute was provided after each block of 20 words, with a longer 10-15 minute break after each block of 120 words. After the listeners judged one section, they then transferred their answers to a Scantron sheet. This sheet enabled the investigator to use a computer-assisted response reader to score the responses. Speech intelligibility results obtained from the computer-scanned responses were then transferred to a spreadsheet for subsequent statistical analysis.

CHAPTER III

RESULTS

This study provided a means for examining the differences in single word intelligibility scores during aided and unaided conditions and the differences between stimulus presentation modes for single word production. Data were collected from selected individuals with dysarthria. Intelligibility scores were obtained from a group of 16 listeners. Results of those intelligibility scores are reported for the aided and unaided conditions and for the three stimulus presentation modes (i.e., imitation, picture, and written).

Aided vs. Unaided Condition

All subjects

Tables 1 and 2 present the mean percentage of intelligibility scores for single words and standard deviations for each speaker across the aided and unaided conditions and the three stimulus presentation modes with overall means and standard deviations also included. Appendix F is included to show how these summary data were derived for one subject (Subject A) engaged in one condition (Imitation Aided) across all 16 listeners. During the aided condition, when all dysarthric subjects were combined, the mean intelligibility scores across the conditions ranged from 87.4% (S.D. = (Imitation

Table 1.

Mean percentage of intelligibility and standard deviations for the aided task during the various stimulus presentation modes as rated by the 16 listeners across 20 words.

	Imitative Aided		Picture Aided		Written Aided		Total Aided	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	84.4	17.6	82.2	19.6	84.1	21.8	83.6	1.19
B	90.9	21.4	91.6	16.1	92.8	16.5	91.8	0.96
C	93.1	13.5	92.8	17.5	96.3	8.70	94.1	1.94
D	74.7	37.1	73.4	39.7	87.2	38.4	78.4	7.62
E	90.9	23.3	87.8	22.6	93.1	21.4	90.6	2.66
F	94.4	15.8	96.6	6.80	90.8	22.3	93.9	2.93
Mean	88.1		87.4		90.7		88.7	
SD	7.4		8.42		4.41		6.34	

Table 2

Mean percentage of intelligibility and standard deviations for the unaided task during the various stimulus presentation modes as rated by the 16 listeners across 20 words.

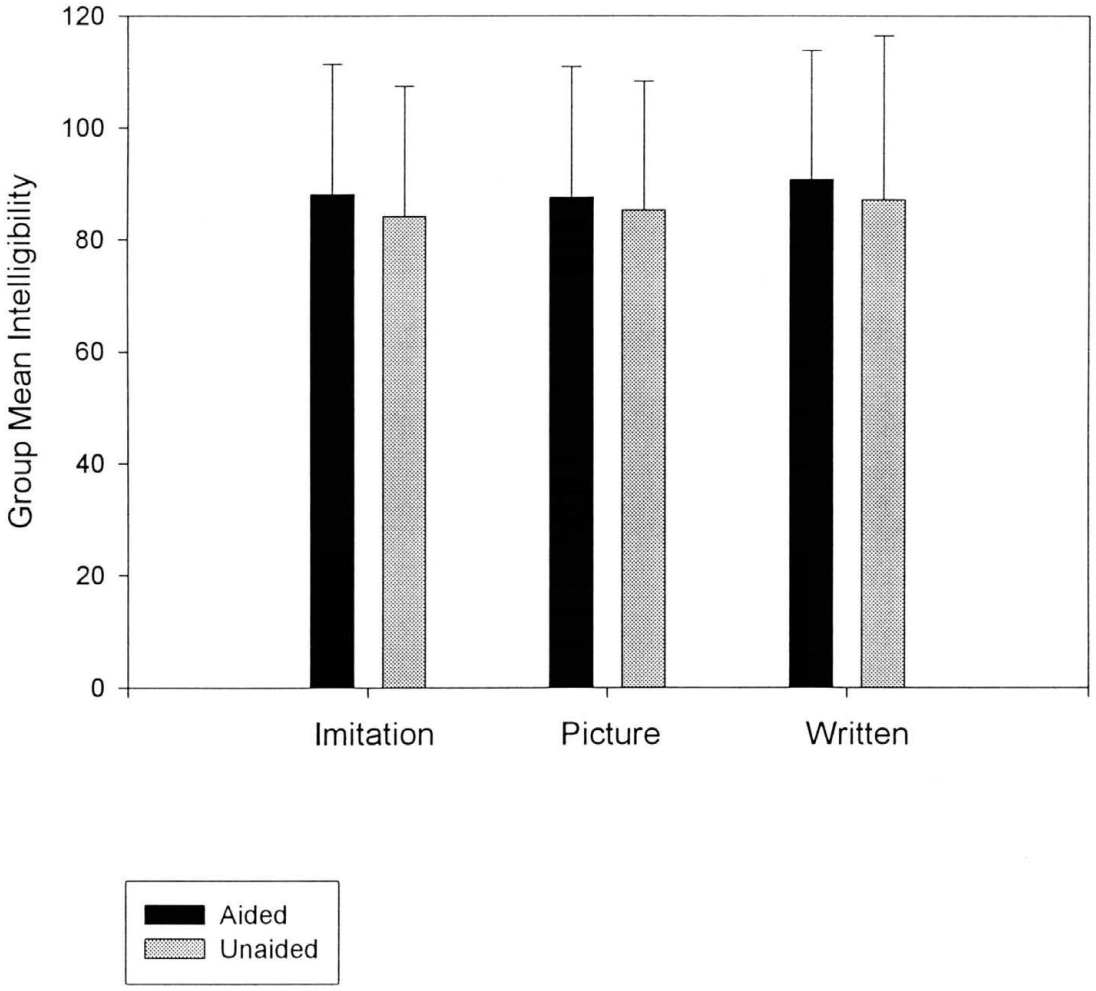
	Imitative Unaided		Picture Unaided		Written Unaided		Total Unaided	
Subject	Mean	SD	Mean	SD	Mean	SD	Mean	SD
A	74.1	26.0	82.2	18.2	76.6	26.4	77.6	4.15
B	81.9	24.0	86.3	20.8	83.5	36.1	84.0	2.23
C	90.3	17.0	86.3	20.4	90.6	16.9	89.1	2.40
D	80.0	30.6	74.1	34.6	63.7	41.9	72.6	8.25
E	90.3	21.8	88.8	25.0	88.1	24.4	89.1	1.12
F	88.1	14.9	93.4	11.9	96.3	8.9	92.6	4.16
Mean	84.1		85.2		83.1		84.1	
SD	6.55		6.55		11.6		7.69	

Aided) to 90.7% (Written Aided). The overall mean score across all the aided conditions was 88.7% (S.D. = 6.34). During the unaided condition, when all dysarthric subjects were combined, the mean intelligibility scores across the conditions ranged from 83.1% (S.D. = 711.61) (Written Unaided) to 84.1% (S.D. = 6.55) (Imitation Unaided). The overall mean score across all the unaided conditions was 84.1% (S.D. = 7.69). The group mean percentage of intelligibility scores by condition and mode are illustrated in Figure 1. Error bars represent one standard deviation. A one-way repeated measures Analysis of Variance (ANOVA) procedure was performed to compare group differences for the aided and unaided conditions. Data passed the normality test ($p < 0.05$) and an equal variance test ($p = 0.095$). Again, all statistical comparisons were performed with an alpha level of 0.05. The ANOVA revealed a significant difference in intelligibility scores across the conditions with ($F (5, 119) = 2.975$, $p = 0.012$). Further post hoc analysis using a multiple comparison procedure (Student-Newman-Keuls Method) revealed that only one comparison was found to be significantly different. For all subjects combined, intelligibility for the aided condition was greater than for the unaided condition, when elicited in the written stimulus mode ($q = 4.621$, $p = 0.014$). No other comparisons were significantly different.

Individual subjects

Because analysis of all speakers revealed a statistically significant difference, further analysis was conducted to determine if a pattern of improved intelligibility was evident for individual subjects performing this task. An additional one-way repeated measures Analysis of Variance (ANOVA) was performed to compare differences for the

Figure 1. Mean intelligibility of aided and unaided conditions across three stimulus presentation modes.



individual subjects across all tasks and conditions. Results indicated that there was a statistically significant difference ($F(35, 19) = 2.532$, $p < 0.001$). Power computed for this analysis was 0.995 with alpha = 0.05. Although this analysis indicated differences between the aided and unaided conditions, it was likely that the statistically determined difference may have resulted from comparisons that were not meaningful in this particular investigation. A post-hoc pairwise multiple comparison procedure (Student-Newman-Keuls Method) was performed to determine which condition (aided vs. unaided) and which stimulus presentation mode was significantly different for each subject. Although all comparisons were tested, only comparisons between aided and unaided conditions within the same stimulus presentation mode were of interest. Results of the Student-Newman-Keuls procedure revealed that only one meaningful comparison was significantly different. This was for Subject D during the written aided condition versus the written unaided condition (D:WA vs. D:WU). Intelligibility for the Written Aided condition was significantly higher. Although only this one comparison between the aided and unaided conditions was found to be statistically significant, it should be noted that across all subjects and conditions, 13 of the 18 comparisons showed slightly improved intelligibility during the aided condition.

Stimulus Presentation Condition

All subjects

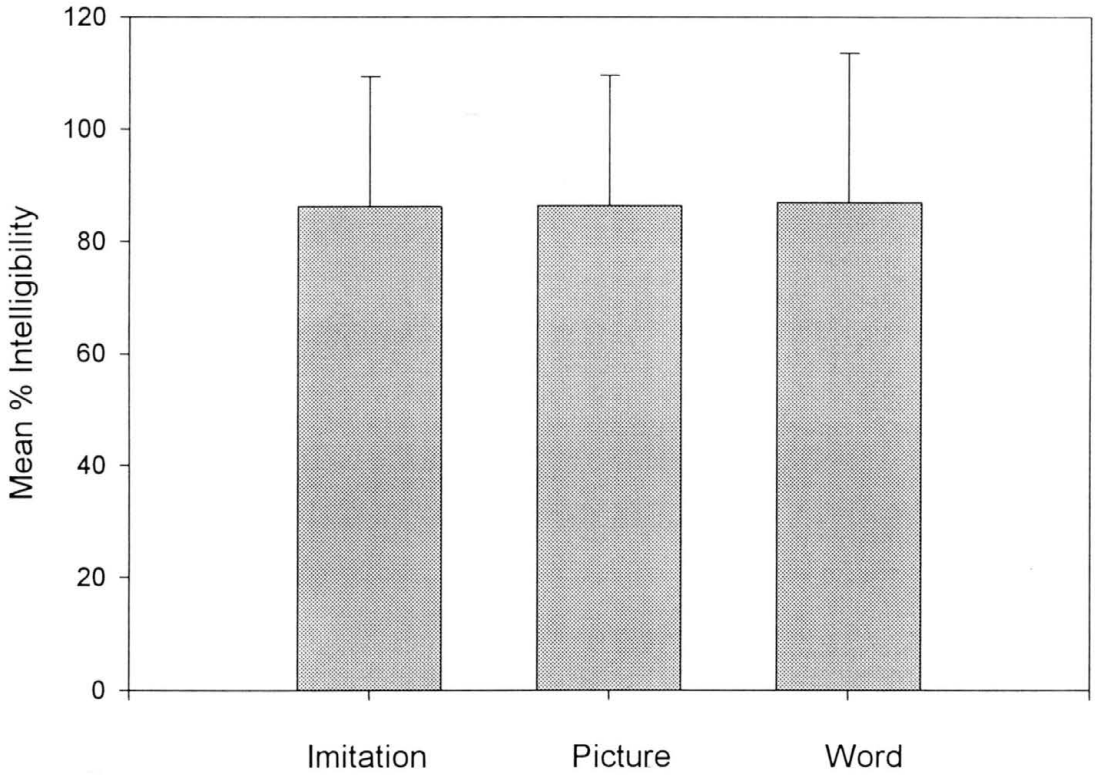
The secondary purpose of this investigation was to determine if the stimulus presentation mode had a significant influence on the intelligibility scores obtained in this investigation with these subjects. Specifically, was there a difference between the mean

intelligibility scores when the target words were elicited through imitation, picture, or by written word? The mean intelligibility scores and standard deviations for all subjects combined are provided in Table 2 and are illustrated in Figure 2. Mean percentage of intelligibility scores were as follows: imitation was 86.1% (SD = 23.3), picture was 83.3% (SD = 23.3), and written word was 86.9% (SD = 26.7). A one-way repeated measures ANOVA was computed to determine if the differences found among the overall mean scores were statistically significant. Results indicated that there was no statistically significant difference between the imitation, picture, or written stimulus presentation modes ($F(2, 239) = 0.143$, $p = 0.866$). Figure 2 illustrates the minimal difference across the three modes. Therefore, intelligibility scores based on this group of subjects was not significantly affected by the way in which the stimuli were presented.

Individual subjects

Further analysis was conducted to determine if comparisons across stimulus presentation mode for individual subjects were consistent with the group results when controlling for both the aided and unaided conditions. Although a one-way repeated measures ANOVA found a significant difference across comparisons of the three modes when grouped by aided an unaided condition ($F(5, 119) = 2.975$, $p = 0.012$), post hoc comparisons revealed no significant differences for meaningful comparisons regarding stimulus presentation mode. Therefore, even when controlling for the aided and unaided conditions, stimulus presentation mode had no significant effect on the intelligibility scores.

Figure 2. Combined mean intelligibility across three stimulus presentation modes



In summary, the results of this study revealed that intelligibility during the aided condition was significantly greater than intelligibility during the unaided condition. One should interpret this finding cautiously, in that statistical power during several of these comparisons was below the desired 0.80 for these types of comparisons. Also, through post-hoc analyses, it was revealed that one comparison accounted for the overall effect. Additionally, there were no significant differences between the three stimulus presentation modes (i.e., imitation, picture, or word).

CHAPTER IV

DISCUSSION

Purpose

The purpose of this study was to determine if the use of an aided device (i.e., an alphabet board) increased single-word intelligibility in speakers with dysarthria. Secondly, this investigation sought to determine if the stimulus presentation mode increased the intelligibility.

Interpretation of the Results

Previous studies using alphabet board supplementation revealed increases in intelligibility in single words, in sentences and in conversation (Yorkston & Beukelman, 1977; Crow & Enderby, 1989). However, as revealed in those studies, other factors such as reduced speaking rate and use of additional communicative information provided to the listener, may have been primarily responsible for increased intelligibility.

In order to exclude those factors, this current investigation focused on the intelligibility of single words without listener exposure to the visual cues provided by the alphabet board or facial cues. Therefore, it is difficult to compare this current study to studies that have been performed in the past.

Aided vs. unaided condition

This study demonstrated that for the dysarthric subjects as a group, there was a statistically significant difference between the aided and unaided conditions. Overall, the aided condition resulted in greater group[mean] and median intelligibility scores than the unaided condition. This result suggested that alphabet board supplementation may be a valid means of improving intelligibility in single words. These conclusions should be interpreted cautiously, however, as these results do not consider the influence of stimulus presentation mode.

Between group comparisons of the aided versus unaided condition among the stimulus presentation mode were also conducted. As a group, aided intelligibility was better than unaided intelligibility only when the target word was presented through the written modality. No significant differences were found among the aided and unaided conditions of the imitative and picture modalities. When written cards were used to elicit the individual words, subjects were exposed to yet another cue of the initial phoneme. Subjects first saw the initial letter on the written card, and then continued by pointing to the initial letter on the alphabet board. Possibly, the complexities of cognitive processing required by both seeing and pointing to the letter facilitated improved intelligibility. Further studies involving response time measures may be necessary to delineate cognitive load and task performance across such tasks.

Both the overall findings and the advantage of the aided condition during the written stimuli, were not entirely supported by further analysis of individual subject intelligibility scores. Analysis of individual subjects revealed that only one subject the written aided condition demonstrated significantly improved intelligibility. It is unknown

why this task facilitated the subject's performance so much more than the other subjects during this task. Although only one comparison between the aided and unaided conditions was found to be statistically significant, it should be noted that 13 of the 18 comparisons showed some degree of improved intelligibility during the aided task.

Stimulus presentation condition

Although the primary emphasis of this study was on the affect of alphabet board supplementation on speech intelligibility for single words, another factor in this study was mode of stimulus presentation. This study revealed no significant difference between the three means of presenting the stimuli. Therefore, for these subjects similar results were obtained, regardless of whether the stimuli were elicited by imitation, picture, or written word.

In developing the stimuli for this study, nouns were selected given that these words are more easily represented. The exclusive us of nouns may have limited the diversity of the target words and foils for the listening task. In generating the foils, the intent was to include nouns that were easily confused according to errors in manner, place, and voicing distinctions. Limiting the foils exclusively to nouns reduced the number of possible phonemic errors, some of which are characteristic of dysarthric speech.

Because the results of this study yielded no difference between the stimulation presentation modes with these subjects, it is not necessary to present the stimuli with a particular mode with these subjects (i.e., imitative, written, picture). Because there were no significant differences noted, target word selection does not need to be restricted to

nouns. Action words, nonsense words, and nouns could be used during an evaluation to determine a subject's intelligibility at the word level.

Single word vs. sentence intelligibility

The subjects that participated in this study exhibited Sentence Intelligibility Test (SIT) scores that ranged from 25% to 95%. Although the subjects' SIT scores ranged from mild to severe, they exhibited significantly increased intelligibility on the single-word tasks. Subject performance for words and sentences were noticed to improve when they entered the more structured therapy environment and when they knew they were going to participate in a speech therapy activity. Due to the SIT scores and to the subjects knowing they were participating in a task associated with speech therapy, a ceiling effect during the single word production task.

Previous research studying the effects of the use of an alphabet supplementation board focused on intelligibility during sentence and conversational tasks. Rate, intonation, and pause influenced the results of those studies. However, because this study focused on single word speech tasks, prosodic factors did not contribute to the outcome of the intelligibility scores. Although prosodic factors did not influence the results of this study, future studies should investigate the segmental rate of single words during aided and unaided tasks. Furthermore, even though the overall speaking rate cannot be calculated, single word segmental rate should be analyzed to determine if segmental rate changes are evident within single words during aided task or unaided tasks.

Homogeneity of subjects

The subjects chosen for this study exhibited intelligibility scores ranging from mild to severe during the SIT. Not only did the intelligibility scores vary, but the factors contributing to the intelligibility level varied. Specifically, several subjects' decreased intelligibility was attributed to some combination of the following speech characteristics: reduced articulatory accuracy, prosody, reduced vocal quality, and hypernasality. At least one subject exhibited increased vocal tremors during the aided task, which was accompanied by extraneous body movements characterized by limb action tremors.

These subjects also varied in the months post-onset of the traumatic brain injury. Patients with a long-term history of dysarthria have possibly implemented their own articulatory compensatory strategies or maladaptive behaviors during speaking tasks. Due to the motor learning theory, modification of those behaviors is difficult to obtain.

Future studies investigating the use of an alphabet supplementation board to increase single word intelligibility should include subjects with similar dysarthic characteristics such as articulatory precision, resonance, voice, and prosody. Other conditions to control include the amount of time since the onset of the disease/disorder, cognitive functioning levels, and subjects possessing the same etiologies such as Amyotrophic Lateral Sclerosis, Parkinson's Disease, Cerebral Palsy, and subjects who have experienced cerebral vascular accidents.

Resource allocation explanation

The primary focus of this study was to determine if the use of an aided task increased the level of intelligibility during single word speech tasks. The use of the aided

tasks requires additional motoric tasks (pointing to the initial letter of the target word on an alphabet board) and additional cognitive processes (determining the initial phoneme of the word and then locating it on the letter board). Due to the motoric and cognitive requirements, dual-task processing may have resulted in less benefits from the aided task, which can be accounted for by resource allocation models. That is, having a dual task may have consumed cognitive resources by sharing the resources across the tasks thus decreasing the speech production performance. Therefore, the increased demands on resources offset any advantages for the aided task, resulting in no difference between the aided and unaided conditions. These results then revealed no net effect, with no difference.

Listener variables

The individuals chosen for the listening task had no exposure to the subjects in the study, and they had minimal exposure to dysarthic speech in general. The listeners knew that the study involved dysarthric speakers; however, they did not know the purpose of the study nor were they aware of the variables involved. Although the target words were randomized across words, aided conditions, and subjects, due to the repetition of the words across each subject and speaking task, it is possible that the listeners may have become familiar with the target words produced. Because the subjects in this study exhibited relatively high single word intelligibility scores, future investigations replicating this study should implement an open-ended response format instead of a multiple choice format. It is hypothesized that if an open-ended response format had

been utilized with these subjects, the individuals listening would have recorded lower single word intelligibility scores across the aided and unaided tasks.

Conclusions, Clinical Implications, and Future Studies

The findings of this study indicate that overall the aided task increased the intelligibility during single word tasks. Although a statistically significant difference was found, post hoc analyses revealed that differences resulted from a limited number of comparisons. Therefore, there was not a consistent trend in the effects of alphabet board supplementation for these subjects. Generally, most subjects demonstrated some absolute improvement during the aided condition; however there were a few conditions where performance during the aided condition actually decreased. Therefore, additional studies are warranted before concluding that alphabet board supplementation should be advocated as a means of increasing intelligibility during single word tasks such as these.

One such investigation should involve a comprehensive analysis of the acoustic changes that occur when intelligibility has improved. In other words, can the perceptual changes of improved intelligibility be confirmed through changes in segmental acoustic parameters? The procedures for such a study would involve replicating this study, possibly with a more homogeneous group of speakers, then measuring acoustic dimensions that have been demonstrated to affect intelligibility in dysarthria. Although emphasis should be placed on segmental analysis of the initial consonants segments (i.e., VOT, spectral tilt of the burst, intensity of aspiration, and duration and frequency of frication), one should also investigate sequential vowel segments (i.e., S/N ratio, formant

durations, and formant transitions) since contextual or coarticulatory influences yield much to the intelligibility of the utterance.

Appendix A.

Subject biographic information.

Subject	Age (years)	Gender	Months post onset	Sentence Intelligibility Score	Ranchos Los Amigos Scale of Cognitive Levels
A	34	M	97	25%	V
B	21	M	19	95%	VII
C	55	M	132	81%	VII
D	31	M	106	53%	VI
E	45	M	83	80%	VII
F	24	F	71	85%	VIII

Appendix B.

Consent forms for speakers and listeners.

CONSENT FORM 1

Title:	The Effect of Stimulus Presentation Mode With the Use of An Aided Task on The Intelligibility of Speakers With Dysarthria
Investigator:	Natasha D. Montez, B.S. Graduate Student
Supervisor:	Barry L. Slansky, Ph.D. Assistant Professor

You are invited to participate in a study of speech intelligibility following brain injury. I am a graduate student in the department of Communication Disorders at Southwest Texas State University in San Marcos, Texas. This study is related to my thesis that is necessary for graduation from the department of Communication Disorders. I hope to learn how various presentations of stimuli and the use of aided conditions increase intelligibility in speakers with dysarthria. You were selected as a possible participant in this study because you have had a brain injury that resulted in communication difficulties.

If you decide to participate in the study, it will require approximately 3 hours of your time, which will be conducted over two sessions. During the first session, several standardized language, speech, and hearing tests will be conducted to determine your eligibility to continue the study. During the second session, you will be asked to repeat several words under differing conditions. There are no known risks to you from any of the above procedures, although you may experience mild fatigue from completing the tasks. There are no known direct benefits to you for participating in this study, but your help may benefit others in the future with communication difficulties resulting from a brain injury.

Any information that is obtained with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The results of this study may be presented at professional conferences or published in medical related journals, however at no time will your personal identity be made public.

Your decision whether or not to participate will not prejudice your future relations with Southwest Texas State University or Tangram Rehabilitation Network. If you decide to participate, you are free to discontinue your participation at any time.

If you have any questions at this time, please ask me. If you have any additional questions later, you may reach Dr. Slansky at (512) 245-2554.

Appendix B. (continued)

You will be offered a copy of this form to keep.

You are making a decision whether or not to participate. Your signature indicates that you have read the information above and have decided to participate. You may withdraw at any time without prejudice after signing this form, should you choose to discontinue participation in this study.

_____ _____

Signature of Participant Date

_____ _____

Signature of Parent or Legal Guardian Date

_____ _____

Signature of Witness (when appropriate) Date

_____ _____

Signature of Investigator Date

Appendix B. (continued)

CONSENT FORM 2

Title: The Effect of Stimulus Presentation Mode With the Use of An Aided Task on The Intelligibility of Speakers With Dysarthria

Investigator: Natasha D. Montez, B.S.
Graduate Student
Supervisor: Barry L. Slansky, Ph.D.
Assistant Professor

You are invited to participate in a study of speech intelligibility following brain injury. I am a graduate student in the department of Communication Disorders at Southwest Texas State University in San Marcos, Texas. This study is related to my thesis that is necessary for graduation from the department of Communication Disorders. I hope to learn how various presentations of stimuli and the use of aided conditions increase intelligibility in speakers with dysarthria. You were selected as a listener for this study to judge the intelligibility of subjects with dysarthria as varying modes of stimulus presentation are utilized.

If you decide to participate in the study, it will require approximately 2 hours of your time, which will be conducted during one session. During the session, you will be listening to speech samples that were collected from subjects with dysarthria as they produced single words while varying stimulus presentation modes were presented. There are no known risks to you from any of the above procedures, although you may experience mild fatigue from completing the tasks. There are no known direct benefits to you for participating in this study.

Any information that is obtained with this study and that can be identified with you will remain confidential and will be disclosed only with your permission. The results of this study may be presented at professional conferences or published in medical related journals, however at no time will your personal identity be made public.

Your decision whether or not to participate will not prejudice your future relations with Southwest Texas State University. If you decide to participate, you are free to discontinue your participation at any time.

If you have any questions at this time, please ask me. If you have any additional questions later, you may reach Dr. Slansky at (512) 245-2554.

You will be offered a copy of this form to keep.

You are making a decision whether or not to participate. Your signature indicates that you have read the information above and have decided to participate.

Appendix B. (continued)

You may withdraw at any time without prejudice after signing this form, should you choose to discontinue participation in this study.

Signature of Participant	Date
Signature of Parent or Legal Guardian	Date
Signature of Witness (when appropriate)	Date
Signature of Investigator	Date

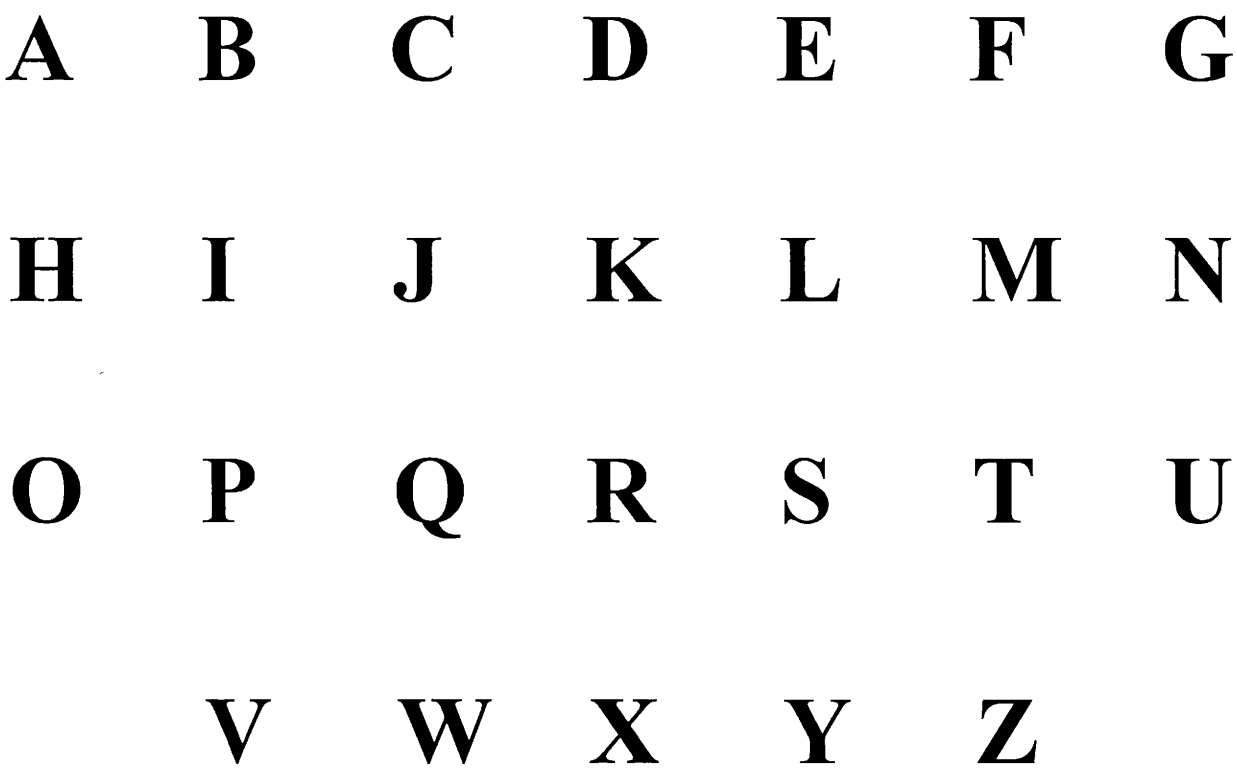
Appendix C.

Target words and foils for listening tasks.

	Target Word	Foils			
1.	cat	catch	gash	cash	bat
2.	dice	knife	night	nice	lice
3.	bed	bat	pad	bad	met
4.	duck	nut	dug	tug	but
5.	chair	share	tear	air	bear
6.	coat	tote	goat	code	doe
7.	ball	hall	all	tall	mall
8.	goat	tote	code	coat	doe
9.	fork	four	forks	cork	soar
10.	bat	mat	pat	pot	pad
11.	pot	bat	pat	pad	mop
12.	cake	bake	date	take	ache
13.	knife	nice	mice	dice	lice
14.	hair	air	fair	tear	share
15.	tail	ail	sail	hail	pail
16.	snake	steak	take	sake	fake
17.	ship	sip	tip	zip	snip
18.	hand	band	and	sand	land
19.	hat	at	fat	add	cat
20.	eyes	lies	wise	rise	dice

Appendix D.

Alphabet supplementation board used for the aided task



Appendix E.

Randomization form used for the listening task.

RANDOMIZATION FORM

	TRIAL #1	TRIAL #2	TRIAL #3	TRIAL #4	TRIAL #5	TRIAL #6
1	A-IA01	B-IA01	C-IA01	D-IA01	E-IA01	F-IA01
2	B-WA01	A-WA01	C-WA01	F-WA01	E-WA01	D-WA01
3	B-WU02	C-WU02	A-WU02	F-WU02	D-WU02	E-WU02
4	E-IA07	A-IA07	F-IA07	B-IA07	C-IA07	D-IA07
5	F-PU18	C-PU18	D-PU18	B-PU18	E-PU18	A-PU18
6	E-IU08	B-IU08	F-IU08	A-IU08	C-IU08	D-IU08
7	F-IU11	C-IU11	E-IU11	B-IU11	D-IU11	A-IU11
8	A-WA11	D-WA11	B-WA11	E-WA11	C-WA11	F-WA11
9	E-PA08	B-PA08	A-PA08	F-PA08	D-PA08	C-PA08
10	E-IA02	B-IA02	C-IA02	A-IA02	F-IA02	D-IA02
11	D-PA11	A-PA11	B-PA11	E-PA11	C-PA11	F-PA11
12	F-WU11	A-WU11	C-WU11	D-WU11	B-WU11	E-WU11
13	A-PU01	E-PU01	F-PU01	D-PU01	B-PU01	C-PU01
14	C-PU02	F-PU02	D-PU02	B-PU02	A-PU02	E-PU02
15	F-IA03	D-IA03	B-IA03	E-IA03	A-IA03	C-IA03
16	E-WU12	B-WU12	D-WU12	A-WU12	F-WU12	C-WU12
17	B-WA09	C-WA09	D-WA09	E-WA09	A-WA09	F-WA09
18	E-WA10	F-WA10	A-WA10	B-WA10	C-WA10	D-WA10
19	D-IU06	E-IU06	A-IU06	B-IU06	C-IU06	F-IU06
20	F-PU19	E-PU19	D-PU19	A-PU19	B-PU19	C-PU19
21	E-PA09	D-PA09	F-PA09	C-PA09	B-PA09	A-PA09
22	E-PA19	B-PA19	C-PA19	A-PA19	F-PA19	D-PA19
23	E-PA01	D-PA01	A-PA01	C-PA01	F-PA01	B-PA01
24	A-IU17	B-IU17	D-IU17	E-IU17	C-IU17	F-IU17
25	C-IA04	A-IA04	B-IA04	E-IA04	D-IA04	F-IA04
26	E-WU01	B-WU01	D-WU01	A-WU01	C-WU01	F-WU01
27	A-WA18	B-WA18	D-WA18	E-WA18	F-WA18	C-WA18
28	A-IA20	F-IA20	C-IA20	B-IA20	E-IA20	D-IA20
29	E-WU13	B-WU13	F-WU13	A-WU13	C-WU13	D-WU13
30	E-PA10	A-PA10	C-PA10	D-PA10	B-PA10	F-PA10

Appendix E. (continued)

	TRIAL #1	TRIAL #2	TRIAL #3	TRIAL #4	TRIAL #5	TRIAL #6
31	F-PU10	E-PU10	B-PU10	C-PU10	D-PU10	A-PU10
32	E-WA19	B-WA19	A-WA19	F-WA19	C-WA19	D-WA19
33	A-WA03	B-WA03	C-WA03	D-WA03	F-WA03	E-WA03
34	A-PU11	B-PU11	D-PU11	C-PU11	F-PU11	E-PU11
35	A-IU18	F-IU18	B-IU18	C-IU18	E-IU18	D-IU18
36	B-IA05	E-IA05	F-IA05	A-IA05	C-IA05	E-IA05
37	A-PA14	F-PA14	D-PA14	C-PA14	B-PA14	E-PA14
38	D-WA16	E-WA16	A-WA16	B-WA16	C-WA16	F-WA16
39	F-IU09	A-IU09	C-IU09	E-IU09	B-IU09	D-IU09
40	F-IU10	B-IU10	F-IU10	A-IU10	C-IU10	D-IU10
41	B-IA06	E-IA06	C-IA06	D-IA06	A-IA06	F-IA06
42	F-WA02	C-WA02	B-WA02	E-WA02	D-WA02	A-WA02
43	E-PA07	A-PA07	B-PA07	D-PA07	F-PA07	C-PA07
44	A-IU14	B-IU14	D-IU14	F-IU14	C-IU14	E-IU14
45	C-IA17	E-IA17	F-IA17	B-IA17	D-IA17	A-IA17
46	E-PU20	F-PU20	A-PU20	B-PU20	D-PU20	C-PU20
47	E-WA08	B-WA08	A-WA08	D-WA08	C-WA08	F-WA08
48	F-IU01	C-IU01	E-IU01	A-IU01	B-IU01	D-IU01
49	A-PA17	D-PA17	F-PA17	C-PA17	B-PA17	E-PA17
50	A-WU10	F-WU10	C-WU10	D-WU10	B-WU10	E-WU10
51	D-WU17	E-WU17	B-WU17	C-WU17	F-WU17	A-WU17
52	E-IU07	D-IU07	F-IU07	C-IU07	B-IU07	A-IU07
53	E-WU16	B-WU16	C-WU16	F-WU16	A-WU16	D-WU16
54	D-PU12	A-PU12	E-PU12	B-PU12	F-PU12	C-PU12
55	E-IU16	B-IU16	C-IU16	F-IU16	D-IU16	A-IU16
56	E-WU15	C-WU15	D-WU15	F-WU15	B-WU15	A-WU15
57	B-IU02	A-IU02	E-IU02	D-IU02	C-IU02	F-IU02
58	F-PU13	D-PU13	A-PU13	B-PU13	C-PU13	E-PU13
59	E-WU14	C-WU14	F-WU14	B-WU14	D-WU14	A-WU14
60	F-IA08	C-IA08	A-IA08	E-IA08	B-IA08	D-IA08
61	A-PU09	E-PU09	F-PU09	C-PU09	D-PU09	B-PU09
62	A-PA18	F-PA18	B-PA18	D-PA18	C-PA18	E-PA18
63	E-IA09	C-IA09	F-IA09	D-IA09	A-IA09	B-IA09
64	F-WU18	E-WU18	A-WU18	B-WU18	D-WU18	C-WU18
65	D-WU05	C-WU05	A-WU05	B-WU05	F-WU05	E-WU05

Appendix E. (continued)

	TRIAL #1	TRIAL #2	TRIAL #3	TRIAL #4	TRIAL #5	TRIAL #6
66	E-WA07	B-WA07	C-WA07	A-WA07	F-WA07	D-WA07
68	F-IA10	A-IA10	B-IA10	E-IA10	C-IA10	D-IA10
69	A-WA15	C-WA15	B-WA15	D-WA15	F-WA15	E-WA15
70	C-WU20	F-WU20	B-WU20	E-WU20	D-WU20	A-WU20
71	E-PA02	A-PA02	B-PA02	D-PA02	C-PA02	F-PA02
72	D-WA17	B-WA17	A-WA17	E-WA17	C-WA17	F-WA17
73	B-PU03	C-PU03	D-PU03	E-PU03	A-PU03	F-PU03
74	A-IA11	F-IA11	E-IA11	B-IA11	D-IA11	C-IA11
75	D-IU19	C-IU19	B-IU19	F-IU19	A-IU19	E-IU19
76	F-WA04	A-WA04	B-WA04	D-WA04	E-WA04	C-WA04
77	F-IA12	C-IA12	A-IA12	E-IA12	B-IA12	D-IA12
78	B-PA16	E-PA16	A-PA16	D-PA16	F-PA16	C-PA16
79	B-WU03	F-WU03	E-WU03	A-WU03	C-WU03	D-WU03
80	F-IU04	C-IU04	A-IU04	B-IU04	E-IU04	D-IU04
81	E-WA12	F-WA12	A-WA12	B-WA12	C-WA12	D-WA12
82	E-IU13	F-IU13	D-IU13	A-IU13	B-IU13	C-IU13
83	B-IA13	C-IA13	D-IA13	A-IA13	E-IA13	F-IA13
84	E-PA05	F-PA05	A-PA05	B-PA05	D-PA05	C-PA05
85	F-PA20	C-PA20	E-PA20	B-PA20	D-PA20	A-PA20
86	A-PA06	E-PA06	D-PA06	B-PA06	F-PA06	C-PA06
87	D-PU14	E-PU14	A-PU14	C-PU14	F-PU14	B-PU14
88	B-WU08	E-WU08	D-WU08	A-WU08	F-WU08	C-WU08
89	E-IA14	D-IA14	A-IA14	F-IA14	B-IA14	C-IA14
90	E-WU09	B-WU09	A-WU09	C-WU09	D-WU09	F-WU09
91	E-PU08	F-PU08	A-PU08	B-PU08	D-PU08	C-PU08
92	B-IU20	C-IU20	E-IU20	F-IU20	D-IU20	A-IU20
93	A-IA19	C-IA19	D-IA19	F-IA19	B-IA19	E-IA19
94	A-PU16	F-PU16	D-PU16	E-PU16	B-PU16	C-PU16
95	F-WU06	D-WU06	E-WU06	A-WU06	B-WU06	C-WU06
96	D-WA14	E-WA14	A-WA14	B-WA14	C-WA14	F-WA14
97	E-PA03	A-PA03	B-PA03	D-PA03	F-PA03	C-PA03
98	F-IU15	B-IU15	D-IU15	E-IU15	A-IU15	C-IU15
99	C-PA13	E-PA13	B-PA13	A-PA13	D-PA13	F-PA13

Appendix E. (continued)

	TRIAL #1	TRIAL #2	TRIAL #3	TRIAL #4	TRIAL #5	TRIAL #6
100	A-PU04	E-PU04	B-PU04	D-PU04	C-PU04	F-PU04
101	E-PU15	B-PU15	A-PU15	F-PU15	C-PU15	D-PU15
102	E-PU05	A-PU05	B-PU05	D-PU05	C-PU05	F-PU05
103	E-IU12	B-IU12	A-IU12	D-IU12	C-IU12	F-IU12
104	A-IA15	B-IA15	D-IA15	F-IA15	C-IA15	E-IA15
105	F-WA20	E-WA20	D-WA20	A-WA20	C-WA20	B-WA20
106	E-IU05	B-IU05	A-IU05	C-IU05	D-IU05	F-IU05
107	E-WU19	D-WU19	F-WU19	A-WU19	B-WU19	C-WU19
108	A-PA04	E-PA04	D-PA04	F-PA04	B-PA04	C-PA04
109	B-PA15	C-PA15	E-PA15	F-PA15	D-PA15	A-PA15
110	A-PU07	F-PU07	E-PU07	D-PU07	C-PU07	B-PU07
111	C-WU04	A-WU04	F-WU04	D-WU04	E-WU04	B-WU04
112	D-IA18	F-IA18	A-IA18	B-IA18	C-IA18	E-IA18
113	E-PU17	A-PU17	B-PU17	D-PU17	F-PU17	C-PU17
114	A-WA05	F-WA05	D-WA05	B-WA05	E-WA05	C-WA05
115	B-IU03	C-IU03	E-IU03	D-IU03	A-IU03	F-IU03
116	E-WU07	D-WU07	A-WU07	F-WU07	C-WU07	B-WU07
117	E-PU06	A-PU06	C-PU06	F-PU06	D-PU06	B-PU06
118	C-WA06	F-WA06	A-WA06	E-WA06	B-WA06	D-WA06
119	A-WA13	B-WA13	D-WA13	E-WA13	F-WA13	C-WA13
120	D-IA16	E-IA16	B-IA16	C-IA16	F-IA16	A-IA16

Appendix F.

Accuracy of listener's responses to target words. Data presented for Subject A, imitation aided condition.
1 = correct, 0 = incorrect

Subject: A Imitation aided condition

Target Word	Listeners																Percentage of Intelligibility
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	
1.	1	1	0	1	1	1	1	1	1	0	1	1	0	1	1	1	**81.3**
2.	0	0	0	1	0	1	1	1	1	1	0	1	0	1	0	0	**50.0**
3.	1	0	1	1	0	1	0	1	1	1	0	0	0	1	1	1	**62.5**
4.	0	1	1	0	1	1	0	1	1	1	1	0	1	1	1	0	**68.8**
5.	1	1	1	0	1	1	1	1	1	1	1	1	1	1	1	1	**93.8**
6.	1	1	0	1	1	0	1	1	0	1	0	1	1	1	1	1	**75.0**
7.	1	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1	**68.8**
8.	0	1	0	1	1	0	1	0	1	1	1	1	1	0	1	1	**68.8**
9.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
10.	1	0	1	1	0	0	1	1	1	0	1	1	0	0	0	0	**50.0**

Appendix F. (continued)

Target Word	Listeners																Percentage of Intelligibility
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
11.	1	0	1	1	1	1	1	0	0	1	1	1	1	1	1	1	**81.3**
12.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
13.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
14.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
15.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
16.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
17.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
18.	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1	1	**93.8**
19.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	**100**
20.	1	1	1	1	1	1	0	1	1	1	1	1	1	1	1	1	**93.8**

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