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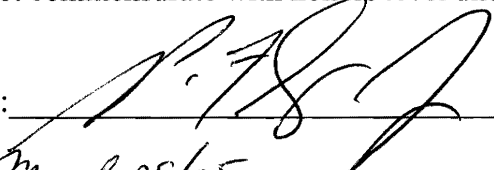
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PROJECT TITLE: Prosody and Voice Characteristics of Children with Cochlear Implants.

I have reviewed this completed senior honors thesis with this student and certify that it is a project commensurate with honors level undergraduate research in this field.

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Approval

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 X Based on its academic merits, I recommend that this project be digitally catalogued and archived by Hodges Library to make it widely available.

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* this project was completed as well or better than most graduate theses I have seen. I strongly recommend Jessica for this award.

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Prosody and Voice Characteristics of Children with Cochlear Implants

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Introduction

Since cochlear implants first appeared in the 1980's, researchers have examined several aspects of the speech produced by recipients of these devices. In particular, researchers have analyzed speech perception (Carney, Kienle, & Miyamoto, 1990; Miyamoto, Kirt, Robbins, Todd, & Riley, 1996; Mondain, Sillon, Vieu, Lanvin, Reudillard-Artieres, Tobey, & Uziel, 1997; Tyler, 1990), as well as speech production by children with prelingual deafness who have been fitted with multichannel cochlear implants (Ertmer & Mellon, 2001; Osberger & McGarr, 1982; Miyamoto et al., 1996; Miyamoto, Kirk, Svirsky, & Sehgal, 1999; Tobey, et al., 1991; Tobey, Geers, & Brenner, 1994). Of those studies looking at production, several have focused on vowel production (Ertmer, Kirk, Sehgal, Riley, & Osberger, 1997; Ertmer & Mellon, 2001; Osberger & McGarr, 1982), while others have looked at consonant production (Kirk, Diefendorf, Riley, & Osberger, 1995; Tobey et al., 1991). In these studies, the only prosodic aspect of speech to be mentioned appears to be nasality. Thus, there appears to be almost no specific evidence available relative to the development of the suprasegmental aspects of conversational speech by cochlear implant users. The current study sought to fill in some of this missing information. In particular, this study analyzed the prosody and voice characteristics of children with cochlear implants.

Many of the previous studies in this area that have looked at very specific aspects of speech have used very controlled, previously prepared sentences or word lists. A few investigators have used conversational speech samples (e.g., Blamey, Barry, & Jacq, 2001; Blamey, et al., 2001; Bow, Blamey, Paatsch, & Sarant, 2002). Unconstrained (i.e., spontaneous) conversation provides the most natural sample of speech, but continuous

conversation is also the most difficult type of sample to analyze. Gordon-Brennan (1994), for example, reported that conversational speech tends to yield the most unintelligible speech in cochlear implant users. When speech is unintelligible, analysis is a problem because there is no reference for making judgments about the accuracy of speech sound production or the appropriateness of prosodic aspects of speech such as intonation or stress. Most of the studies that have used free conversation have focused on overall speech intelligibility (Chin, Tsai, & Gao, 2003; McGarr, 1983; Robbins, Kirk, Osberger, & Ertmer, 1995; Svirsky, Sloan, Caldwell, & Miyamoto, 2000; Svirsky, Chin, Miyamoto, Sloan, & Caldwell, 2002; Tobey et al., 1994). In the current study free conversational speech samples were collected from six (6) young children with prelingual severe-profound deafness who have been implanted with multichannel cochlear implant devices prior to age 3;0 (years;months). Between five (5) and eight (8) speech samples were collected from each child; the samples from each child were separated in time by three months. The resulting forty (40) speech samples were analyzed using the Prosody-Voice Screening Profile (PVSP; Shriberg, Kwiatkowski, & Rasmussen, 1990).

Children and Hearing Loss

Hearing loss affects more children than cystic fibrosis, hypothyroidism, hemoglobinopathy and phenylketonuria combined. Approximately 3 out of every 1,000 newborns have a hearing loss (Mehl, 1998). Of the children born with hearing loss, 20% will have a profound hearing loss (i.e. greater than a 90dB). After birth, up to 3% more children may develop a hearing loss (Speaking, 2002).

For those individuals with a bilateral severe to profound hearing loss, cochlear implants may be an option. If hearing aids do not provide enough benefit, if there are no

signs of a severe anomaly in the anatomical structures of the ear or mastoid process, if there are appropriate expectations, and if the individual is older than 12 months, that individual may be a good cochlear implant candidate (Zwolan, 2000). The Food and Drug Administration (FDA) has approved cochlear implants for those 12 months and older, but there have been cases of successful implantations in even younger infants (Zwolan, 2000).

Cochlear Implants and Children with Hearing Loss

The first report of hearing with electrical stimulation of the ear was in 1800 by Count Alessandro Volta following an experiment he performed on himself; he inserted metal rods in each of his ears and connecting them to a battery compound (Clark, 1995). The first single-channel cochlear implant was introduced in 1972, and more than 1,000 people were implanted in the 1970's and 1980's, including several hundred children (American, 2004). According to Clark (1995), the first multi-channel cochlear implant in a prelingually deaf patient took place in 1983. The patient had used sign language his entire life and was implanted at age 25. The first prelingually deaf child was implanted with a multi-channel cochlear implant device at age 10 in 1985, followed by a 5 year old in 1986. These first implantations provided evidence that better results are likely to be seen with children, specifically those who have an oral or verbal background.

As of 2002, the world wide total of individuals with cochlear implants exceeded 59,000. In the United States, 23,000 people had been implanted by this point. Of that number, 10,000 were children (Turkington & Sussman, 2004). Multichannel cochlear implants were approved by the Food and Drug Administration (FDA) for children in 1990 and are the most popular implant device. The three multichannel cochlear implants

that are used today are the Nucleus by Cochlear Corporation, the Clarion by Advanced Bionics, and the Med-EL by Medical Electronics Corporation (American, 2004). Single channel implants were used throughout the 1980's, but their use has become almost obsolete in current medical practice (Chin & Svirsky, 2000).

Factors Affecting Implant Success

Early diagnosis and intervention of hearing loss is critical to speech and language development. Studies show that the earlier the implantation age, the more intelligible the child's speech will be (Fryauf-Bertschy, Richard, Kelsay, Gantz, & Woodworth, 1997; Miyamoto, et al., 1999). The number of years of intervention as well as the type of intervention is also important. Research suggests that the longer a child has used an implant, the higher the speech intelligibility scores are (Flipsen & Colvard, 2003; Miyamoto, et al., 1996; Mondain, et al., 1997; Robbins, et al., 1995; Svirsky, et al., 2000). Robbins, et al. (1995) and Svirsky, et al. (2000) have shown that pre-implant speech intelligibility scores of cochlear implant users are at or around 0%. However, Svirsky and colleagues (2000) reported rates of increase of 7.6% to 10% for each year of implant use. Studies have offered evidence that with 3;5 (years;months) of implant use, speakers achieve speech intelligibility scores of 40% and above (Miyamoto, et al., 1996; Mondain, et al., 1997; Robbins, et al., 1995), and speakers may continue to improve even after 8 years of implant use (Osberger & McGarr, 1982).

Choosing which method of intervention may be the most important decision that parents have to make for their hearing impaired child. If the parents choose a verbal method, two available options are (1) a strictly oral communication method and (2) total communication, which is a combination of speech and Signed English. The method

chosen can affect the speech intelligibility scores of these speakers. Research suggests that intelligibility scores are higher in oral communication users than in total communication users (Osberger, Robbins, Todd, Riley, 1994; Svirsky, et al., 2000; Tobey, et al., 2000). Osberger, et al. (1994) found that even with pre-implant scores near 0%, oral communicators received scores of 48% intelligible after three years of implant use, while total communicators received scores of only 21%. Tobey, et al. (1994) stated that “without training, profoundly deaf children do not ordinarily produce more intelligible speech as they grow older” (p. 124). So it would appear that the intervention method is the one of the keys to success.

The amount of residual hearing also appears to play an important role in speech and language development in children fitted with cochlear implants. It has been documented that the more residual hearing a child has, the higher the speech intelligibility scores will be (Mondain, et al., 1997; Svirsky, et al., 2002). The Svirsky et al. study compared intelligibility scores of hearing aid users with different levels of residual hearing. Svirsky discovered that hearing aid users with a hearing threshold of 90-100 dBHL had speech intelligibility scores greater than 70% while those with thresholds at 100-110 dBHL had scores around 50%. Those individuals with thresholds of 110+ dBHL had the poorest speech intelligibility scores, lower than 20% intelligible. However, it is important to note that children who used cochlear implants for three years demonstrated performance comparable to that of children with pure tone thresholds at 90-100dBHL (Tobey, et al., 1994). Tobey, et al. also found that after three years of device use, tactile aid and hearing aid users’ speech intelligibility improved 20%, while cochlear implant users improved 36%. Even though hearing aid users may initially have more

residual hearing, the additional sound sensitivity that the cochlear implant provides allows users to see significantly higher gains in speech intelligibility over time.

Prosody and Voice

Suprasegmentals, such as prosody, are information that is added to the segmental, or phonemic elements of speech. The smallest domain over which prosodic features extends is the syllable; prosody is not found on individual sounds (Couper-Kuhlen, 1986).

Prosodic features carry important linguistic information; for example, grammatical prosody (expressed as shifts in syllable stress) can distinguish whether a word is a noun, verb or adjective (e.g., *pérfect* versus *perfect*; Grant & Walden, 1996). Grammatical prosody (expressed as differing patterns of pitch change or intonation) is also used to denote whether an utterance is a question (rising intonation) or a statement (falling intonation). Prosodic features also play an important role in expressing emotion. According to Crystal (1969), in English, clipped or shortened syllables convey anger, impatience and irritation; strongly stressed syllables convey anger, vexation, impatience and disapproval. Drawled syllables express boredom, vexation and grimness. Complex pitch ranges are employed to express excitement, puzzlement and pleasure. Loud speech is used when the speaker is excited, angry, vexed, impatient or irritated; soft speech is usually equated with puzzlement, amusement, questioning and apologizing. A fast tempo is used when the speaker is irritated, impatient, vexed or excited, while a slow tempo portrays a more puzzled, apologetic, amused or questioning speaker. High tones or pitches convey anger, matter of fact statements and irritation. Precise, questioning and apologetic speech is conveyed through lower tones or pitches. High tension also

expresses anger, disapproval, impatience and grimness, whereas lax speech most commonly conveys boredom.

Several different approaches have been used to discuss prosody and voice. One way in which linguists have analyzed prosody is in the form of hierarchies. The typical prosodic hierarchy used by linguists includes the tone group (i.e. utterance), foot (i.e. syllable group), syllable and phoneme. An English foot must contain at least one stressed/strong syllable. Weak syllables are optional. Content words such as nouns, verbs, or adjectives may receive more stress on one syllable, and less stress is placed on function words such as determiners, auxiliaries, or copulas. In English, strong and weak syllables tend to alternate with one another providing the rhythm of speech. Any normally unstressed syllable that receives stress is viewed as being contrastive or emphatic (Couper-Kuhlen, 1986). An example of prosodic analysis is that reported by Panagos and Prelock (1997) who monitored the speech of a 4;6 year old girl with normal prosody but a mild phonological delay. Using normal prosodic characteristics, the girl placed more emphasis on new information. The emphasized portions were louder, longer and included a rising pitch. To mark weak syllables, the child used a falling pitch and segment lengthening.

The rules of English stress are extensive and include many exceptions; it is the exceptions which cause problems for non-native speakers and those with speech-language delays or disorders. However, most fluent speakers know the rules even if they cannot express them verbally (Halle & Keyser, 1971).

Some researchers and linguists may discuss prosody and voice in combination without providing a clear line of distinction between the two. Others believe that voice

differs from prosody in that it refers to the “vibratory signal upon which speech is carried” (Stemple, Glaze, & Klaben, 2000; p.1). According to Kreiman, Gerratt, Kempster, Erman and Berke (1993), one can objectively measure this vibratory signal in several ways, but “voice quality is fundamentally perceptual in nature” (p. 21). Therefore, voice commonly refers to the overall subjective impression of how a person sounds. Some common descriptors of voice include high pitched, deep, harsh, breathy, weak, strained, nasal, and denasal. These descriptors are directly linked to fundamental frequency, subglottal pressure, velopharyngeal function and vocal fold performance, all of which can be analyzed using objective measures. Measurement of the rate of vibration of the vocal folds yields the fundamental frequency, which is expressed in Hertz (Hz) or cycles per second. Fundamental frequency is the objective measurement of pitch; a low fundamental frequency correlates to a low pitched voice. Generally, the higher the fundamental frequency is, the higher the perceived pitch will be. Vocal intensity measures may be made using a sound pressure level (SPL) meter to provide more objective acoustic measurements for vocal loudness. A low vocal intensity signal would signify a weak, breathy or too soft voice. Another acoustic measure of voice is signal-to-noise ratio which measures the ratio of the “periodic or harmonic signal energy to the aperiodic or noise energy in the waveform” (Stemple, et al., 2000; p.201). The greater the signal-to-noise ratio, the better the voice generally sounds in regards to harshness. Subglottal air pressure measurements refer to the build-up of pressure below the vocal folds in the larynx, and a low amount of air pressure generally yields a weak or breathy vocal quality. Using imaging techniques and technology such as the rigid endoscope, electroglottography (EGG), and electromyography (EMG), the performance of the vocal

folds and surrounding muscles and structures can be analyzed. Poorly abducted or adducted vocal folds and improper muscle control can cause too little or too much tension, resulting in a breathy or harsh voice. Imaging techniques, such as endoscopy, can also provide feedback to velopharyngeal closure; improper closure can lead to abnormal airflow through the nose resulting in a hyponasal or hypernasal voice. The Nasometer is a device which “measures and visually demonstrates the degree of nasalance on a computer screen” (Stemple, et al., 2000; p.300). Generally, objective measurements are used to support a subjective impression of vocal quality, though they are not a regular part of routine clinical practice of most speech-language pathologists.

Prosody and Voice Measurements on the PVSP

Although there are several ways in which one may analyze prosody and voice characteristics, the Prosody-Voice Screening Profile (PVSP; Shriberg, et al., 1990) represents a more comprehensive view and is clinically useful as a screening for possible prosodic and vocal problems. It was for these reasons that the PVSP method was used in this study to analyze the prosody and voice characteristics of children with cochlear implants.

The Elements of Prosody: Phrasing

As defined by the PVSP, prosody includes three components. The first of these, phrasing, is defined as “the flow of speech” (Shriberg, et al., 1990; p.22). Phrasing is measured using observable behaviors such as repetitions, revisions, fillers, sound blocks and prolongations to determine appropriate phrasing for the speaker’s age, emotional state and intended content. Highly emotional speech tends to produce uncharacteristic phrasing patterns; therefore, emotional speech is excluded from the sample.

Rate

The second aspect of prosody considered by the PVSP is rate. According to the PVSP, rate is considered to be appropriate, slow or fast depending on the speaker's age, emotional state and dialect. Speech that contains fewer than two syllables per second is considered to be slow. Fast speech contains more than four syllables per second.

Stress

Stress is the third aspect of prosody that is examined by the PVSP. Stress plays an important role in the English language, and it is marked by changes in pitch, loudness and/or duration, either alone or in combination. Unlike Latin influenced languages, such as Spanish or French, in which every syllable receives "roughly the same articulation effort" (Panagos & Prelock, 1997; p.2), the English language is a "stress-timed language in which multiple linguistic functions are served by stress" (p.2).

The PVSP uses perceptual judgments to determine appropriate stress patterns. As noted by Shriberg, et al. (1990), "changes in stress are moderated by variations in the pitch, loudness, and duration of sounds" (p. 29). The PVSP does distinguish between lexical, phrasal and emphatic stress. Lexical stress reflects rules for stress patterns within a word; phrasal stress reflects rules of as to which grammatical forms are expected to be stressed versus unstressed. Emphatic stress reflects pragmatics and affect. Even though emphatic stress may break some of the lexical and phrasal stress rules, it is not judged as inappropriate if the speaker's intent is to emphasize one syllable or grammatical form more than the other.

The Elements of Voice: Loudness

As defined by the PVSP, there are four elements of voice. The first of these is loudness which is the subjective equivalent to amplitude. Loudness is altered by increasing air pressure below the glottis (i.e., the space between the vocal folds in the larynx). Average loudness for speech is 65dB SPL. Soft speech is around 45dB SPL, and loud speech is 85dB SPL. Average speech intensity, or loudness, for women is 3dB SPL less than that of men (Calvert & Silverman, 1983; p.31). Loudness, or intensity, cues are used to stress higher fundamental frequencies, or pitch (Crystal, 1969).

Pitch

Pitch (another element of voice considered by the PVSP) is the subjective measure of fundamental frequency. It is a phenomenon that although a critical aspect of prosody and intonation patterns, is difficult to measure. Pitch can be viewed as “a succession of perceivable speech events” (Couper-Kuhlen, 1986; p.63), because individuals do not perceive a pitch change whenever there is a change of fundamental frequency, nor do “they perceive regular increments in frequency as regular increments of pitch” (p.63). There is an absence of research that describes what constitutes normal pitch and when a given pitch contour ceases to be normal.

Pitch is usually rated on some type of rating scale or using descriptive phrases such as “too high” or “too low”. Objectively pitch is easy to measure using fundamental frequency, because changes in pitch occur when the frequency of vibration of the vocal folds increases. The average fundamental frequency for men is around 125 Hz (i.e. Hertz, cycles per second). Women and children have higher fundamental frequencies around 200 and 240 Hz respectively.

Laryngeal Quality

Laryngeal quality refers to vocal characteristics such as breathy, harsh, rough, stained and tremulous. The PVSP requires that each utterance be evaluated as to whether the laryngeal quality is within the normal limits of a speaker's age, gender and dialect. For a breathy voice, "the perceived amount of vocal tone must be equal or less than the unvoiced airflow" (p.37). A rough voice contains a harsh or gravelly vocal quality. Pitch shifts and voice breaks are also included under laryngeal quality.

Resonance Quality

Resonance emphasizes certain overtones of fundamental frequency. Resonance blends with fundamental frequency to give perceived vocal quality (Calvert & Silverman, 1983; p. 31), which refers to the "inherent background characteristics of utterances as wholes"; it is a "single impression of voice" (Crystal, 1969; p.123). Resonance is influenced by the vocal tract, trachea, pharynx, oral and nasal cavities, and "normal resonance is highly dependent on normal velopharyngeal structures and function" (Kummer & Lee, 1996; p.271). Using spontaneous connected speech for an evaluation of resonance is important because vocal resonance cannot be assessed adequately with single words or even short utterances (Kummer & Lee, 1996).

As the authors describe, "rate, stress, loudness, and laryngeal quality are associated with the degree of velopharyngeal closure and its timing" (p.41). Improper velopharyngeal closure almost always leads to inappropriate resonance quality. The PVSP describes three types of resonance quality, each making the speech signal sound "muffled". Nasal speech is found when the velopharyngeal port does not close adequately, allowing too much nasal resonance to permeate non-nasal sounds. Denasal speech occurs when the velopharyngeal port does not open adequately, taking away the

nasality that is normally found on nasal sounds. Nasopharyngeal speech is the third type of resonance quality mentioned in the PVSP, and it refers to a “back of the throat” resonance. This classification is used for speech “that is not clearly nasal or denasal” (p.43) but which is still perceived to be abnormal.

Difficulties with Prosody and Voice Measurement

Prosody and voice are not always easily defined, and detailed descriptions of procedures for analyzing child prosody and voice are scarce at best. “Prosodic features are not as rigidly or discretely definable as segmental phonemes” (Crystal, 1969; p.127). There is also a lack of data on normal development of these aspects of speech. Intonation patterns have also been thought of as a difficult speech production characteristic to formally test (Wells & Peppé, 2003). Crystal (1969) notes several other problems with the analysis of prosodic features. One is that prosodic features often have overlapping functions.

“Prosodic speech cues for rhythm, stress and intonation are related primarily to variations in intensity, duration and fundamental frequency” (Grant & Walden, 1996; p.228). This can make it difficult to separate the different characteristics. There is also imprecision in the terminology; for example rough and harsh vocal qualities are often considered synonyms when they are actually exclusive terms (Crystal, 1969). Despite all the problems associated with analyzing prosody and voice in speech, prosodic cues convey lexical, grammatical and emotional information, all of which are important aspects of communication.

Prosody and Language Development

Prosody also appears to play a large role in speech and language development. It has been shown that infants prefer to listen to motherese, or infant directed speech, over adult

directed speech (Cooper & Aslin, 1990; Mehler, Jusczyk, Lambertz, Halsted, Bertoncini, & Amiel-Tison, 1988). Infant directed speech includes exaggerated pitch and varying intonation which appears to appeal to young infants. It is believed that even as infants, children use exaggerated pitch and intonation contours to help them segment speech and assist in syntax development (Kemler, Hirsh-Pasek, Jusczyk, & Wright, 1989). Even in the early words of young children, prosody appears to play a large role. One of the most common phonological processes (i.e., simplification patterns) in children, weak syllable deletion, is directly linked to prosodic cues. Klein (1981) and Fee (1997) demonstrate that children delete weak, unstressed syllable much more frequently than strong, stressed syllables.

It is believed that children develop appropriate stress patterns by age 3 (Clark, Gelman, & Lane, 1985; Klein, 1984; Snow, 1994). Gerken and McGregor (1998) note that, “perceptual and acoustic studies of children’s mastery of various aspects of prosody suggest that this master is achieved slowly from the onset of first words into the early preschool years” (p.43).

Prosody in Children with Hearing Impairment

Irregularities of rhythm in the speech of deaf individuals “appear to have their origins in the difficulty controlling varying loudness, pitch and duration” (Calvert & Silverman, 1983; p.171). Calvert and Silverman describe the relationship between hearing threshold levels and speech and language expectations. A 70-90dB HL, severe hearing loss is commonly associated with abnormal articulation, atypical voice quality and deficient syntax. A 90dB HL or poorer, severe to profound hearing loss is generally equated with irregular speech rhythm, abnormal voice and poor articulation.

In the study by Allen and Arndorfer (2000), analysis of sentence-final intonation patterns by normal and hearing impaired speakers provided evidence that interrogative and declarative sentences produced by hearing impaired speakers may not be perceptually distinct. Interrogative sentences produced by hearing impaired speakers were only correctly identified at a rate of 49.9% by normal hearing listeners, as compared to 96.0% of interrogatives produced by normal hearing speakers. Declaratives produced by the hearing impaired speakers were more commonly identified (76.8%), but still at a lower rate (92.5%) than those of normal hearing speakers' productions. Findings from this study suggested a lower fundamental frequency rise on interrogatives by hearing impaired individuals. Normal hearing speakers demonstrated greater variation in speech intonation.

Phrasing

To date no studies appear to have analyzed syllable/word repetitions or syllable/word revisions in the speech of children with hearing impairment.

Rate

Slower speech, or speech of greater duration, is also a typical problem for deaf speakers. Boone (1966) provided evidence of prolonged vowels and longer interword pauses in deaf speech. Each word appeared separate as opposed to the continuous, overlapping flow found in normal speakers. In the speech of those with normal hearing, vowels preceding voiceless consonants are usually shorter than the same vowel before a voiced consonant (ex. beat versus bead). However, deaf speakers tend to produce those same vowels with undifferentiated duration (Calvert & Silverman, 1983; p.166). Calvert and Silverman offer one explanation for this slowed rate; they suggest that the process of

trying to correctly formulate syntax and articulation might slow the speech of deaf individuals, resulting in disjointed segments.

Stathopoulous, Duchan, Sonnenmeier, and Bruce (1986) also studied pausing in deaf speech. Normal hearing speakers demonstrated shorter pauses between sentences and paused more within sentences. Deaf speech was characterized by longer word durations, and individuals tended to speak slower. Stathopoulous and colleagues hypothesized that deaf speakers rely on the use of long pauses to distinguish sentence boundaries, instead of on falling terminal contours like normal speakers.

It is important to note that rhythm proficiency was found to be “highly related” to total duration measurements by Hood and Dixon (1969) who compared speech rhythm of deaf and normal speakers. The 22 deaf males were found to have less variation of fundamental frequency and intensity, as well as a greater total duration. Duration for the deaf group was 2-3.5 times that of the normal hearing group.

Stress

As mentioned previously, typically developing children acquire appropriate stress patterns by age 3. For most deaf children, this window of time does not apply, because they are unable to hear many of the acoustic and prosodic cues, such as pitch changes, stress and changes in loudness. The perceptual speech cues that are influential in the speech and language development of normal hearing children are not available to prelingually deaf individuals.

Inappropriate stress patterns have also been described as “typical” of hearing impaired speakers (Hargrove, 1997). Maassen (1984) suggested that inappropriate pitch affects the speaker’s ability to correctly produce lexical stress. Maassen also found that

during the production of stress by hearing impaired speakers, the timing is “distorted”, not matching normal timing patterns found in normal hearing speakers.

Nickerson (1975) describes the stress patterns of deaf speakers “almost as if deaf speakers only produce stressed syllables” (p.344). Other stress patterns observed included monotony or excessive, erratic pitch variation. Nickerson reported that deaf individuals tend to vary pitch less often resulting in excessive stress on all syllables or a flat monotone stress pattern throughout the utterance.

Prosody and Speech Intelligibility

Studies of speech intelligibility tend to show that its association with speech sound production accuracy is modest at best. In other words, speech sound production accuracy does not account for all of the variability we see in intelligibility. This has led researchers to suggest that prosody might be involved in a significant way. Some investigators have begun to examine the association between prosody and speech intelligibility. For example, Ewing (1954) suggested that the lack of conventional intonation does seem to detract from the intelligibility of speech. Maassen and Povel (1984, 1985) have documented a slight increase in speech intelligibility with corrected suprasegmental errors. The findings of their 1984 study showed that with corrected temporal structure and intonation patterns in the speech of deaf children, speech intelligibility scores increased 13% (from 20% to 33%). In combination with segmental correction, the effects of improved suprasegmental production yielded “almost perfectly understandable sentences” (1985; p.877).

Even though correcting segmental errors yields more intelligible speech than correcting suprasegmental errors alone (Maassen & Povel, 1985), prosody can help fill in when there are substitution errors (Grant & Walden, 1996). Smith (1975) suggested that

“training toward improvement in the stress and intonation patterns of the deaf child’s speech should enable a listener to compensate for omitted and substituted elements and should result in better intelligibility” (pp.109-110). Hargrove (1997) also suggested that “prosody and language are both vital to communication and should be managed jointly throughout the treatment program” (p.76).

Voice Quality in Children with Hearing Impairment

Smith (1975) found several significant factors that appear to be related to poor speech production in deaf children. These include poor phonatory control with broken phonation, inappropriate loudness and pitch variation as well as excessive variability in intonation (i.e. pitch patterns). Parkhurt and Levitt (1978) found that prosodic errors of deaf speech include pitch breaks and excessive duration. Subtelny, Whitehead, and Orlando (1980) also discovered faulty prosodic features in hearing impaired speech that included poorly blended sounds and words in regards to time, inappropriate stress on both syllables and words, and improper pitch. This same study noted that “because of the speakers’ inadequate management of the aerodynamics for speech, it is probable that voice quality will be adversely affected” (p.87); a breathy/weak voice could occur due to poor adduction, and extra strain from over adduction could result in a tense/strained vocal quality.

Loudness

The signal intensity at which normal speakers most easily understand speech is 50dB above their hearing threshold. However to avoid discomfort, speech can only be presented at 15-20 dB above threshold for deaf individuals (Calvert & Silverman, 1983; pp.92-93). For deaf individuals, changes in pitch may be perceived as overall changes in

loudness. For example, a rising pitch may be perceived as a decrease in loudness (Calvert & Silverman, 1983; p.82). Modifications of loudness levels are thought to be easier for deaf children to acquire than modifications in pitch, because the control of pitch leads to more laryngeal awareness which usually results in hypertonicity or overtension of laryngeal muscles (Ewing, 1954; p.164).

Pitch

Pitch in deaf speech has been characterized by monotonicity, excessive pitch changes and diplophonia (Monsen, 1978). McGarr and Osberger (1978) studied pitch deviations in deaf speech using a 5-point rating scale. A rating of 5 signified appropriate pitch for that age and gender, and a 1 meant that the speaker could not sustain phonation. Out of 57 deaf children evaluated by McGarr and Osberger, 32 received ratings higher than 4.0. However, no child with a hearing loss greater than 90dB HL received a rating of 5.0.

As noted previously, pitch can also be measured objectively using fundamental frequency. Boone (1966) compared the fundamental frequencies and perceived pitch of 44 deaf children and 44 children with normal hearing. At ages 7;0-8;0, there appeared to be no difference in the perceived pitch for both males and females. As many hearing children had inappropriate high voices as the deaf participants. There were no significant differences in fundamental frequencies until after adolescence. At this time, a greater departure in pitch was seen, particularly in the male population.

Stathopoulos and colleagues (1986) also used acoustical (i.e., fundamental frequency) analysis to determine if the perceived pitch of deaf female speakers was actually different from that of normal-hearing female speakers. Findings showed that the deaf speakers had an overall higher fundamental frequency (269 Hz) than the hearing

subjects (232 Hz). The deaf speakers also had a more restricted frequency range (157 vs. 192 Hz), a higher average fundamental frequency at the beginning of sentences (279 vs. 254 Hz), as well as a higher fundamental frequency at the end of sentences (268 vs. 189 Hz). The normal-hearing speakers used falling intonation to signal sentence closure, but no such pattern was discovered for deaf speakers.

Laryngeal Quality

The speech of individuals with hearing impairments has often been said to have a “unique” quality. The vocal quality of deaf speakers has been described as “tense”, “flat”, “breathy”, “harsh” and “throaty” (Calvert, 1962). Vocal quality can also be breathy, harsh or strident. Greater reliance on tactile impressions (as opposed to auditory input) may result in more constriction and tension in deaf speech, which may lead to stridency or harshness. Excessive force on plosives before a vowel, which is common in deaf speech, also may result in a breathy quality (Calvert & Silverman, 1983; p.169). These vocal qualities are just a few of the features that give deaf speech its unique sound.

Although deaf speakers do tend to have a very unique vocal quality, this quality may only be audible in continuous speech. In his study, Calvert (1962) studied the ability of deaf educators to distinguish the speech of deaf children from that of normal hearing children. It is interesting that the teachers of the deaf could only distinguish between sentences produced by the two groups. Solitary vowels were undistinguishable. This emphasizes the need to analyze vocal quality in long sentences as opposed to single sounds or short phrases.

The deviant vocal quality of deaf speech has also been examined using acoustical approaches. A study by Thomas-Kersting and Casteel (1989) looked at vocal effort and

spectral noise levels in severe to profoundly hearing impaired children. These authors found that the vocal quality of hearing impaired speech deviated from normal speech in that spectral noise levels tended to increase as the degree of vocal effort was perceived to be more severe. In the production of the vowel /u/, hearing impaired speakers had significantly higher spectral noise levels with a higher perceived vocal effort. Hearing impaired speakers were described as sounding “tense”, “strained” and “metallic” in continuous speech. Physical signs of muscular tension were also noted.

Resonance Quality

Vocal quality of deaf speakers is also characterized by a pharyngeal focused resonance. Boone (1971) describes the vocal quality of deaf speech as “hollow” due to the retraction of the tongue toward the pharyngeal wall. Cul-de-sac resonance, as well as the term “hot potato voice” (Finkelstein, Bar-Ziv, Nachmani, Berger, & Ophir, 1993), have been used to describe the phenomena of deaf resonance quality. “Hot potato voice” is the result of hypernasality and inconsistent nasal emission in conjunction with a muffled oral resonance (Finkelstein, et al., 1993).

Severe to profound hearing loss is commonly associated with hypernasality. Fletcher, Mahfuzh, and Hendarmin’s findings (1999) showed that deaf children have significantly more nasalance than normal hearing speakers when nasal consonants are not present and significantly less when an utterance has many nasal consonants. Hypernasality in the hearing impaired is thought to be a result of improper control of the velum, and Fletcher hypothesized that deaf speakers are simply overwhelmed by all other speech demands and are unable to monitor nasal resonance all the time. This is not to say that nasal resonance cannot be controlled by the deaf speaker. Nasal resonance has a

frequency range around 500 ± 150 Hz (Fletcher & Bishop, 1970; Calvert & Silverman, 1983) which may be within the residual hearing range of some deaf speakers or at least available through amplification. Fletcher and Higgins (1980) discovered that excessive nasalance is modifiable in hearing impaired speakers using nasometric detection and visual feedback. Nickerson (1975) suggested that the additional nasal resonance provides additional speech cues for those with hearing impairment. Hypernasality in both deaf and normal speech is best judged in conversational speech and is often accompanied by audible nasal air emission during consonant production (Kummer & Lee, 1996).

Prosody and Voice in Children with Cochlear Implants

As can be seen from the above, there is much we know about the prosody and voice characteristics of individuals with hearing impairment, but the bulk of the research relates to individuals who used hearing aids or tactile devices, not cochlear implants. One study on speech perception of children with cochlear implants noted that children implanted with single channel cochlear implants perceived intonation more readily than the number of syllables or syllable stress in a word (Carney, et al., 1990). Tobey, et al. (1991) discovered that after only one year of cochlear implant experience, speakers were better able to imitate prosodic features in their own speech. However, it is not yet clear what prosodic differences are apparent in the speech of hearing aid or tactile device users versus the speech of multichannel cochlear implant users. Future research may provide evidence that the prosodic features of cochlear implant users, although not quite “normal”, may not fall into the category of “typical deaf speech” but rather have unique characteristics of its own.

Measurement of Prosody and Voice

At this moment, there is no universal, standard system to measure prosody and voice. Current assessment methods include checklists, rating scales or acoustical analysis. For example, McGarr and Osberger (1978) used a rating scale from 1-5 to describe pitch deviancies. Stathopoulos, et al. (1986) used acoustic analysis to measure fundamental frequencies to determine pitch appropriateness and Smith (1975) used a simple checklist (present/not present) system to monitor errors.

Although all of these can be useful, each method has its shortcomings. Checklists often do not include severity rankings. Rating scales do not describe what types of errors the speaker makes. Acoustical analysis does not take into account the importance of listener perception, and conversational speech is too difficult to analyze using most acoustical approaches.

Prosody-Voice Screening Profile (PVSP)

The Prosody-Voice Screening Profile (PVSP) developed by Shriberg, Kwiatkowski and Rasmussen (1990) is a procedure that provides qualitative data and more detail on error patterns than a simple 1-10 rating scale. The PVSP is an assessment method intended for use with conversational speech samples; it allows the user to describe specific errors and provides percentage correct/incorrect scores along with a graphic representation of overall prosody-voice performance.

Speech samples are first collected from unconstrained conversation. Samples are then separated into utterances and glossed following guidelines provided by the authors. In order to enhance the sampling validity, certain utterances may be excluded from the sample. Using the exclusion codes that appear in Figure 2, utterances may be excluded if found that “they might prohibit, contraindicate, or bias prosody-voice coding” (Shriberg,

et al., 1990; p.11). The suggested number of codable utterances (i.e., utterances that are included in the sample) is 20-25, of which a minimum of 50% must contain 4 or more words. These guidelines help ensure that the samples will yield more stable scores.

Codable utterances are analyzed relative to seven parameters described above (phrasing, rate, stress, loudness, pitch, laryngeal quality, resonance quality). Each utterance is coded as either appropriate or inappropriate on each of the parameters. Inappropriate utterances are assigned one or more of the 32 prosody-voice codes for each of the parameters.

There is a 90% cutoff score for passing the screening (i.e., if at least 90% of the utterances are deemed appropriate on a particular parameter, the speaker passes the screening for that parameter). The failure level is 80%, and scores of 80-90% are considered borderline. One or two instances of inappropriate behavior on any of the parameters can still yield a passing score. The Prosody-Voice Screening Profile kit includes audiocassettes to provide the scorer with training in how to use the procedure including practice modules. The authors recommend that the manual and audiocassettes be revisited often to ensure proper scoring (see Figures A1-A4 in the Appendix for copies of the PVSP form).

Previous studies using Prosody-Voice Screening Profile

To date, very few studies have utilized the PVSP. Pollock, Chow and Tamura (2004) analyzed the prosodic characteristics of the speech of preschoolers who had previously been adopted from China as infants/toddlers. Twenty-five (25) young girls were selected for the study, and all had at least two years of exposure to the English language. All participants were considered healthy and had similar backgrounds. PVSP results showed

that the mean for all participants in areas of Phrasing, Rate and Stress met the 90% cutoff criteria; this suggested that the adopted Chinese girls were adjusting to the new prosodic characteristics of English.

Shriberg, Paul, McSweeny, Klin, Cohen and Vokmar (2001) used the PVSP to assess prosody-voice characteristics of fifteen (15) adult males with high functioning autism and fifteen (15) adult males with Asperger's Syndrome. These profiles were compared to each other and to profiles from fifty-three (53) normal adult males. Results showed that for the High-Functioning Autism group, phrasing, stress, laryngeal quality and resonance quality all appeared to be problem areas with 33.3% or more of speakers failing the screening (i.e., more than 20% of utterances coded as inappropriate). The most failed screenings for this group were observed for Stress with 53.3% of speakers receiving failing scores. For the Asperger Syndrome group, 33.3% or more of the speakers failed in only two categories Phrasing (66.7%) and Laryngeal Quality (33.3%). All speakers of the Asperger Syndrome group passed both Rate and Pitch. In the control group, the Laryngeal Quality section of the PVSP was the only problem area; 37.3% of speakers failed.

Hargrove, Frerichs, and Heino (1999) performed a longitudinal study on a male who had a portion of his posterior left hemisphere removed due to the presence of a benign meningioma. The participant was 2;4 at beginning of study and was followed until he was 9;11. Prosodic analysis was performed using the PVSP every quarter. All seven prosody-voice parameters demonstrated variability throughout the course of the study. No improvements were seen in any area. Resonance quality was the only characteristic that remained the same through the study with a 0% passing percentage (i.e. all scores for

all quarters fell below 90%). The most common phrasing errors were Sound/Syllable Repetitions and Word Repetitions. All utterances coded as inappropriate for rate were scored as Slow Articulation/Pause Time. Most pitch errors were coded as Low or Low Pitch/Glottal Fry, and the most common error for vocal quality was Nasopharyngeal. The client's progress could not be represented clearly but did provide more descriptive information than traditional perceptual rating scales.

A study by Velleman and Shriberg (1999) used a portion of the Prosody-Voice Screening Profile to analyze stress patterns in the speech of children with suspected developmental apraxia of speech. It was found that 52% of the 53 children had inappropriate stress patterns in conversational speech. The most common code was Prosody-Voice Code 15: Excessive/Equal/Misplaced Stress (more than one half of inappropriate stress patterns). This characteristic set the children with suspected developmental apraxia of speech apart for those with speech delay of unknown origin. The authors suggest that inappropriate stress might be a diagnostic marker for a subtype of speech delay-developmental apraxia of speech (SD-DAS).

To date no studies appear to have used the PVSP to evaluate the speech of the hearing-impaired.

Objective of the Current Study

Objectives of this study were to describe prosody and voice characteristics in several children who had been implanted with cochlear implants and to provide evidence of any differences that may exist between the prosody and voice characteristics of children with cochlear implants and those speech characteristics of deaf speakers who have not been implanted, as noted in previous studies.

Method

Data Source

Data for the current study were obtained by Dr Peter Flipsen Jr of the Dept of Audiology and Speech Pathology at the University of Tennessee, Knoxville (UTK). The children who participated in the study were all receiving oral-based therapy in the Child Hearing Services Program at UTK.

Participants

Six (6) children (see Table 1) with prelingual deafness who had been fitted with multi-channel cochlear implants at least 18 months prior to the onset of testing were identified and their parents agreed to have them participate in the current study. Three (3) children were implanted with Clarion cochlear implants, and three (3) children were implanted with Nucleus-24 cochlear implants. The six children ranged in chronological age from 3;9 to 6;2 at the beginning of the study and 5;2 to 7;11 at the termination of the study. Amount of implant use ranged from 1;11 to 3;6 at the beginning of the study and 3;0 to 5;1 at the termination of the study. The participants included one (1) male and (5) females. Between five (5) and eight (8) samples were obtained from each child. The samples for each child were separated in time by three (3) months. A total of 40 samples were available for PVSP coding (41 recordings were obtained but one was unusable for technical reasons).

The children were selected based on several criteria. They were all prelingually deaf as defined by the onset of hearing loss prior to age 3;0. They all had unaided hearing loss of at least 90dB in the better ear. Multi-channel cochlear implants had been fitted by age 3;0 in all children. The participants also had at least 18 months of cochlear implant

use prior to testing. The Peabody Picture Vocabulary Test-Third Edition (PPVT-III, Dunn & Dunn, 1997) was used to test receptive vocabulary, and all participants scored within two standard deviations of their age group mean (i.e., a standard score of at least 70).

Table 1: Participant Characteristics

Participant	Gender	Age of ID ^a	Age at Implantation ^a	Initial Implant Experience ^a	Implant Type	PPVT-III ^b
1	F	0;8	2;4	2;11	Clarion	89
2	F	0;0	2;6	1;11	Nucleus-24	99
3	F	1;0	3;0	3;2	Clarion	72
4	F	0;3	2;0	3;6	Nucleus-24	77
5	F	1;3	2;7	2;3	Clarion	81
6	M	0;11	1;8	2;1	Nucleus-24	76
Group Mean (StDev)		0;8 (0;6)	2;4 (0;6)	2;8 (0;8)		82.3 (10.0)

^a Expressed in years;months

^b Standard Score on the Peabody Picture Vocabulary Test - Third Edition (Dunn & Dunn, 1997).

Design

In the current study, the conversational speech samples were evoked as part of a larger protocol lasting 60-90 minutes per session. The first session for each child included administration of the PPVT-III and thus was slightly longer than the others. Samples were evoked inside a single-wall sound-treated booth by one of two trained graduate student clinicians. A parent or the clinician who was providing treatment to the child was also often present and participated during many of the samples. The samples were recorded on digital audiotape using a Sony PCM-M1 portable digital tape recorder

through a Sony TCM-150 microphone mounted on the tabletop (i.e., held by a puppet). A sampling rate of 48 KHz was used. A variety of topics (e.g., favorite movies or cartoons, current activities in therapy) and materials such as age appropriate toys and activity pictures from the Bracken Concept Development Program (Bracken, 1998) were used to evoke the conversational samples. A sample size target of at least 90 different words was selected; samples of this size have been shown to provide a representative sample of English phonemes and canonical forms (Shriberg, 1986). Story telling and other narratives were avoided because of concern that they might evoke the use of atypical prosody in narrative registers (Shriberg, et al., 1990).

Procedure

Before listening to the speech samples, training for the PVSP was completed by the current author to ensure proficiency. The PVSP manual and audiotapes provide guidelines, examples and practice modules that include samples from speakers of different ages, genders and speech-language impairments. The PVSP procedures were reviewed prior to the onset of scoring. Training was completed within two (2) months. In addition to the training modules, and in order to obtain practice with coding complete sample sets, the current author carried out PVSP coding on several unrelated conversational speech samples that had previously been coded by a transcriber with extensive experience using the PVSP.

The conversational speech samples had previously been broken down into individual utterances during the course of narrow phonetic transcription. The phonetic transcripts (including the regular spelling gloss) were used for determining codable utterances, numbering of utterances and in coding the speech samples.

Because of concerns about coder familiarity (which might arise because each child would be heard multiple times), the forty (40) speech samples were randomly separated into eight (8) CD's, each containing five (5) samples. Samples did not contain any participant information, including age and sex, in order to prevent scorer bias.

Prosody and voice characteristics of the forty (40) speech samples were analyzed using procedures described in the PVSP manual (see also above). The percentage of appropriate/inappropriate utterances for each of the seven PVSP parameters were then calculated. Samples were analyzed over a seven (7) week time period (see Figures 1-4 in the Appendix for a sample of PVSP form).

Reliability

To evaluate intrajudge reliability, a random sample of five (5) speech samples was selected and PVSP analysis was repeated. Reliability testing occurred five (5) weeks after initial testing. Analysis of reliability was carried out two ways. First overall scores on % appropriate utterances between the two test times were correlated with each other using Spearman rank-order correlations. Correlations ranged from 0.34 to 1.0 with only one correlation below .87. The low correlation was due to one sample being rated as 100% appropriate utterances in regards to *Pitch* for the first screening and 80% for the second screening. It is important to note that in the first screening, additional comments were made concerning *Pitch* on that particular sample; it was noted that overall the speech sample sounded too high pitched, even though no utterances were coded as inappropriate. Since all scores for participants were near ceiling and rank-order correlations were used, these effects could have combined to yield a low correlation that is actually not meaningful.

The second approach to reliability assessment involved the use of point-to-point agreement. Relative to assignment of *Exclusion Codes*, agreement was 97.9% across all five samples. Agreement for the seven PVSP parameters in terms of matching utterances as appropriate or inappropriate ranged from 90.4% to 100% (mean = 95.0%). Relative to matching on exact choice of inappropriate code, agreement ranged from 83.2% to 100% (mean = 93.4%).

Results

Prosody-Voice Findings

The Appendix contains all prosody-voice figures referenced in the following discussion.

Results are presented intra-individually and across individuals.

PVSP Exclusion Codes

The Appendix (Figure A2) contains all Exclusion Codes included in the Prosody-Voice Screening Profile. The thirty-one (31) Exclusion Codes are divided into four categories: *Content/Context*, *Environment*, *Register*, and *States*. Exclusion codes are used to reflect “some situation or type of utterance that might prohibit, contraindicate, or bias prosody-voice coding” (Shriberg, et al., 1990; p. 11).

Participant 1. Participant 1 had a total of 478 excluded utterances out of 650 total utterances. 405 (84.7%) utterances were excluded based on *Content/Context*. Of these utterances, 62 or 15.3% were coded *C12: Too Many Unintelligibles*. An utterance is coded *C12: Too Many Unintelligibles* when it does not meet the 3:1 ratio of intelligible to unintelligible words as defined by the authors (i.e., at least 75% of the words must be understood). There were no *Environmental* exclusion codes, and 70 *Register* exclusion codes (14.7% of total excluded utterances). Of the *Register* codes, 67 or 95.7% were *R2: Narrative Register*. Three (3) utterances or 0.6% were excluded based on *States*.

Participant 2. Participant 2 had the lowest number of total exclusion codes at 171 out of 304 total utterances. 157 (91.8%) utterances were excluded based on *Content/Context*. Of these 12 (13.4%), were excluded due to *C12: Too Many Unintelligibles*. *Environment* made up 1.8% of total exclusions with 3 excluded

utterances. *Register* exclusions included 11 (6.4%) utterances. There were no *States* exclusions.

Participant 3. With 1068 excluded utterances out of 1208 total utterances, participant 3 has the proportion of exclusions (88.4%). *Content/Context* made up 77.9% of total exclusion codes with 823 excluded utterances. Of these 823, only 85 (10.2%) were based on *C12: Too Many Unintelligibles*. Five hundred and fifty-two (552; 67.1%) of these utterances were coded as *C7: Only One Word. Environment* included 15 (1.4%) excluded utterances. 230 (21.5%) of total excluded utterances were based on *Register*. Of the register exclusions, 97.0% were coded *R2: Narrative Register*. No utterances were coded under *States*.

Participant 4. Participant 4 had 229 (53.5%) out of 432 utterances excluded. 217 utterances were coded for *Content/Context*, 33.6% of those were *C12: Too Many Unintelligibles*. There were no *Environment* exclusions. *Register* included 11 exclusions, and 1 utterance was excluded based on *States*. Each represented less than 5% of total excluded utterances.

Participant 5. There were 540 (80.2%) of 673 utterances excluded from the speech sample of participant 5. 420 (77.8%) of the total excluded utterances were listed under *Content/Context*. Of these 79 (18.8%) were coded as *C12: Too Many Unintelligibles*. Seven (7) utterances were coded under *Environment*, less than 2% of exclusions. *Register* accounted for 112 (20.7%) of excluded utterances. Of these 92.0% were coded *R2: Narrative Register*. Only 1 utterance was coded under *States*.

Participant 6. A total of 680 (84.0%) of 810 utterances were excluded from the speech sample of participant 6. 607 (89.3%) utterances were excluded due to

Content/Context. Of these 196 (32.3%) were coded *C12: Too Many Unintelligibles*, which was the largest number of utterances coded C12 out of all participants. Two hundred and sixty-eight (268; 44.2%) were coded *C7: Only One Word*, and 70 (11.5%) were coded *C11: Second Repetition*. *Environment* accounted for 2.1% of exclusions, and *Register* included 59 (8.7%) excluded utterances. Forty-one (41) of the utterances under *Register* were coded as *R2: Narrative Register*. No utterances were excluded based on *States*.

All Participants. Of the 4077 total utterances, 3166 were excluded (i.e., 77.7% of all utterances). *Content/Context* posed the biggest concern for all participants. Of the total 3166 excluded utterances, 2629 (83.0%) were coded under *Content/Context*. Of that number 516 (19.6%), were coded *C12: Too Many Unintelligibles*. The second greatest concern was *Register* which included 493 (15.6%) of total excluded utterances. The remaining two categories accounted for less than 2% of total excluded utterances. Thirty-nine (39) or 1.2% of utterances was excluded under *Environment*, while *States* only accounted for 5 of the excluded utterances (0.2%).

PVSP Prosody Voice Codes

The Appendix includes graphs indicating the percent of utterances coded as appropriate on each of the seven (7) parameters for each individual for each sample. Figures A11, A18, A25, A32, A39, A46, and A53 show the average percent of utterances codes as appropriate on each of the parameters for each participant.

Phrasing

The seven inappropriate *Phrasing* codes include: *Sound/Syllable Repetition*, *Word Repetition*, *Sound/Syllable and Word Repetition*, *More than One Word Repetition*, *One*

Word Revision, More than One Word Revision, and Repetition and Revision.

Participant 1: Figure A5 shows *Phrasing* scores for participant 1 over eight (8) PSVP screenings. She received an average score of 95.8% appropriate utterances for *Phrasing*, the lowest average *Phrasing* score of all participants. For Screenings 1, 3, 4, and 6 the participant had no instances of inappropriate phrasing. In the second screening, only one (1) utterance was scored as inappropriate *PV6: One Word Revision*. Screening 5 had one (1) inappropriate *PV3: Word Repetition*. Screenings 7 and 8 were the only screenings to fall into the borderline category with scores of 88% and 86% respectively. The seventh screening had three (3) inappropriate utterances which included *PV2: Sound/Syllable Repetition*, *PV3: Word Repetition*, and *PV6: One Word Revision*. Screening 8 also had three (3) inappropriate utterances, all of which were *PV3: Word Repetition*. Participant 1 appeared to regress over time with the two (2) borderline scores appearing on the last two screenings.

Participant 2. As seen in Figure A6, participant 2 passed all screenings with greater than 90% appropriate utterances. The average score was 96.8% appropriate utterances. Screenings 2 and 4 received scores of 100% appropriate utterances. Screening 1 had one inappropriate utterance, *PV2: Sound Syllable Repetition*. Screening 2 also had one inappropriate utterance, *PV3: Word Repetition*. Screening 3 included two inappropriate scores, both of which were *PV3: Word Repetition*. Since participant 2 passed all screenings, there was little deviation in scores over time.

Participant 3. Figure A7 shows the data for participant 3. The average *Phrasing* score for participant 3 was 98.5% appropriate utterances, the highest average score for all six participants. Screenings 1, 2, 3, 4, 5, and 6 all received scores of 100% appropriate

utterances. Screening 7 received one (1) *PV3: Word Repetition*, and Screening 8 received two (2) *PV3: Word Repetition*. There was little deviation in the scores of participant 3, but the last two screenings did receive the lowest passing scores.

Participant 4. As indicated in Figure A8, participant 4 passed all screenings with greater than 90% appropriate utterances. Screenings 3, 4 and 5 had no instances of inappropriate utterances. Screening 1 had two (2) inappropriate utterances, coded *PV2: Sound/Syllable Repetition* and *PV3: Word Repetition*. Screening 2 had one (1) inappropriate coding, *PV3: Word Repetition*. Screening 6 included *PV3: Word Repetition* and *PV6: One Word Revision*. Screening 7 also received a *PV3: Word Repetition* code. There was little deviation in the percent appropriate scores for participant 4 with the middle three screenings receiving the highest passing scores.

Participant 5. Figure A9 includes the percentages of appropriate *Phrasing* for participant 5. The average was 98.0%. Screenings 1, 2, 3, 6, and 7 all received 100% appropriate utterances scores. Screening 4 could not be analyzed because of some technical problems with the recording. Screening 5 was the only screening to receive a score less of than 90%. There were three (3) utterances coded as inappropriate for a score of 88% appropriate utterances. Codes included *PV2: Sound/Syllable Repetition*, *PV3: Word Repetition*, and *PV8: Repetition and Revision*.

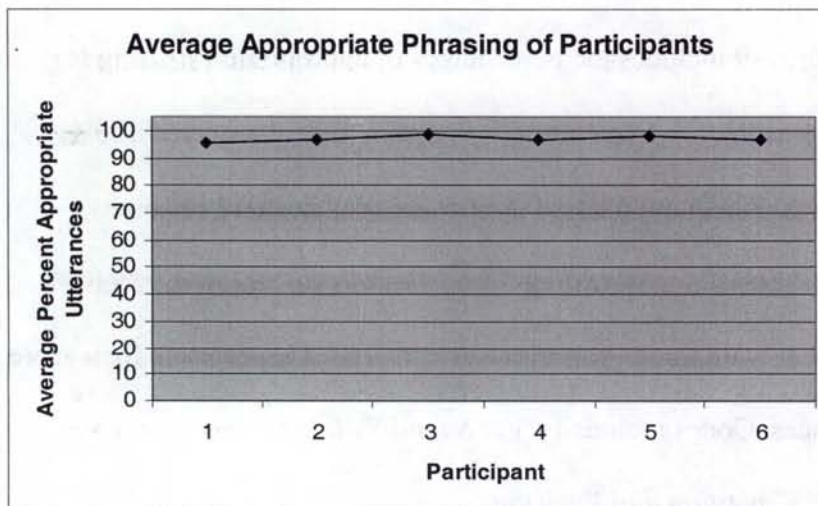
Participant 6. Figure A10 contains the *Phrasing* data for participant 6. The average appropriate *Phrasing* score for this participant was 96.7%. Screenings 1, 2, 3 and 6 all were 100% appropriate in regards to *Phrasing*. Screening 4 received two (2) inappropriate scores, both coded as *PV2: Sound/Syllable Repetition*. Screening 5 fell into the borderline range with a score of 88% appropriate utterances. Inappropriate coded

included one (1) *PV2: Sound/Syllable Repetition* and two (2) *PV3: Word Repetition*.

Screenings 4 and 5 were the only deviant scores for participant 6; no clear pattern over time emerged.

All Participants. (See also Figure 1 below; also shown as Figure A11 in the Appendix). No participant failed a single screening for Phrasing. The average *Phrasing* scores show that all participants passed with a score of greater than 90% appropriate utterances. The most common error codes were *PV2: Sound/Syllable Repetition* and *PV3: Word Repetition*. Overall, *Phrasing* appeared to be normal in all cochlear implant recipients with the average for all participants at 97.1% appropriate.

Figure 1: Average Phrasing Scores for All Participants



Rate

Appropriate *Rate* is defined by the authors of the PVSP as two to four syllables per second (p. 27). It is not necessary to time every utterance, but the use of a stopwatch is suggested for “utterances that are suspect for rate” (p. 27). Inappropriate codes for *Rate*

include *PV9: Slow Articulation/Pause Time*, *PV10: Slow/Pause Time*, *PV11: Fast*, and *PV12 Fast/Acceleration*. Utterances coded *PV12: Fast/Acceleration* cannot be judged for *Stress*.

Participant 1. Figure A12 presents the *Rate* scores for participant 1. The average percentage of utterances appropriate in regards to *Rate* placed participant 1 in the borderline category with a score of 82.9%, the lowest average *Rate* score for all participants. Screening 1 was the only screening to receive a score of 100% appropriate utterances. Screening 2 received the lowest score with 60% appropriate utterances. Nine (9) utterances were coded *PV9: Slow Articulation/Pause Time* and one (1) *PV11: Fast*. Screening 3 had seven (7) utterances coded as *PV9: Slow Articulation/Pause Time*. Screening 4 had one (1) *PV9: Slow Articulation/Pause Time* and one (1) *PV11: Fast*. Screening 5 received five (5) *PV9: Slow Articulation/Pause Time* codes. The sixth screening had two (2) *PV9: Slow Articulation/Pause Time* and one (1) *PV11: Fast* codes. Screening 7 presented two (2) *PV9: Slow Articulation/Pause Time* and three (3) *PV10: Slow/Pause Time*. Screening 8 included two (2) codes for *PV9: Slow Articulation/Pause Time*. Overall, slow articulation and/or pause time appeared to be the biggest problem for participant 1.

Participant 2. As indicated in Figure A13, the overall average percent of appropriate utterances for *Rate* for participant 2 was 93.8%, a passing score. Screenings 2, 4 and 5 all received 100% appropriate scores. Screening 1 had two (2) inappropriate utterances, both scored *PV9: Slow Articulation/Pause Time*. Screening 3 had a dramatic drop in scoring with only 72% appropriate utterances. Six (6) utterances were coded as *PV9: Slow Articulation/Pause Time* and one (1) was coded *PV11: Fast*. As with

participant 1, the main concern was slow articulation and/or pause time for participant 2 as well.

Participant 3. Figure A14 shows *Rate* scores for participant 3. The average appropriate utterances score was 88.6%, a borderline score. Screening 4 was the only screening to receive a 100% appropriate score. Screening 1 had one (1) code for *PV11: Fast*. Screening 2 received five (5) codes for *PV11: Fast*. The third screening had one (1) *PV9: Slow Articulation/Pause Time* and one (1) *PV11: Fast* code. The fifth screening showed two (2) codes for *PV9: Slow Articulation/Pause Time* and one (1) for *PV11: Fast*. Screening 5, 6, and 7 each had three (3) *PV9: Slow Articulation/Pause Time* codes. Participant 3 seemed to have mixed problems with both slow and fast rate.

Participant 4. As seen in Figure A15, participant 4 had an average *Rate* score of 88.0%, a borderline score. Screening 1 received a failing *Rate* score with 76% appropriate utterances. Three (3) utterances were coded as *PV9: Slow Articulation/Pause Time* and three (3) utterances were coded as *PV11: Fast*. The second screening had three (3) codes for *PV11: Fast* and one (1) for *PV9: Slow Articulation/Pause Time*. Screening 3 had two (2) codes for *PV11: Fast* and one (1) for *PV9: Slow Articulation/Pause Time*. The remaining screenings all passed with a greater than 90% appropriate utterances score. Screening 4 had only one (1) inappropriate code: *PV9: Slow Articulation/Pause Time*. The fifth screening included one (1) code for *PV11: Fast* and one (1) for *PV12: Fast/Acceleration*. Additional comments also noted that overall rate tended to be slightly fast. Screening 6 received one (1) code for *PV9: Slow Articulation/Pause Time* and one (1) for *PV11: Fast*. Screening 7 had two (2) inappropriate utterances, both coded *PV9:*

Slow Articulation/Pause Time. Again, the overall *Rate* of participant 4 tended to be mixed with both slow and fast rates.

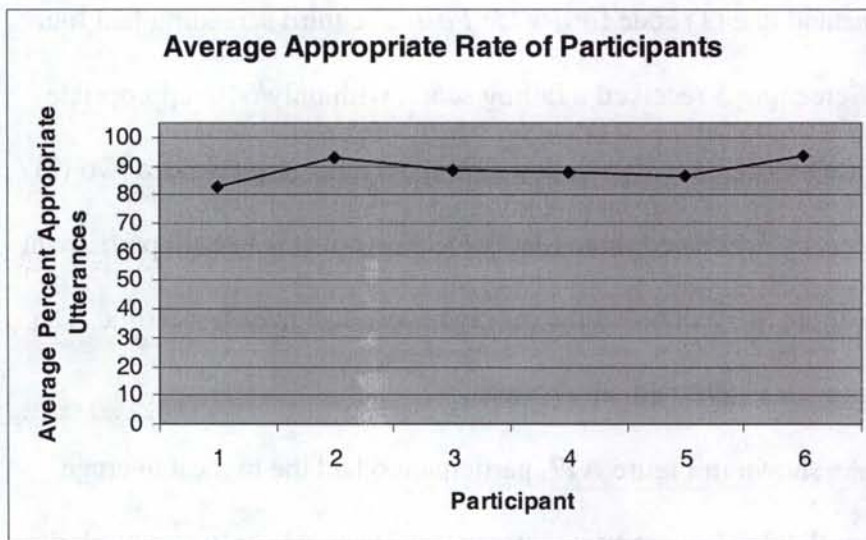
Participant 5. The percentages of appropriate *Rate* for Participant 5 are represented in Figure A16. The average percentage of appropriate utterances in regards to *Rate* for this participant was 86.7%. The first screening received a 100% appropriate utterances score. The next screening yielded one (1) code for *PV9: Slow Articulation/Pause Time* and one (1) code for *PV11: Fast*. The third screening had four (4) *PV11: Fast* codes. Screening 5 received a failing score, with only 64% appropriate utterances. There were nine (9) *PV11: Fast* codes. The sixth screening also had two (2) *PV11: Fast* codes. Screening 7 received three (3) *PV11: Fast* codes. Overall, participant 5 appeared to have a fast rate of speech, but the average score still rates borderline. The scores over time were not consistent with any pattern.

Participant 6. As shown in Figure A17, participant 6 had the highest average appropriate *Rate* score with 93.8% appropriate utterances. There was only one borderline score with all the remaining scores 90% or above. Screening 1 had one (1) code, *PV11: Fast*. Screening 2 received a 100% appropriate score. The third screening also had only one (1) code, *PV9: Slow Articulation/Pause Time*. Screening 4 received the only borderline score with 80% appropriate utterances. There were five (5) codes for *PV11: Fast*. Screenings 5 and 6 each had one (1) utterance coded *PV11: Fast*. Overall, participant 6 appeared to have moments of fast speech, but clearly received a high overall passing score.

All Participants. *Rate* did not appear to be a major concern for all participants (see also Figure 2 below; also shown as Figure A18 in the Appendix). Participants 2 and

6 received an average passing score, while the remaining participants had average borderline scores. Some participants did fail individual screenings, but these same individuals passed other individual screenings with greater than 90% appropriate utterances. The average appropriate score for all participants was 88.8%.

Figure 2: Average Rate Scores for All Participants



Loudness

Inappropriate codes for *Loudness* are *PV17: Soft* and *PV18: Loud*. In order for utterances to be coded for inappropriate *Loudness*, at least 50% of words must be inappropriately soft or loud.

Participant 1. As Figure A19 shows, participant 1 had the highest average percent appropriate score for loudness with a 99% appropriate utterance score. Screenings 1, 2, 3, 5, 7, and 8 all were rated at 100% appropriate for loudness. Screening

4 and 6 each had one inappropriate coding, *PV17: Soft*. *Loudness* was not a problem for participant 1.

Participant 2. Figure A20 indicates that participant 2 had the lowest average appropriate loudness score with 85.6%, but still fell within the borderline range. Participant 2 did fail the *Loudness* portion of the *PVSP* on Screenings 1 and 3 with score of 72% and 76% appropriate utterances respectively. For the first screening, seven (7) utterances were coded as *PV17: Soft*. The third screening, rated one (1) utterance as *PV18: Loud* and five (5) utterances as *PV17: Soft*. Screening 2 was in the borderline range with 84% appropriate utterances and four (4) utterances judged as *PV17: Soft*. Screening 4 was rated as 100% appropriate in relation to *Loudness*. Screening 5 had one (1) inappropriate utterance coded as *PV17: Soft*. Although, on average participant 2 had a borderline score, the participant did fail two screenings due to too soft speech. The scores did, however, appear to increase over time.

Participant 3. As Figure A21 shows, participant 3 failed three (3) of the screenings. Since only 12 utterances were available for coding and three (3) were coded as *PV17: Soft*, the appropriate utterance score was only 75%. However, Screening 2 had twenty-five (25) codable utterances, and the participant still failed on the *Loudness* scale with a score of 68% appropriate utterances. Five (5) utterances were scored as *PV17: Soft*. Screening 3 also shows a failing score with 75% appropriate utterances. Six (6) utterances were rated as *PV17: Soft*. However, not all screenings were failed. In fact, Screenings 4, 6, and 7 received 100% appropriate scores. Screening 5 also received a passing score of 96% appropriate; one (1) utterance was coded as *PV18: Loud*. Screenings 8 was rated as borderline at 80% appropriate; five (5) utterances were coded

as *PV17: Soft*. It appears that participant 3 may have problems with appropriate loudness levels, even though the average score shows a borderline ranking. Overall, speech was rated as too soft. Scores appeared to increase over time and were relatively higher on the final screenings.

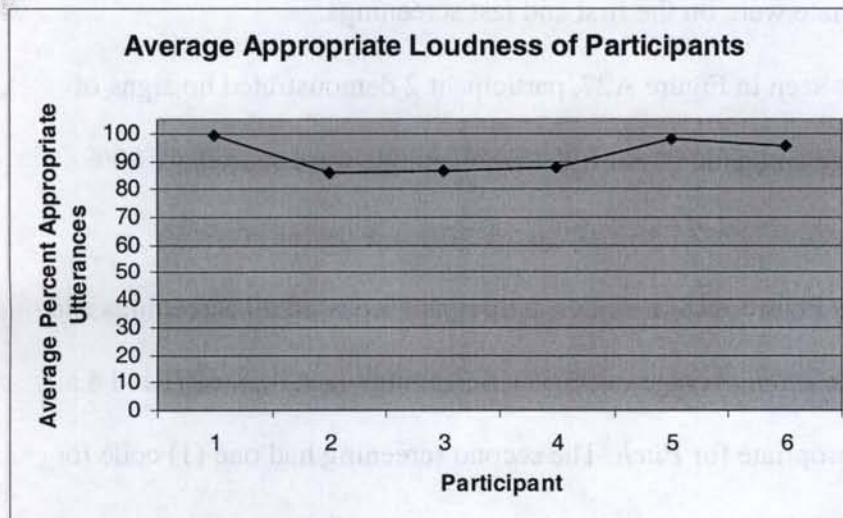
Participant 4. Data for participant 4 are presented in Figure A22. The average appropriate *Loudness* for participant 4 was 88.6%. Although the average score placed the participant in the borderline category, she passed six (6) of the screenings. However, Screening 6 received a failing score with only 56% appropriate utterances. There were nine (9) utterances coded *PV17: Soft* and one (1) utterance coded *PV18: Loud*. The first screening received a passing score of 92% appropriate with two utterances coded *PV17: Soft*. Screening 2 had no inappropriate codes. Screening 3 had one (1) utterance coded *PV17: Soft* and one (1) utterance coded *PV18: Loud*. Screening 4 only had one (1) code for *PV18: Loud*. The fifth screening received two (2) inappropriate codes of *PV18: Loud*. The seventh screening had one (1) *PV17: Soft* and one (1) *PV18: Loud*. Although there appeared to be some mixed loudness issues, the failed screening was due to a too soft voice. The sixth screening appeared to be an outlier with all other screenings receiving passing scores.

Participant 5. As shown in Figure A23, participant 5 passed all screenings with an overall average of 98% appropriate utterances. Screenings 3, 5, 6, and 7 all were scored at 100% appropriate. The first screening had two (2) utterances coded *PV18: Loud*. The second screening had one (1) *PV18: Loud*. *Loudness* was not a problem for participant 5. Although all screenings were passed, the lowest passing scores were received on the first two screenings.

Participant 6. Figure A24 indicates that participant 6 passed all screenings as well. Screenings 1 and 6 all received 100% appropriate utterance scores. The second screening had one (1) utterance coded as *PV18: Loud*. The third, fourth, and fifth screenings each had two (2) *PV18: Loud* codes. The average appropriate utterances score for participant 6 was 95.3%. All screenings were passed with the highest passing scores on the first and last screenings.

All Participants. Figure 3 below (also shown as Figure A25 in the Appendix) shows the average *Loudness* scores for all participants. Using average scores, three (3) of the participants passed the screenings, and three (3) received borderline scores. Several of the screenings were failed by participants, but overall loudness does not appear to be a major concern with the average for all participants at 92.2% appropriate.

Figure 3: Average Loudness Scores for All Participants



Pitch

“Appropriate pitch is defined as being within normal limits for the speaker’s age and gender” (Shriberg, et al., 1990; p.35). *Pitch* must be inappropriate in at least 50% or more of the words in order to be considered inappropriate. The authors consider the general rule to be that the pitch should be coded appropriate if it does not “call attention to itself” (p. 35). Inappropriate *Pitch* codes include *PV19: Low Pitch/Glottal Fry*, *PV20: Low Pitch*, *PV21: High Pitch/Falsetto*, and *PV22: High Pitch*. Utterances coded *PV19: Low Pitch/Glottal Fry* and *PV21: High Pitch/Falsetto* cannot be judged for *Laryngeal Quality*.

Participant 1. As Figure A26 shows, participant 1 demonstrated appropriate *Pitch* for age and gender across all screenings. Screenings 2, 3, 4, 5, 6, and 7 were all scored as 100% appropriate. Screening 1 had one (1) inappropriate code of *PV22: High Pitch*. Screening 8 also had one (1) inappropriate code, but this time it was *PV20: Low Pitch*. The average appropriate *Pitch* score for this participant was 98.9%. The only scores not 100% appropriate were on the first and last screenings.

Participant 2. As seen in Figure A27, participant 2 demonstrated no signs of inappropriate *Pitch* for age and gender. All five (5) screenings were scored at 100% appropriate utterances.

Participant 3. As Figure A28 indicates, participant 3 passed all screenings and had an overall appropriate *Pitch* average of 99.5%. Screenings 1, 3, 4, 5, 6, 7, and 8 all were scored at 100% appropriate for *Pitch*. The second screening had one (1) code for *PV22: High Pitch*.

Participant 4. Figure A29 shows the data for participant 4. The average appropriate *Pitch* score for screenings was 94.9%. The sixth screening was coded as

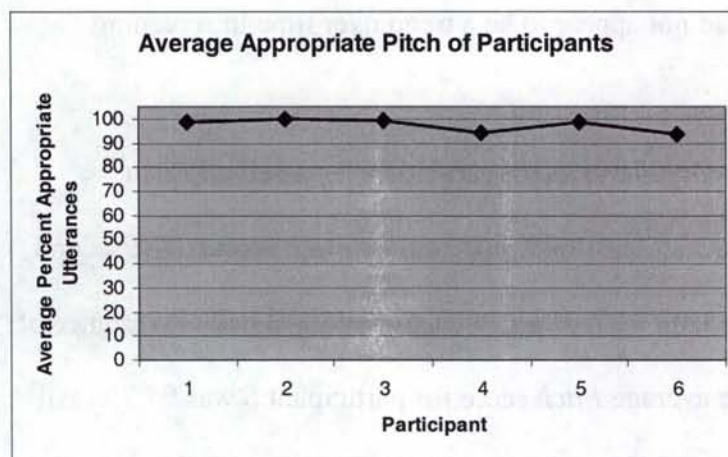
borderline with an 88% appropriate *Pitch* score. There were two (2) utterances coded as *PV19: Low Pitch/Glottal Fry* and one (1) coded as *PV22: High Pitch*. Screenings 2 and 4 had 100% appropriate utterances. The first screening had one (1) code of *PV20: Low Pitch*. The third screening had one (1) *PV19: Low Pitch/Glottal Fry* and one (1) *PV20: Low Pitch*. Screening 5 included two (2) *PV19: Low Pitch/Glottal Fry*, and Screening 7 had one (1) instance of *PV20: Low Pitch*. Almost all the inappropriate codes were for low pitch, but there was one (1) instance of high pitch. Overall, *Pitch* did not appear to be a problem for participant 4. There did not appear to be a trend over time in screening scores.

Participant 5. As indicated by Figure A30, participant 5 passed all *Pitch* screenings. Screenings 1, 3, 5, and 7 all had 100% appropriate *Pitch* scores. The second screening had one (1) utterance coded *PV22: High Pitch*. Screening 3 had (1) instance of *PV19: Low Pitch/Glottal Fry*. The average *Pitch* score for participant 5 was 98.7%. All screenings were passed with little deviation in scores over time.

Participant 6. Figure A31 shows that participant 6 passed five (5) screenings and received a borderline score for (1) screening. Screenings 2, 5, and 6 all were scored at 100% appropriate for *Pitch*. The first and third screenings received two (2) codes for *PV22: High Pitch*. Screening 4 had four (4) instances of *PV22: High Pitch* resulting in a borderline score of 80% appropriate utterances. A note was made by the scorer that the overall perception of the participant's speech was that it was slightly high for speaker's gender, but it was difficult to determine which utterances were clearly too high. The average *Pitch* score for participant 6 was 93.7%. No clear trend in scores emerged over time.

All Participants. Figure 4 below (also shown as Figure A32 in the Appendix) for average appropriate *Pitch* of all participants. Using averages, all participants passed *Pitch* screening. Age and gender for these participants played a large role in distinguishing between normal high pitches and abnormal high pitches. The average *Pitch* for all participants was 97.6%.

Figure 4: Average Pitch Scores for All Participants



Stress

Inappropriate *Stress* codes include: *PV13: Multisyllabic Word Stress*, *PV14:*

Reduced/Equal Stress, *PV15: Excessive/Equal/Misplaced Stress*, and *PV16: Multiple*

Stress Features. Multisyllabic word stress occurs when the speaker uses “primary stress

on a normally unstressed syllable” (Shriberg, et al., 1990; p.30). Reduced/equal stress is

characterized by a reduction of stress in stressed syllables and may sound weak, softer,

with reduced effort and contrastiveness, possible breathiness and nasality, and longer

syllables. Excessive/equal/misplaced stress is characterized by “monostressed speech

characterized by forceful, punctuated stress” (Shriberg, et al., 1990; p.31). This pattern of

stress is associated with increased effort, louder speech, increased contrastiveness, sharp onsets and segment transitions, shorter syllables and possibly more vocal roughness and strain. Of particular note in the current study is that the authors of the PVSP note that those with severe hearing impairments usually present with excessive/equal/misplaced stress (p. 32).

Participant 1. As shown in Figure A33, participant 1 failed seven out of eight of the *Stress* screenings, but the overall average for *Stress* at 51.3% appropriate was the third highest of all participants. The first screening received a 36% appropriate score, and all sixteen (16) errors were coded as *PV15: Excessive/Equal/Misplaced Stress*. The second screening had seven (7) errors coded *PV15: Excessive/Equal/Misplaced Stress* and one (1) coded *PV14: Reduced/Equal Stress*. The third screening had eleven (11) inappropriate utterances coded *PV15: Excessive/Equal/Misplaced Stress* and one (1) coded *PV14: Reduced/Equal Stress*. Screening 4 received nine (9) *PV15: Excessive/Equal/Misplaced Stress* codes. Screening 5 showed a 0% appropriate utterances score for *Stress* with all twenty-five utterances codes as *PV15: Excessive/Equal/Misplaced Stress*. The next screening improved with 64% accurate productions and only eight (8) utterances coded *PV15: Excessive/Equal/Misplaced Stress* and one (1) coded *PV14: Reduced/Equal Stress*. The final screening showed greater improvement with a borderline score of 82% appropriate and only four (4) *PV15: Excessive/Equal/Misplaced Stress* codes. *Stress* was clearly a problem area for participant 1. No clear pattern in scores emerged over time.

Participant 2. Figure A34 shows the *Stress* data for participant 2. Participant 2 was the only one to receive an average borderline score with 82.4% appropriate

utterances. The only screening failed by this participant was Screening 2. The score was 72% appropriate and had seven (7) inappropriate utterances coded as *PV15:*

Excessive/Equal/Misplaced Stress. The first screen had a borderline score of 80% appropriate and received five (5) *PV15: Excessive/Equal/Misplaced Stress* codes.

Screening 3 received a 96% appropriate score, the only passing percentage. One (1) utterance was coded *PV15: Excessive/Equal/Misplaced Stress*. Screening 4 received another borderline score with four (4) *PV15: Excessive/Equal/Misplaced Stress* codes and one (1) *PV14: Reduced/Equal Stress*. The final screening was a borderline score with one (1) utterance coded *PV15: Excessive/Equal/Misplaced Stress* and four (4) coded *PV14: Reduced/Equal Stress*. There was no clear pattern in scores over time.

Participant 3. As indicated in Figure A35, participant 3 failed seven out of eight screenings. At an average of 28.5% appropriate, participant 3 received the second worst percentage of appropriate utterances. With only twelve (12) utterances, the first screening had a failing score with five (5) utterances coded *PV15: Excessive/Equal/Misplaced Stress*. Screening 2 had only 20% appropriate utterances with nineteen (19) *PV15: Excessive/Equal/Misplaced Stress* codes and one (1) *PV14: Reduced/Equal Stress*. Screening 3 had five (5) *PV14: Reduced/Equal Stress* and six (6) *PV15: Excessive/Equal/Misplaced Stress*. Screening 4 at 12% appropriate had twenty-two (22) *PV15: Excessive/Equal/Misplaced Stress* codes. The fifth screening had twenty (20) inappropriate *Stress* codes, all *PV15: Excessive/Equal/Misplaced Stress*. The sixth screening received the lowest score at 0% with all sixteen (16) utterances coded *PV15: Excessive/Equal/Misplaced Stress*. Screening 7 had sixteen (16) *PV15: Excessive/Equal/Misplaced Stress* codes and two (2) *PV14: Reduced/Equal Stress* codes.

The final screening also had sixteen (16) inappropriate *PV15: Excessive/Equal/Misplaced Stress* codes and a score of 36% appropriate. Scores varied greatly with no clear trend over time.

Participant 4. As indicated in Figure A36, participant 4 had the second highest percent appropriate score but still received a failing average with 70.1% appropriate utterances. The first screening had eleven (11) *PV15: Excessive/Equal/Misplaced Stress* codes. Screening 2 was rated borderline at 80% appropriate and five (5) *PV15: Excessive/Equal/Misplaced Stress* codes. Screening 3 had a slightly lower average with six (6) inappropriate *Stress* codes, all *PV15: Excessive/Equal/Misplaced Stress*. Screening 4 and 5 were each coded for seven (7) *PV15: Excessive/Equal/Misplaced Stress* codes. The sixth screening had much lower appropriate scores and fourteen (14) utterances coded *PV15: Excessive/Equal/Misplaced Stress* and one (1) for *PV14: Reduced/Equal Stress*. The final screening received a passing score of 92% appropriate and only two (2) instances of *PV15: Excessive/Equal/Misplaced Stress*. There was variation between scores but no pattern was apparent over time.

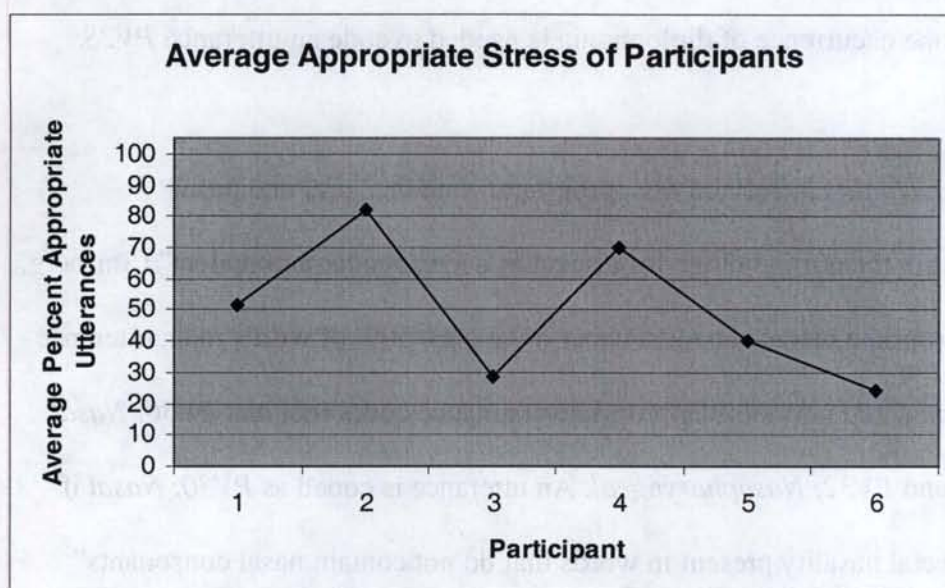
Participant 5. Data for participant 5 is shown in Figure A37. Participant 5 had an average appropriate score of 40%. Nineteen (19) utterances were coded *PV15: Excessive/Equal/Misplaced Stress* in the first screening. The second screening had sixteen (16) inappropriate *PV15: Excessive/Equal/Misplaced Stress* codes. Screening 3 received fifteen (15) codes for *PV15: Excessive/Equal/Misplaced Stress*. The highest percent appropriate score for *Stress* was received on the fifth screening with 60% appropriate utterances and ten (10) codes for *PV15: Excessive/Equal/Misplaced Stress*. Screening 6 was rated at 32% appropriate with seventeen (17) *PV15:*

Excessive/Equal/Misplaced Stress codes. The final screening was also failed with thirteen (13) utterances coded as *PV15: Excessive/Equal/Misplaced Stress*. There was no distinct trend in scores over time.

Participant 6. Data for participant 6 is presented in Figure A38. The average score for participant 6 was the lowest of all participants with a rating of 24.3% appropriate. Out of twenty-one (21) utterances on the first screening, nineteen (19) were coded as *PV15: Excessive/Equal/Misplaced Stress*. Screening 2 only had one (1) appropriate utterance, all the others were rated *PV15: Excessive/Equal/Misplaced Stress*. Nineteen (19) utterances were coded *PV15: Excessive/Equal/Misplaced Stress* in Screening 3. Screening 4 had the second highest appropriate score at 44% and fourteen (14) *PV15: Excessive/Equal/Misplaced Stress* codes. Screening 5 had twenty (20) inappropriate *PV15: Excessive/Equal/Misplaced Stress* codes and one (1) *PV16: Multiple Stress Features*. The final screening received the highest score with 48% appropriate and thirteen (13) utterances coded *PV15: Excessive/Equal/Misplaced Stress*. Scores appeared to increase over time with the exception of Screening 5.

All Participants. See also Figure 5 below (also shown as Figure A39 in the Appendix). No participant passed the *Stress* portion of the *PVSP* based on screening averages. The most frequently occurring error was excessive, equal or misplaced stress. The average score for all participants was 49.4% appropriate.

Figure 5: Average Stress Scores for All Participants



PVSP Voice Quality

Vocal quality is the sixth parameter tested on the *PVSP*. However, it is divided into two subtypes: *Laryngeal Quality* and *Resonance Quality*. Appropriate laryngeal quality is defined by the authors “as vocal characteristics that are within the normal range for the speaker’s age, gender and dialect” (p.37). *Laryngeal Quality* must be appropriate on at least 50% of the words in order to be coded as normal. Inappropriate codes for *Laryngeal Quality* include *PV23: Breathy*, *PV24: Rough*, *PV25: Strained*, *PV26: Break/Shift/Tremulous*, *PV27: Register Break*, *PV28: Diplophonia*, and *PV29: Multiple Laryngeal Features*. *PV24: Rough* “is for voices that are only rough or are both rough and breathy” (p.38). *PV26: Break/Shift/Tremulous* is used when there is any occurrence of a phonation break or pitch shift in an utterance, unless the event occurs on the final, unstressed word due to normal declination patterns. A *Register Break* is defined by the authors of the *PVSP* as “an utterance that contains phonation in both modal and falsetto

registers” (p.39). Diplophonia is “the simultaneous production of two vocal pitches” (p.39), and only one occurrence of diplophonia is needed to code an utterance *PV28*:

Diplophonia.

Resonance Quality is defined as appropriate when the “oral and nasal features...are within the normal range for a speaker’s age, gender and dialect” (Shriberg, et al., p.41). Appropriate resonance must occur on at least 50% of words in an utterance in order to be considered normal. Inappropriate resonance codes include: *PV30: Nasal*, *PV31: Denasal*, and *PV32: Nasopharyngeal*. An utterance is coded as *PV30: Nasal* if there is “nondialectal nasality present in words that do not contain nasal consonants” (p.42), or “abnormal or excessive nasality is present on vowels and diphthongs in assimilative nasal contexts” (p.42). Denasal speech is defined by the “lack of normal nasal resonance on vowels and diphthongs” (p.42), including assimilative contexts where nasality is appropriate. Nasopharyngeal is described as “back of the throat” (p.43) resonance that includes both nasal and denasal resonance and is commonly associated with hearing impaired speech (p.43).

Laryngeal Quality

Participant 1. See Figure A40 for data on *Laryngeal Quality* for participant 1, who received an average 84.9% appropriate on all screenings. Screening 1 had only one (1) inappropriate *Laryngeal Quality* code of *PV26: Break/Shift/Tremulous*. Screening 2, however, had fifteen (15) utterances coded as *PV24: Rough* and one (1) utterance coded *PV29: Multiple Laryngeal Features* and a score of 36% appropriate. Screening 3 also had a failing score with five (5) *PV24: Rough*, one (1) *PV23: Breathy*, and one (1) *PV29: Multiple Laryngeal Features* codes. Two (2) *PV26: Break/Shift/Tremulous* codes

appeared on Screening 4, and one (1) on Screening 5. Laryngeal codes *PV24: Rough* and *PV25: Strained* were each used once (1) in determining appropriate quality for Screening 6. Screening 7 had no inappropriate codes for *Laryngeal Quality*. *PV26: Break/Shift/Tremulous* was coded once (1) in Screening 8. If Screening 1 is excluded, there is a significant increase in scores over time.

Participant 2. As Figure A41 depicts, participant 2 passed the *Laryngeal Quality* screenings with an average of 96.8% utterances appropriate. Screening 1 had two (2) inappropriate utterances, one (1) *PV23: Breathy* and one (1) *PV25: Strained*. Screenings 2 and 3 had one (1) *PV26: Break/Shift/Tremulous* code. Screenings 4 and 5 were 100% appropriate for *Laryngeal Quality*. There is little variation between scores, but there does appear to be a small increase over time.

Participant 3. The average *Laryngeal Quality* for participant 3 was 94% appropriate, as Figure A42 shows. There was one (1) utterance coded *PV24: Rough* in Screening 1. Screenings 2, 3 and 7 were rated as 100% appropriate in regards to *Laryngeal Quality*. The fourth screening had four (4) inappropriate *PV26: Break/Shift/Tremulous* codes and a score of 84% appropriate. Screening 5 was coded for one (1) *PV25: Strained*, and the sixth and eighth screenings each received two (2) codes for *PV26: Break/Shift/Tremulous*. There is no general trend in scores over time.

Participant 4. Figure A43 shows the scores of each screening for participant 4. Overall, participant 4 passed the screening with an average of 92% appropriate utterances. Screening 1 had one (1) code for *PV26: Break/Shift/Tremulous* and one (1) code for *PV29: Multiple Laryngeal Features* of both rough and strained *Laryngeal Quality*. Screening 2 was coded for four (4) *PV26: Break/Shift/Tremulous* events. The

third and fourth screenings had no instances of inappropriate utterances. *PV24: Rough* occurred once (1) during the fifth screening. There were two (2) instances of *PV25: Strained*, one (1) *PV23: Breathy*, and one (1) *PV24: Rough* on Screening 6. Screening 7 had two (2) codes for *PV24: Rough* and one (1) *PV26: Break/Shift/Tremulous*. There does not appear to be a pattern in scores over time for participant 4.

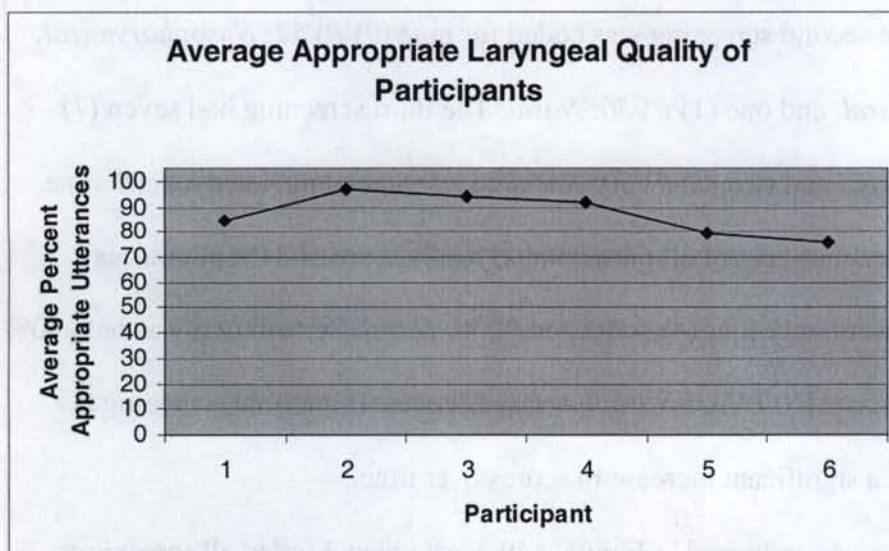
Participant 5. Figure A44 shows scores for participant 5. Participant 5 received an overall average failing score with 79.8% appropriate utterances. The first screening was coded for one (1) *PV24: Rough*, two (2) *PV25: Strained*, and six (6) *PV26: Break/Shift/Tremulous* and received a failing rating of 64% appropriate. Screening 2 also was given a failing score of 68% appropriate and had seven (7) instances of *PV26: Break/Shift/Tremulous* and one (1) *PV25: Strained*. Screening 3 presented four (4) occurrences of *PV26: Break/Shift/Tremulous*. The fourth screening had three (3) *PV26: Break/Shift/Tremulous* codes and one (1) *PV25: Strained* code. The fifth screening received four (4) codes for *PV26: Break/Shift/Tremulous* and one (1) code for *PV24: Rough*. The final screening had no instances of inappropriate utterances in relation to *Laryngeal Quality*. Concerning *Laryngeal Quality*, there is an increase in scores over time for participant 5.

Participant 6. As indicated by Figure A45, participant 6 received the lowest scores for *Laryngeal Quality* with an average score of 75.8% appropriate utterances. The first four screenings were all failed, but the last one received a score of 100% appropriate. The first screening had seven (7) events of *PV26: Break/Shift/Tremulous*. Screening 2 had the lowest score with only 44% appropriate. The screening received six (6) codes for *PV24: Rough*, seven (7) codes for *PV26: Break/Shift/Tremulous*, and one (1) code for

PV29: Multiple Laryngeal Features for rough and break/shift/tremulous quality. Four (4) utterances were coded as *PV26: Break/Shift/Tremulous* and two (2) as *PV24: Rough* on Screening 3. Screening 4 had one (1) *PV24: Rough*, two (2) *PV25: Strained*, two (2) instances of *PV26: Break/Shift/Tremulous*, and one (1) *PV29: Multiple Laryngeal Features* for rough, strained, and break/shift/tremulous quality. The fifth screening had one (1) code for *PV25: Strained* and one (1) for *PV26: Break/Shift/Tremulous*. Screening 6 received a score of 100% appropriate on all utterances. If the outlier is removed, there is a significant increase in scores over time regarding *Laryngeal Quality*.

All Participants. See also Figure 6 below (also shown as Figure A46 in the Appendix). The overall average appropriate score for all participants on screenings was 87.2%. Two (2) participants failed the screenings, one (1) received a borderline score, and three (3) passed with 90% or above appropriate utterances.

Figure 6: Average Laryngeal Quality Scores for All Participants



Resonance Quality

Participant 1. Figure A47 shows screening scores for participant 1. Participant 1 failed all screenings and received an average score of only 1% appropriate utterances.

Screenings 1 and 2 received twenty-four (24) *PV32: Nasopharyngeal* codes. The third screening twenty-four (24) codes for *PV32: Nasopharyngeal* and one (1) code for *PV30: Nasal*. All twenty-five (25) utterances in Screening 4 and 5 were coded inappropriate as *PV32: Nasopharyngeal*. The sixth screening had sixteen (16) codes for *PV32: Nasopharyngeal*, eight (8) for *PV30: Nasal*, and one (1) for *PV31: Denasal*. Screening 7 received twenty (20) *PV32: Nasopharyngeal*, four (4) *PV30: Nasal*, and one (1) *PV31: Denasal* codes. Screening 8 had sixteen (16) codes for *PV30: Nasal*, five (5) *PV32: Nasopharyngeal*, and one (1) *PV31: Denasal*. Scores did not appear to change over time.

Participant 2. Participant 2 had the highest average *Resonance Quality* as seen in Figure A48. The average percentage of appropriate utterances for *Resonance Quality* was 54.4%. Screening 1 had fourteen (14) codes for *PV32: Nasopharyngeal* and three (3) for *PV31: Denasal*. The second screening was coded for nine (9) *PV32: Nasopharyngeal*, two (2) *PV31: Denasal*, and one (1) *PV30: Nasal*. The third screening had seven (7) *PV32: Nasopharyngeal* and two (2) *PV30: Nasal* codes. Screening 4 had a borderline score, the only borderline score of all participants, with a score of 84% utterances appropriate. There were only four (4) codes for *PV30: Nasal*. Screening 5 was only 40% appropriate with fifteen (15) *PV32: Nasopharyngeal* codes. If the final screening is removed, there was a significant increase in scores over time.

Participant 3. As indicated in Figure A49, participant 3 failed all screenings; none of the utterances produced were rated as appropriate (i.e., average of 0%

appropriate). All twelve (12) utterances in Screening 1 were coded *PV32: Nasopharyngeal*. Twenty-four (24) utterances in Screening 2 were coded *PV32: Nasopharyngeal* and one (1) *PV31: Denasal*. All twenty-four (24) utterances in Screening 3 were coded as *PV32: Nasopharyngeal*. Screening 4 received twenty-three (23) *PV32: Nasopharyngeal* codes and two (2) *PV30: Nasal*. All twenty-five (25) utterances in Screening 5 were coded *PV32: Nasopharyngeal*. In the sixth screening, out of sixteen (16) utterances, fifteen (15) were coded *PV32: Nasopharyngeal* and one (1) *PV30: Denasal*. In Screening 7, all twenty-five (25) utterances were coded *PV32: Nasopharyngeal*. The final screening was coded for twenty-one (21) *PV32: Nasopharyngeal*, two (2) *PV31: Denasal*, and two (2) *PV30: Nasal* codes.

Participant 4. Figure A50 shows the scores for participant 4. She received all failing scores and an average of 13.9% appropriate utterances. Screening 1 had twenty-five (25) codes for *PV32: Nasopharyngeal*. Screening 2 had twenty (20) utterances coded *PV32: Nasopharyngeal*, three (3) *PV30: Nasal*, and two (2) *PV31: Denasal*. Screening 3 had nineteen (19) utterances coded *PV32: Nasopharyngeal* and three (3) *PV31: Denasal*. The fourth screening was coded for nine (9) *PV32: Nasopharyngeal*, eight (8) *PV31: Denasal*, and three (3) *PV30: Nasal*. All twenty-three (23) codable utterances in Screening 5 were coded as *PV32: Nasopharyngeal*. Twelve (12) utterances were coded *PV32: Nasopharyngeal* and seven (7) as *PV31: Denasal* in Screening 6. The seventh screening was scored at 60% appropriate with six (6) codes for *PV31: Denasal* and four (4) *PV32: Nasopharyngeal*. There was a weak trend for scores to increase over time.

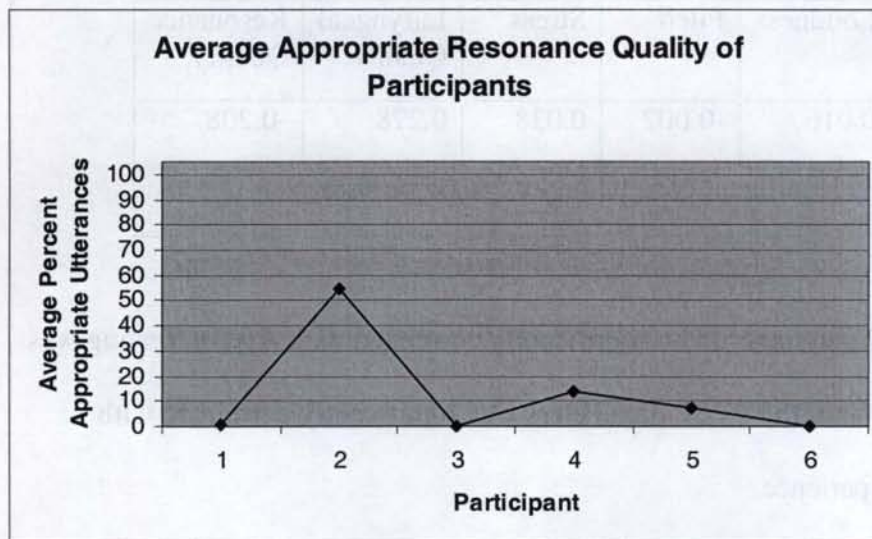
Participant 5. Figure A51 shows screening scores for participant 5. The average for all screenings was 7.3% appropriate utterances. All twenty-five (25) utterances were

coded *PV32: Nasopharyngeal* in Screenings 1 and 3. Twenty-two (22) utterances were coded *PV32: Nasopharyngeal* and two (2) *PV30: Nasal* in Screening 2. Screening 5 received fifteen (15) codes for *PV32: Nasopharyngeal*, four (4) for *PV31: Denasal*, and two (2) for *PV30: Nasal*. The sixth screening had sixteen (16) codes for *PV32: Nasopharyngeal*, six (6) *PV31: Denasal*, and two (2) for *PV30: Nasal*. The final screening received nineteen (19) *PV32: Nasopharyngeal*, one (1) *PV31: Denasal*, and one (1) *PV30: Nasal* codes. There was no clear trend in scores over time concerning *Resonance Quality*.

Participant 6. As shown in Figure A52, participant 6 received failing scores for all screening; as with participant 3 none of the utterances were rated as appropriate. Eighteen (18) utterances were coded *PV32: Nasopharyngeal* and three (3) were coded *PV31: Denasal*. All utterances in Screenings 2, 3 and 5 were coded *PV32: Nasopharyngeal*. The fourth screening received twenty-three (23) codes for *PV32: Nasopharyngeal*, one (1) *PV31: Denasal*, and one (1) *PV30: Nasal*. Screening 6 had twenty-three (23) codes for *PV32: Nasopharyngeal* and two (2) for *PV30: Nasal*.

All Participants. See also Figure 7 below (also shown as Figure A53 in the Appendix). All participants received failing average *Resonance Quality* scores. The average for all participants was 12.8% appropriate utterances. The most common inappropriate code was *PV32: Nasopharyngeal*.

Figure 7: Average Resonance Quality Scores for All Participants



Correlations

In addition to examining individual trends in the data and overall averages on each of the PVSP parameters, values for each parameter were correlated with age at testing and amount of implant experience. Findings for these correlations are shown in Tables 2-3 below.

Table 2: Correlations between PVSP Parameters and Age at Testing.

Phrasing	Rate	Loudness	Pitch	Stress	Laryngeal Quality	Resonance Quality
-0.149	-0.159	-0.036	0.211	-0.018	0.312*	-0.178
* indicates a statistically significant correlation ($p = 0.05$ or less)						

Table 3: Correlations between PVSP Parameters and Amount of Implant Experience

Phrasing	Rate	Loudness	Pitch	Stress	Laryngeal Quality	Resonance Quality
-0.248	-0.131	0.016	-0.002	0.038	0.278	-0.208
* indicates a statistically significant correlation ($p = 0.05$ or less)						

The only PVSP parameter to be significantly correlated with Age of Testing was Laryngeal Quality. None of the PVSP parameters was significantly correlated with Amount of Implant Experience.

Discussion

The primary aim of this investigation was to provide a descriptive analysis of the prosody and voice characteristics of children with severe-profound hearing impairments who have been fitted with cochlear implants. Using the Prosody-Voice Screening Profile (PVSP), forty (40) speech samples were screened for phrasing, rate, stress, loudness, pitch, laryngeal quality, and resonance quality. When comparing the speech samples for each participant, there appears to be little change in screening scores over time for each parameter. In other words prosody and voice performance was relatively stable over the period of the study for these six children.

However, evidence from this study does suggest that the prosody and voice characteristics of children with cochlear implants may differ from what has previously been described as typical deaf speech. All six children received passing scores for phrasing and pitch. For rate and loudness, all six children received at least borderline scores. For laryngeal quality, three children received passing scores, one received a borderline score, and two failed. For stress and resonance quality, all six children received failing scores. These findings are only partially consistent with previous descriptions of the prosody and voice of the hearing impaired who have not had the benefit of cochlear implants.

Stress and resonance are typical problem areas for individuals with hearing impairment (Hargrove, 1997; Nickerson, 1975), which is supported by the findings of this study. There does not appear to have been any previous evaluation of phrasing in the speech of the hearing impaired; findings from this study provide evidence that phrasing may not be a problem for this population. Findings obtained in the current study for

loudness and laryngeal quality appear to be somewhat consistent with previous research (i.e., many children with severe-profound hearing impairment may produce speech that is too soft, too loud, or of varying loudness levels; Smith, 1975). Some utterances in the samples for the current study appeared to have inappropriate loudness levels, but overall loudness was not a problem. Relative to laryngeal quality, previous research suggests that some children with severe-profound hearing impairment have a harsh, breathy, or rough voice with pitch breaks (Calvert & Silverman, 1983; Thomas-Kersting & Casteel, 1989). The current study provides evidence that some children with cochlear implants may have occasional problems with pitch breaks, breathy, harsh, or rough voice quality. However, this was not evident for all of the participants. Pitch, which in previous studies was considered a major problem for the hearing impaired (McGarr & Osberger, 1978; Monsen, 1978), was not a problem for any of the participants in the current study.

Correlational analysis suggested that laryngeal quality improves with age in children fitted with cochlear implants. However, the size of the correlation (.314) was relatively small. Combined with no significant correlation between age and the other PVSP parameters, this suggests that much of what these children need to learn about controlling prosody and voice may already have been learned by the beginning of the study. Recall that all of the participants had at least 18 months of experience with their implants by the time the first samples were obtained. Amount of implant experience did not prove to be significantly correlated with any of the PVSP parameters, so it may not play a role in prosody and voice production. It is of course quite possible that, as with age at testing, the lack of correlation may reflect the fact that these children had already mastered these aspects of prosody and voice before the first samples were obtained.

It was the current author's subjective impression while listening to these samples that the speech of these cochlear implant recipients is quantitatively different from typical hearing impaired speech. Stress and resonance quality were not as severe as typical hearing impaired speech. Phrasing, rate, and loudness in most samples did not sound abnormal from the speech of normal hearing individuals. Pitch, which has been a main problem area for speakers with severe-profound hearing impairment, did not sound deviant from the speech of normal hearing peers. Findings from this study support this suggestion. It would appear that even if cochlear implants do not result in fully normal speech, cochlear implants provide significant benefits to children with hearing impairment in terms of improving prosody and voice characteristics of their speech.

Clinical Implications

The Prosody-Voice Screening Profile was originally developed as a research tool, but may have some applications in the clinical setting. For clinicians looking for a more thorough, highly structured, descriptive method to analyze prosody and voice in conversational speech samples than is possible with the often-used 1-10 rating scales, the PVSP would be an excellent assessment tool. However, it may not be realistic or practical for every clinician to use the PVSP for every assessment. The PVSP requires fairly rigorous training with rather constant revisits to the text and training tapes before one can even begin using it for screening purposes. Although the authors state that "coding procedure requires 15-30 minutes" (p. vii), this may not take into account the initial glossing of utterances. It is the experience of the investigator that a single coding procedure generally takes between 25-60 minutes. Speech samples with a high number of

unintelligible utterances and/or many inappropriate suprasegmentals will naturally take longer to code than appropriate, highly intelligible samples.

In regards to clinical implications of the actual prosody and voice results for this sample population, it appears that new speech goals may be needed for prelingually deaf children who have been fitted with cochlear implants. The ultimate goal of any speech or language intervention is natural sounding speech. Previously, it has been assumed that natural sounding speech for children with severe-profound hearing impairment was an unrealistic goal. However, given this limited sample, the prosody and voice characteristics of children who have been implanted with cochlear implants may actually approximate the prosody and voice characteristics of normal sounding speech. Those two areas which posed a concern for these participants, stress and resonance quality, may prove to be appropriate starting points for prosody and voice intervention.

Implications for Future Research

For this study, only participants who had been previously been fitted with cochlear implants were used. One recommendation resulting from this study would be the addition of participants with severe-profound hearing impairment who are not implanted with cochlear devices but who use hearing aids. Comparisons between the two groups would provide more descriptive analysis as to possible prosody and voice differences between hearing aid users and cochlear implant users and to any improvements that cochlear implants may provide.

Another recommendation would be to include overall subjective impressions of the participants' speech. An additional study could combine speech samples from normal hearing speakers, speakers with severe-profound hearing impairment who use hearing

aids, and speakers with severe-profound hearing impairment who have been fitted with cochlear implants. Trained listeners, such as speech-language pathologists, could listen to the different samples and attempt to categorize which speech sample belongs to each of the three groups. This same study could also be repeated with inexperienced listeners. These perceptual impressions may provide additional support for the possible benefits that cochlear implants provide, as well as provide a spectrum of speech impressions for the three groups.

One area in speech analysis that the PVSP does not excel in is determining severity of involvement. Two participants may each receive the same failing score for resonance quality, but one may demonstrate a more severe nasal resonance. It would be interesting to note the correlation (if any) between perceptual severity ratings for each of the failed screenings and the actual percentage appropriate utterances. It may be that even though a child does not show improvement in the actual percentage appropriate utterances, he/she does show improvement in severity rating scores over time.

✓ A final suggestion would be to repeat this same study, only with a much larger sample size. With a sample of only six children, it is difficult to make inferences about the entire population. A larger number of participants are needed to make more accurate inferences concerning the speech and voice characteristics of children with cochlear implants. The sample, if possible, should be separated into four groups based on gender, age of implantation, amount of implant experience, and PPVT-III scores (or another measure of language skill).

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Prosody-Voice Screening Profile (PVSP) Scoring Form

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Exclusion Codes

Prosody-Voice Codes

Voice

Loudness		Pitch		Quality	
				Laryngeal Features	Resonance Features
1 Appropriate	_____	1 Appropriate	_____	1 Appropriate	_____
17 Soft	_____	19 Low Pitch/Glotal Fry	_____	23 Breathily	30 Nasal
18 Loud	_____	20 Low Pitch	_____	24 Rough	31 Denasal
		21 High Pitch/Falsetto	_____	25 Strained	32 Nasopharyngeal
		22 High Pitch	_____	26 Break/Shift/Tremulous	
				27 Register Break	
				28 Diplophonia	
				29 Multiple Laryngeal Features	

Sequential Utterance Log

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100

Comments

[illegible]

Recommendations

This is a blank sheet of white paper with horizontal blue or grey ruling lines. The lines are evenly spaced and run across the width of the page. There is a vertical margin line on the left side, creating a narrow left margin. The paper appears to be from a notebook or a standard ruled document.

Figure A5: Phrasing Scores for Participant 1

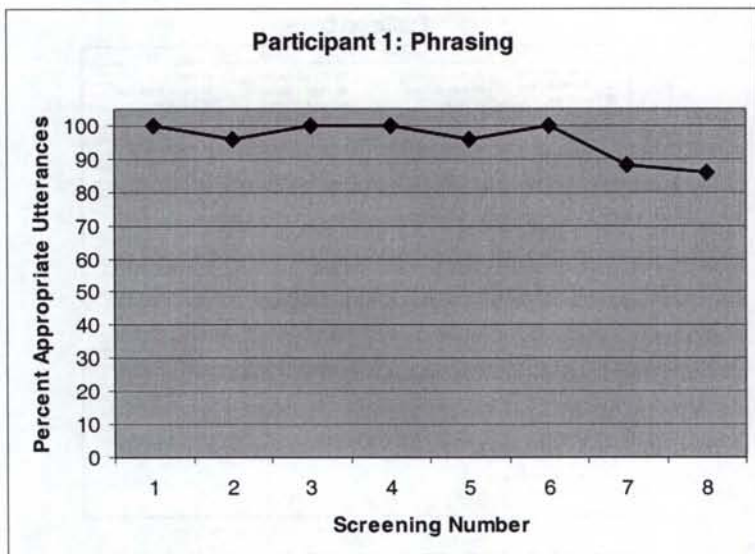


Figure A6: Phrasing Scores for Participant 2

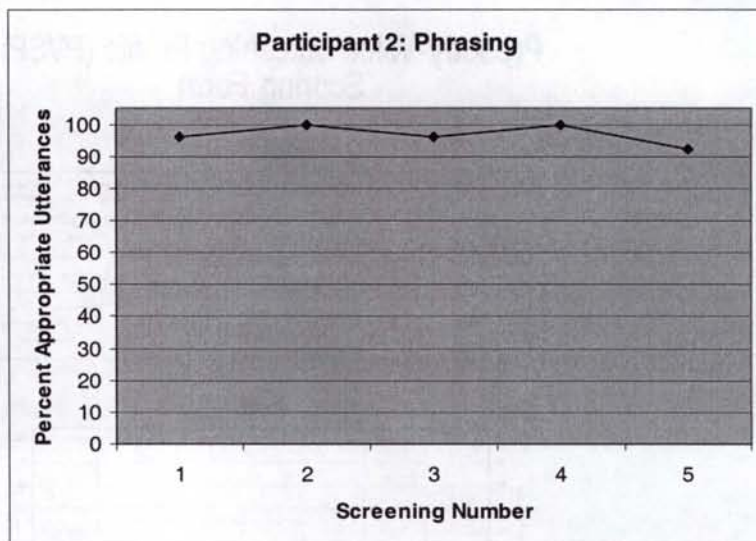


Figure A7: Phrasing Scores for Participant 3

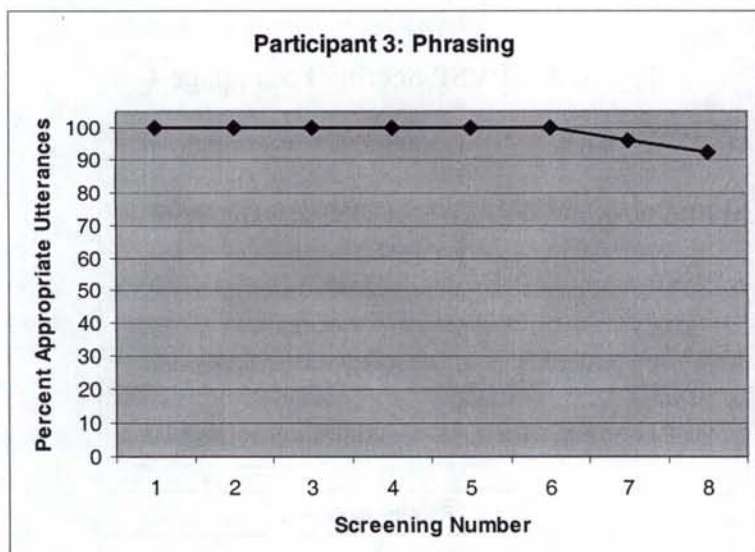


Figure A8: Phrasing Scores for Participant 4

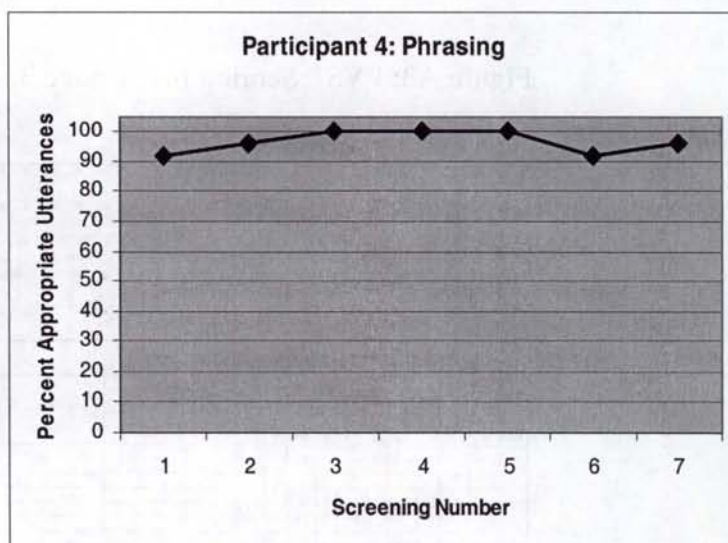


Figure A9: Phrasing Scores for Participant 5

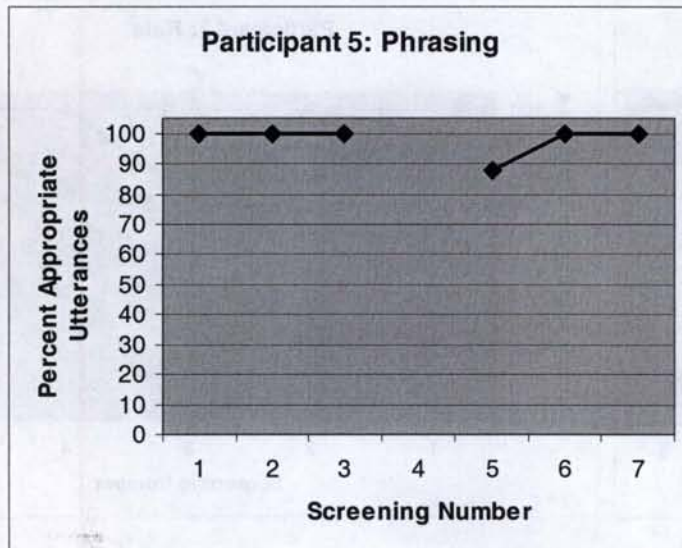


Figure A10: Phrasing Scores for Participant 6

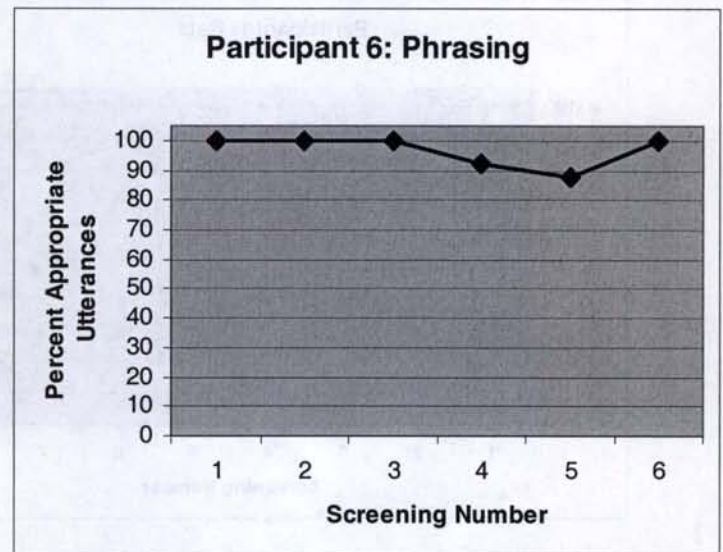


Figure A11: Average Phrasing Scores for All Participants

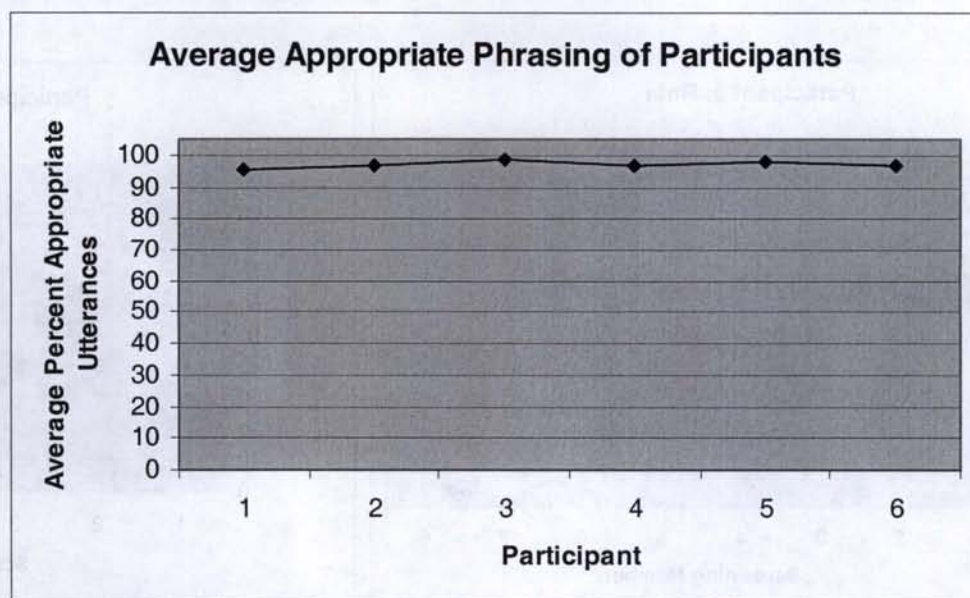


Figure A12: Rate Scores for Participant 1

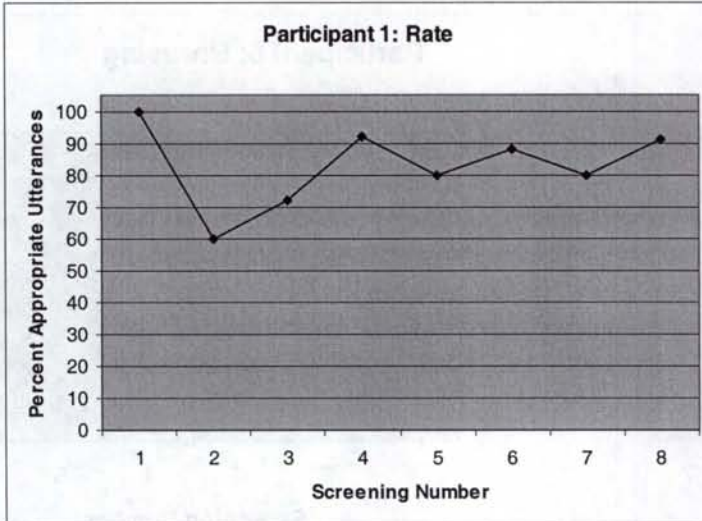


Figure A13: Rate Scores for Participant 2

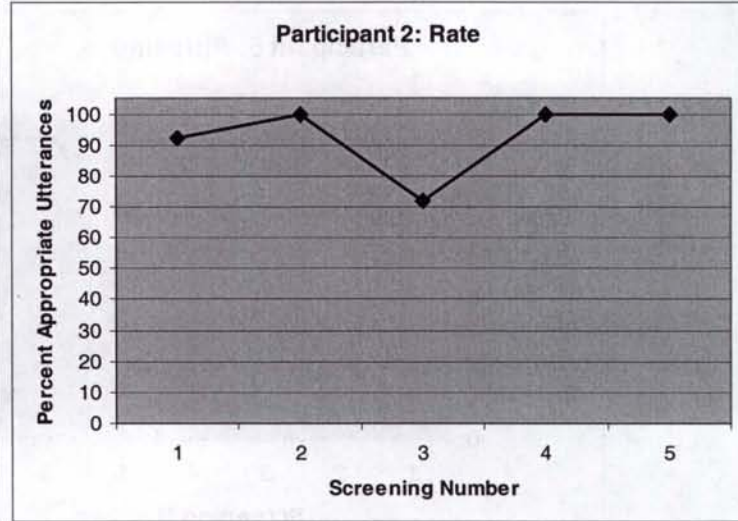


Figure A14: Rate Scores for Participant 3

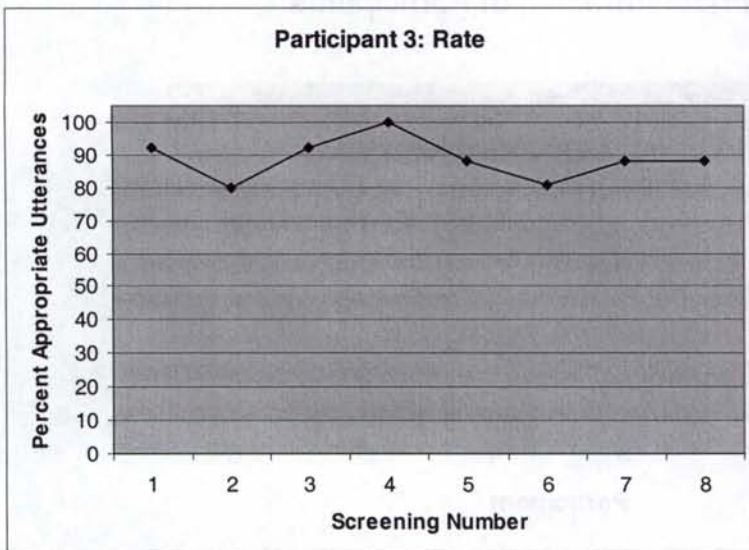


Figure A15: Rate Scores for Participant 4

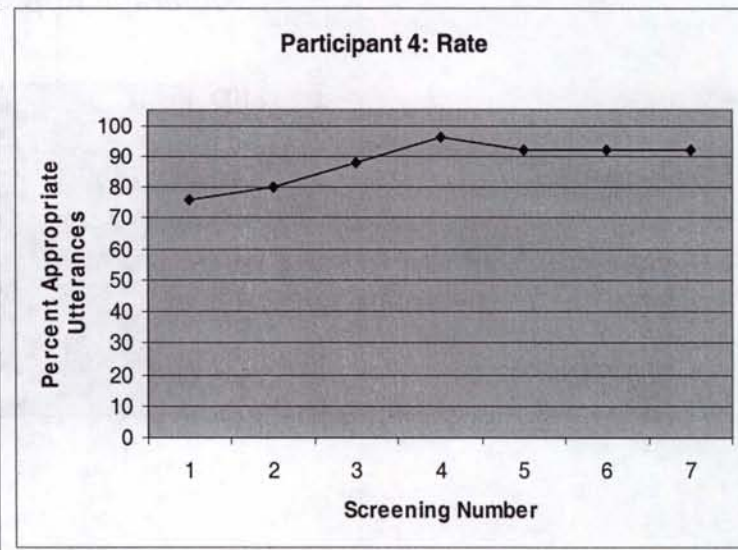


Figure A16: Rate Scores for Participant 5

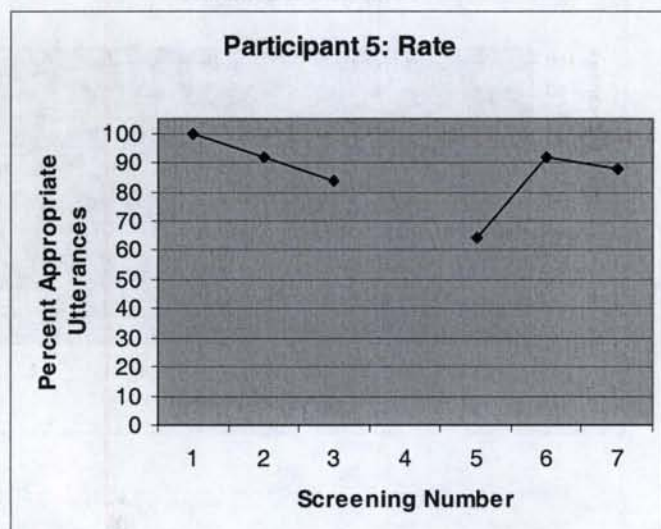


Figure A17: Rate Scores for Participant 6

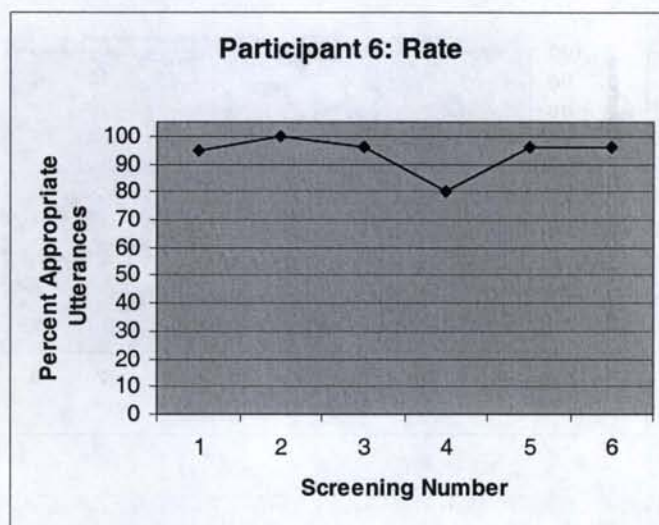


Figure A18: Average Rate Scores for All Participants

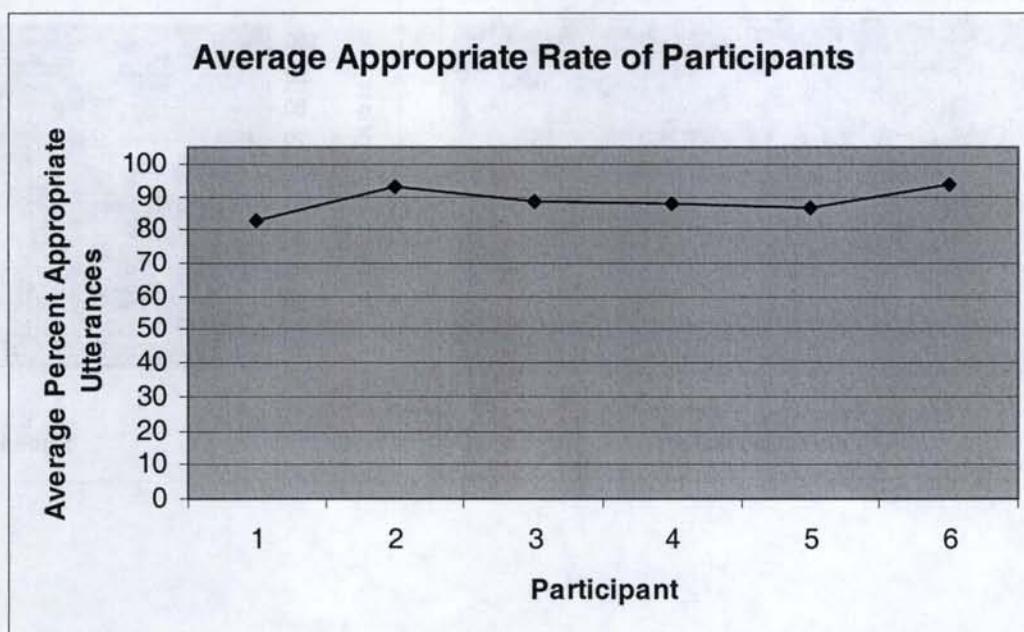


Figure A19: Loudness Scores for Participant 1

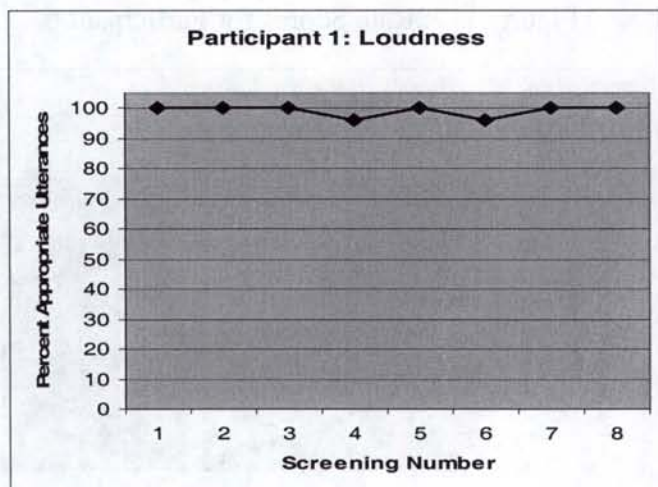


Figure A20: Loudness Scores for Participant 2

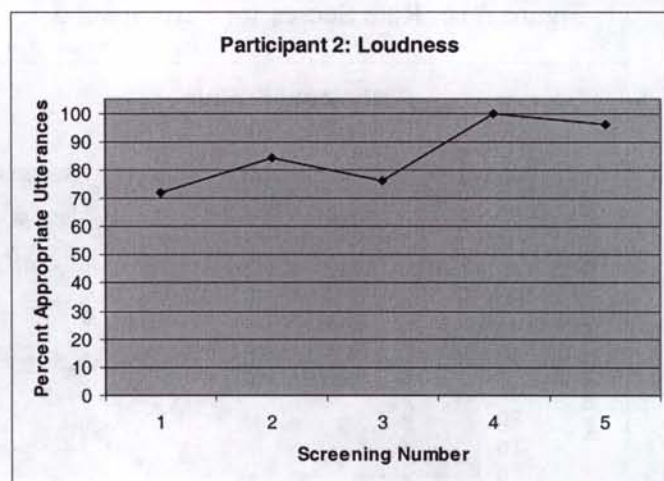


Figure A21: Loudness Scores for Participant 3

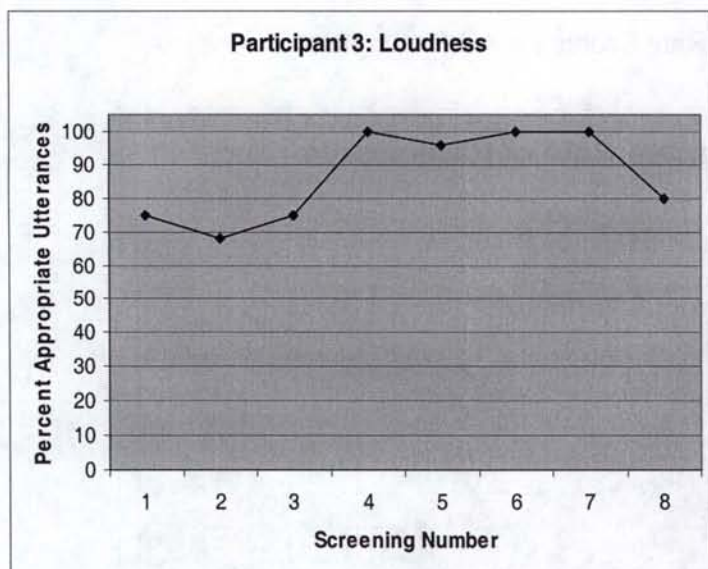


Figure A22: Loudness Scores for Participant 4

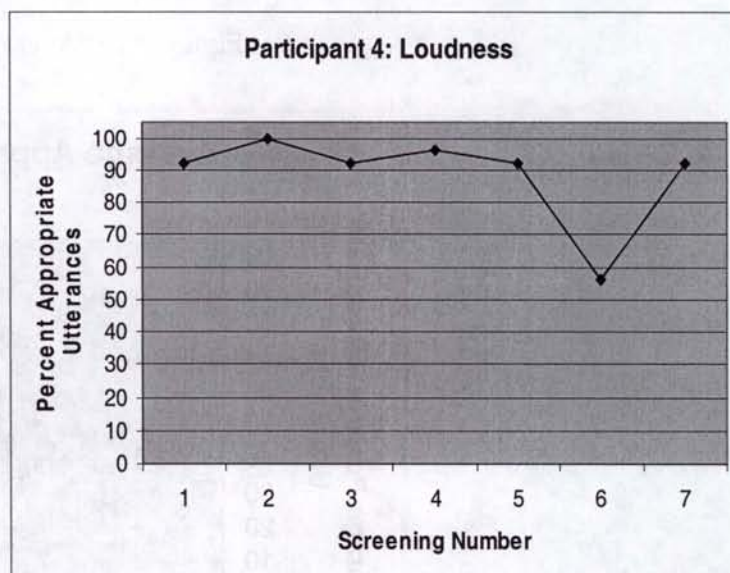


Figure A23: Loudness Scores for Participant 5

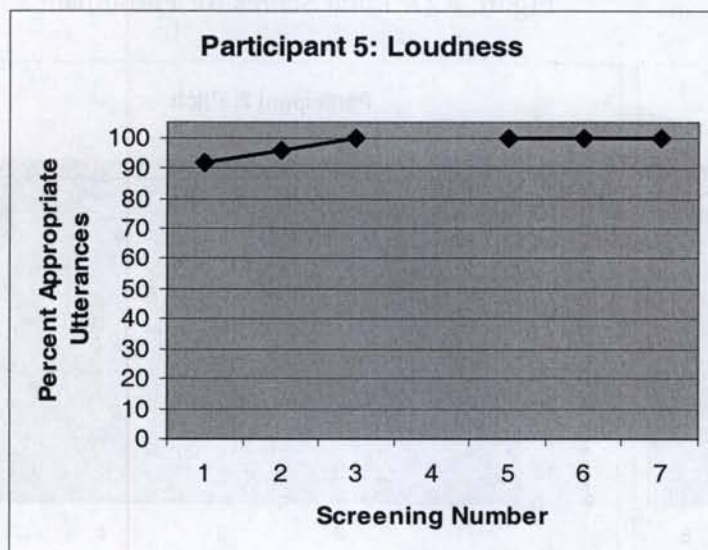


Figure A24: Loudness Scores for Participant 6

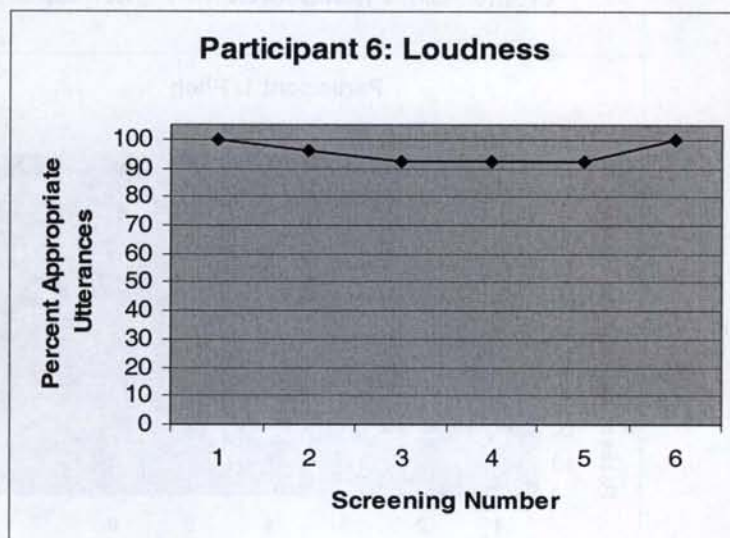


Figure A25: Average Loudness Scores for All Participants

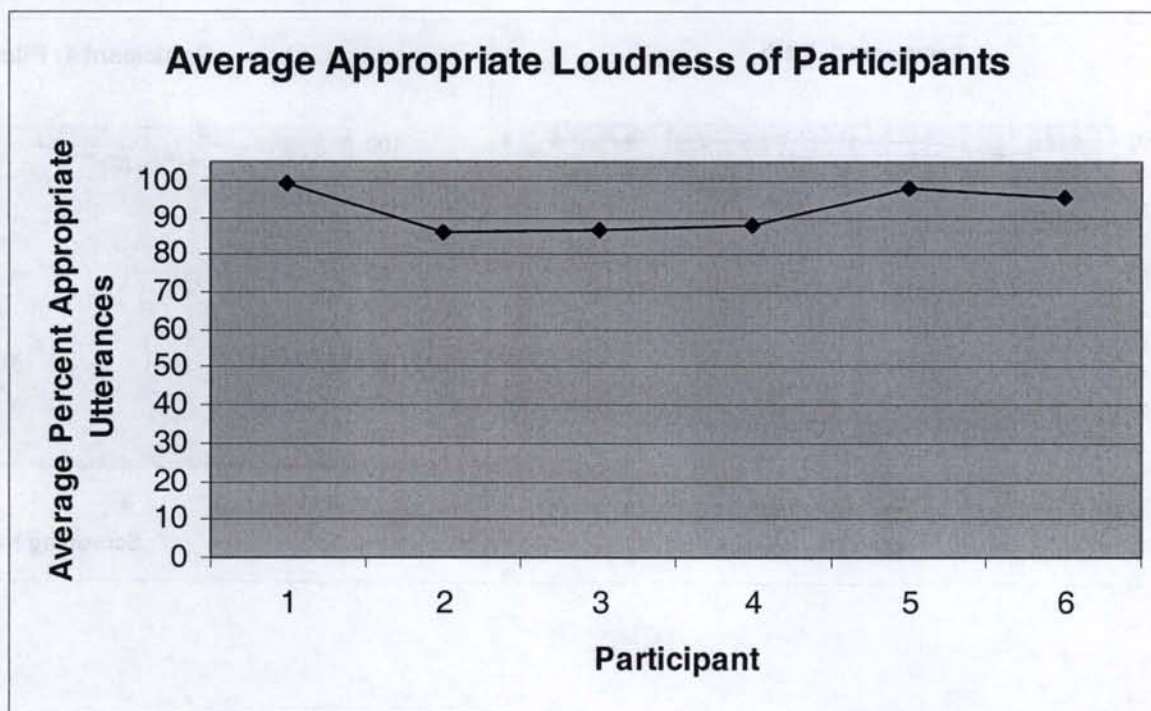


Figure A26: Pitch Scores for Participant 1

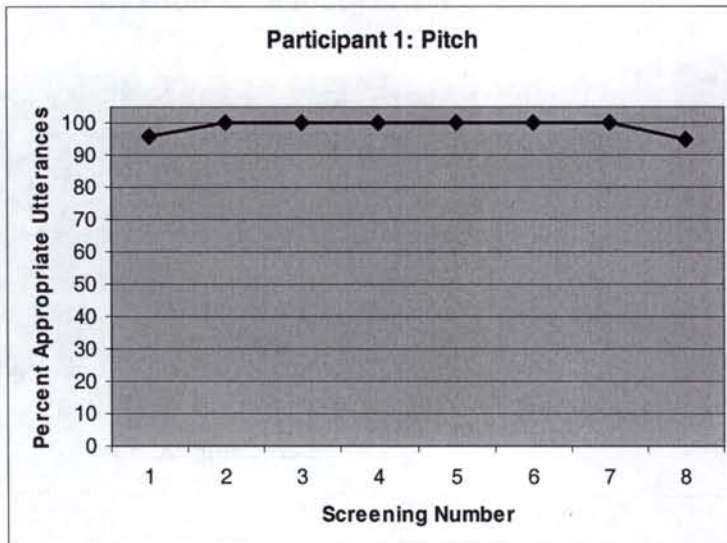


Figure A27: Pitch Scores for Participant 2

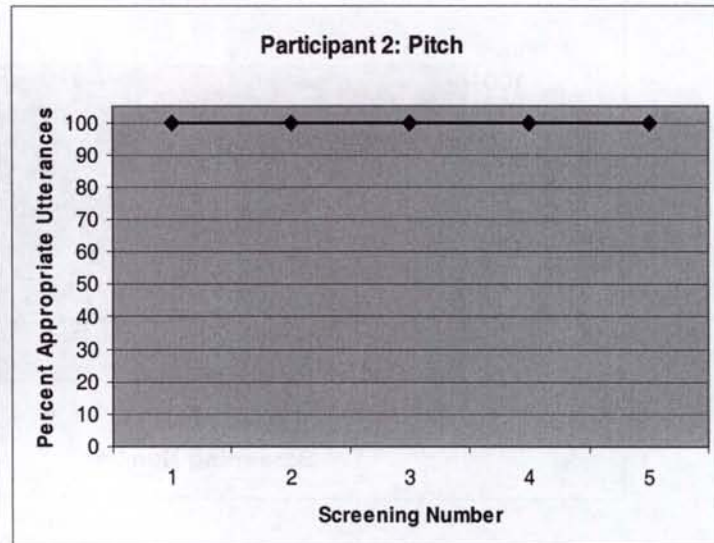


Figure A28: Pitch Scores for Participant 3

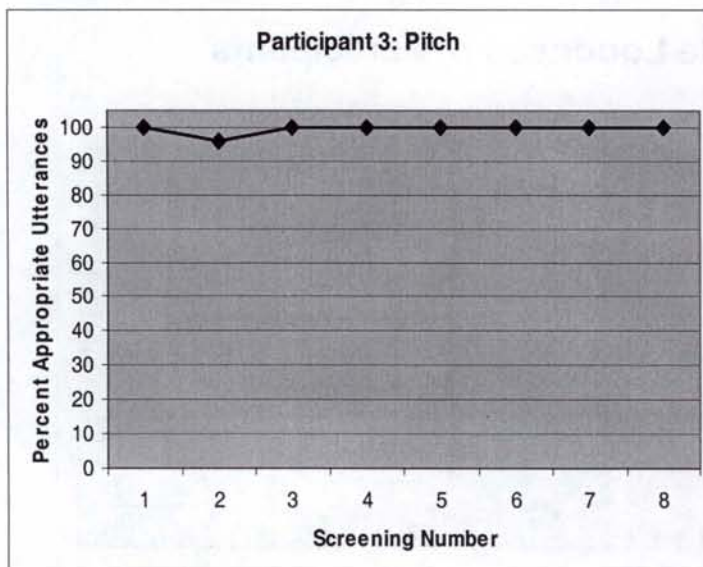


Figure A29: Pitch Scores for Participant 4

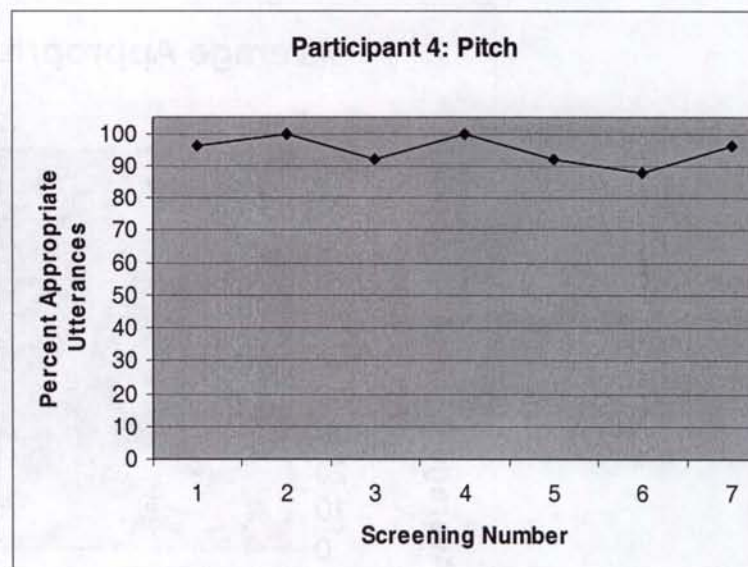


Figure A30: Pitch Scores for Participant 5

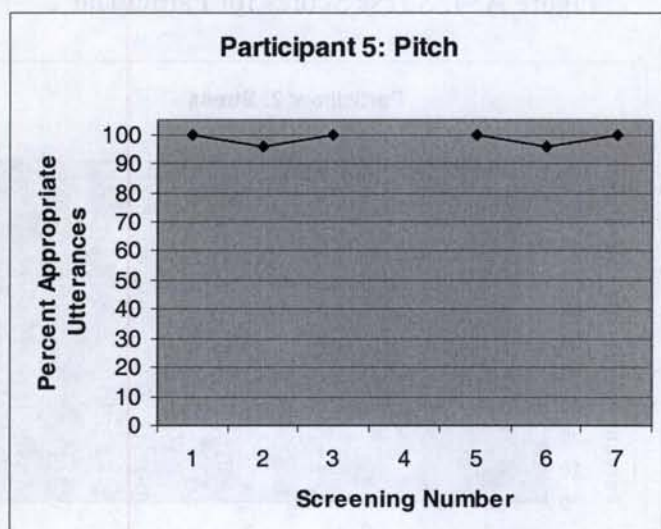


Figure A31: Pitch Scores for Participant 6

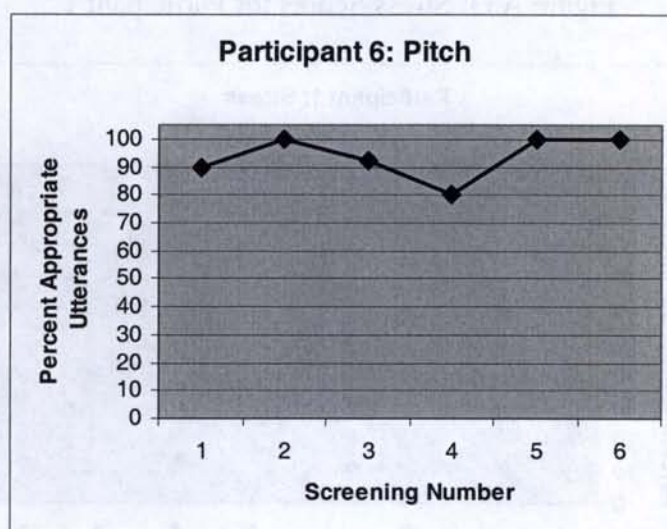


Figure A32: Average Pitch Scores for All Participants

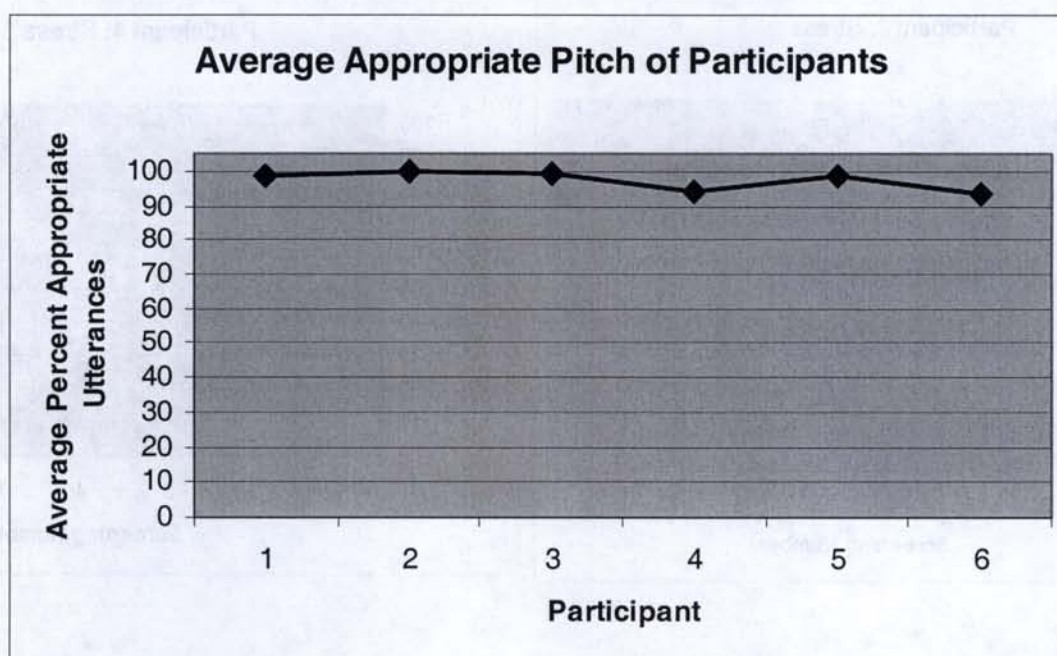


Figure A33: Stress Scores for Participant 1

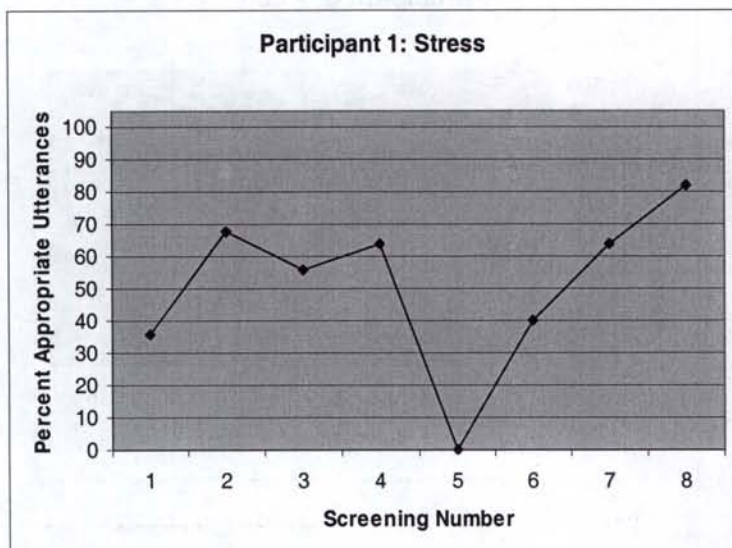


Figure A34: Stress Scores for Participant 2

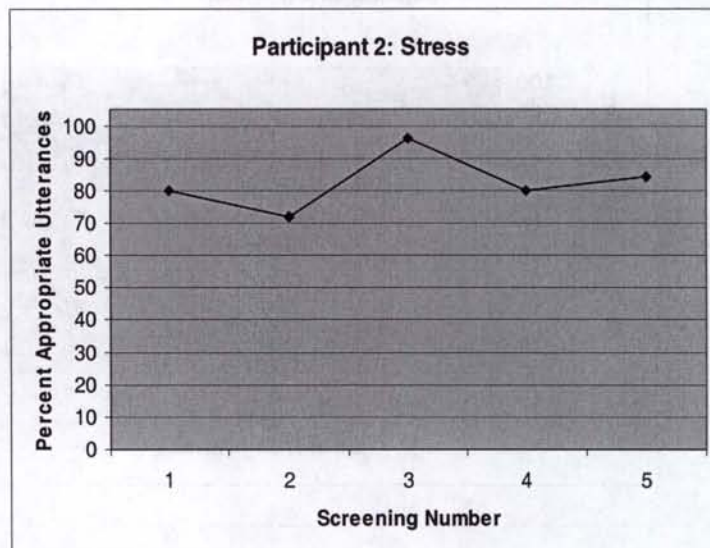


Figure A35: Stress Scores for Participant 3

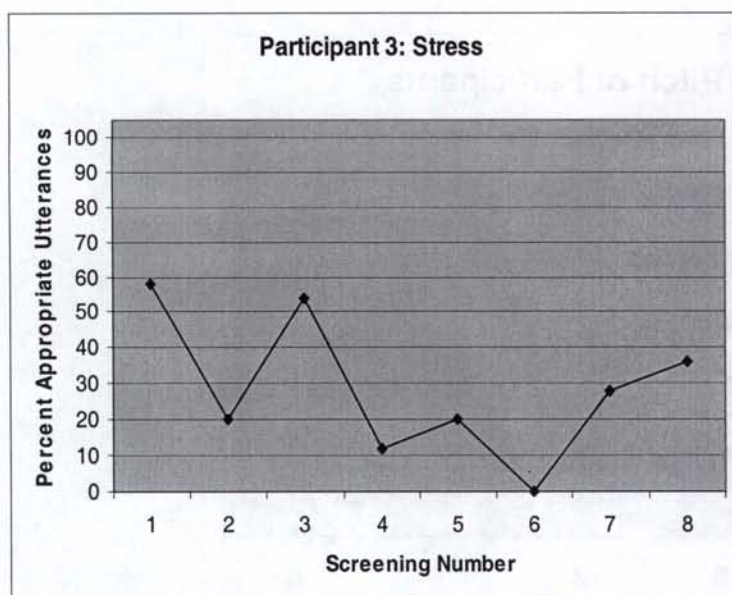


Figure A36: Stress Scores of Participant 4

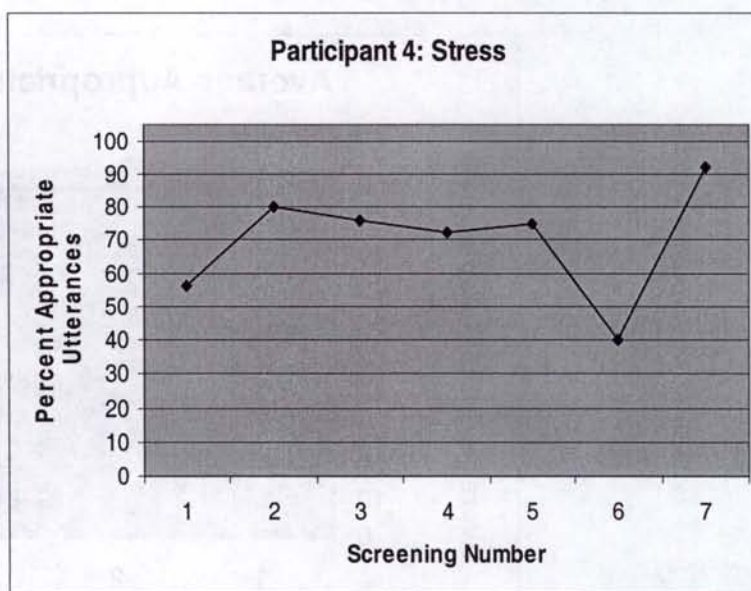


Figure A37: Stress Scores for Participant 5

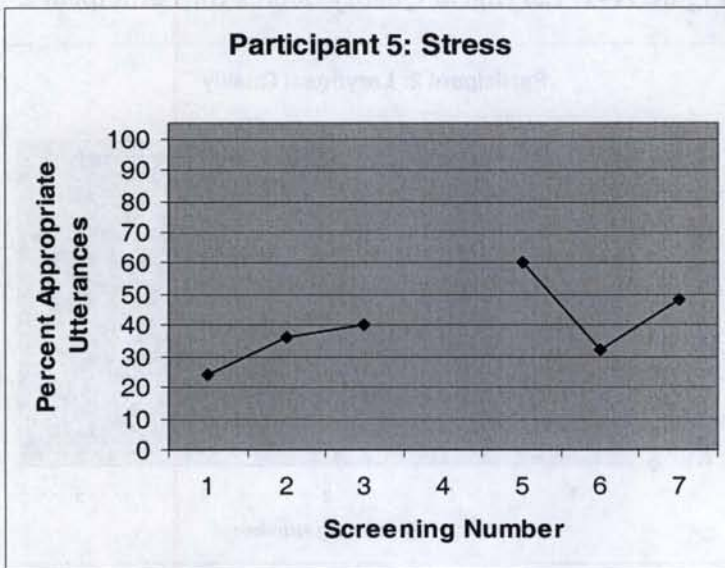


Figure A38: Stress Scores for Participant 6

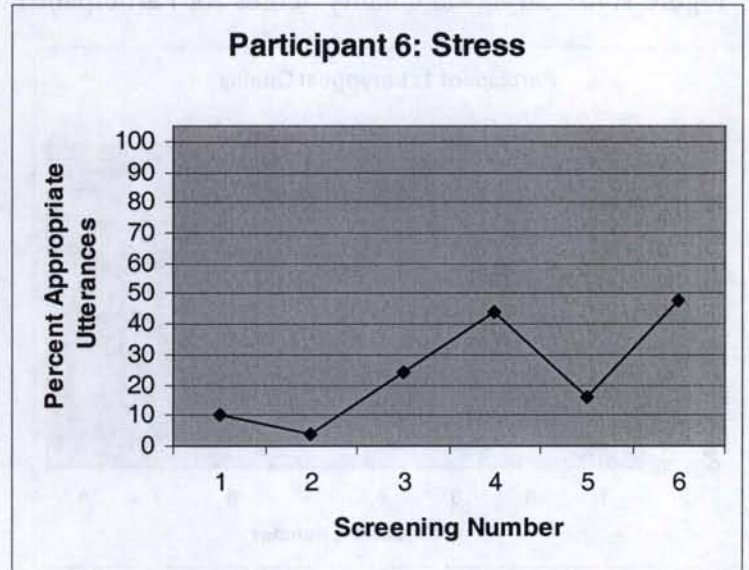


Figure A39: Average Stress Scores for All Participants

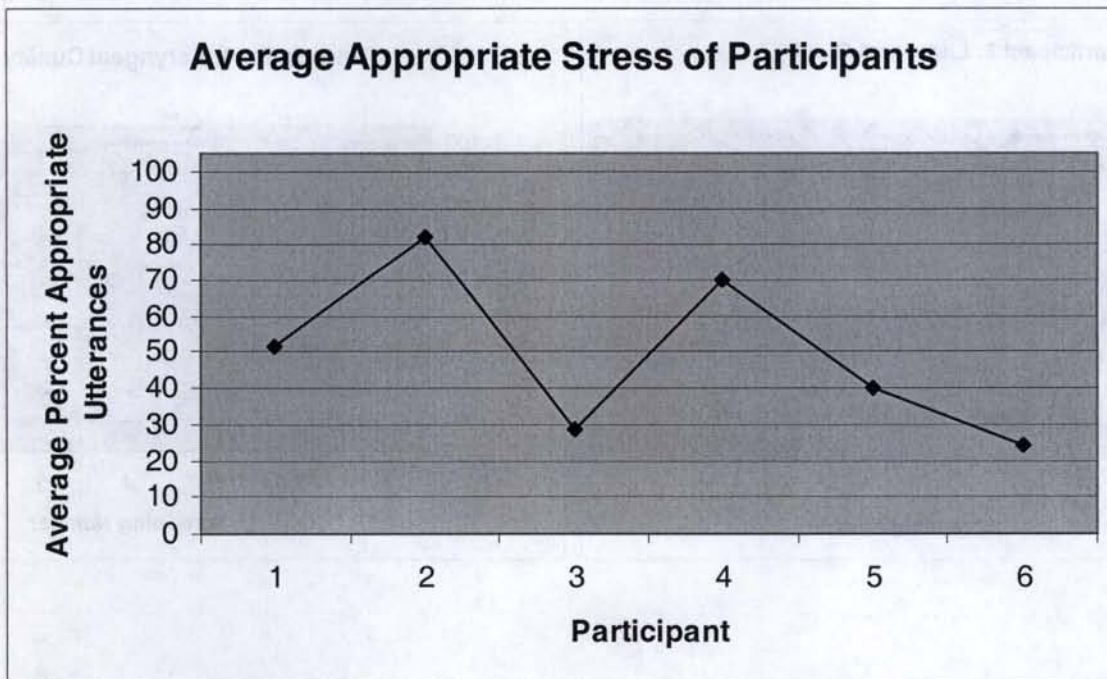


Figure A40: Laryngeal Quality Scores for Participant 1

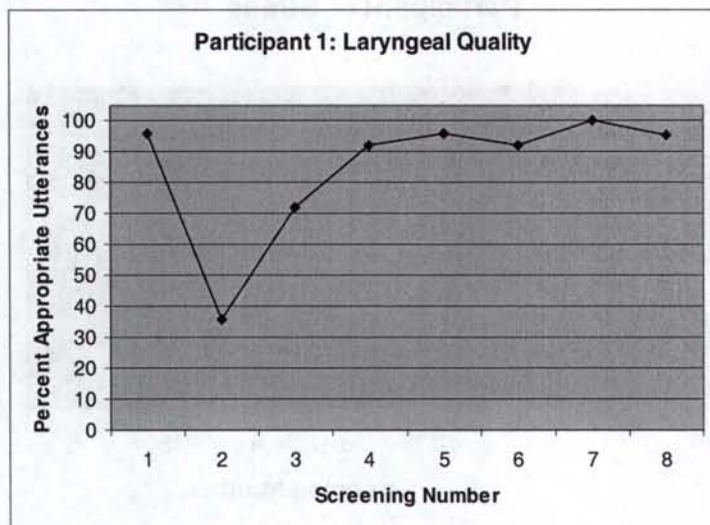


Figure A41: Laryngeal Quality Scores for Participant 2

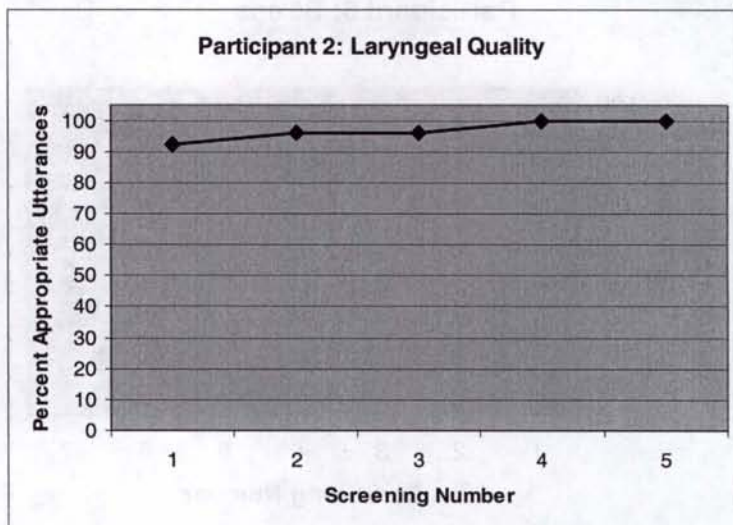


Figure A42: Laryngeal Quality Scores for Participant 3

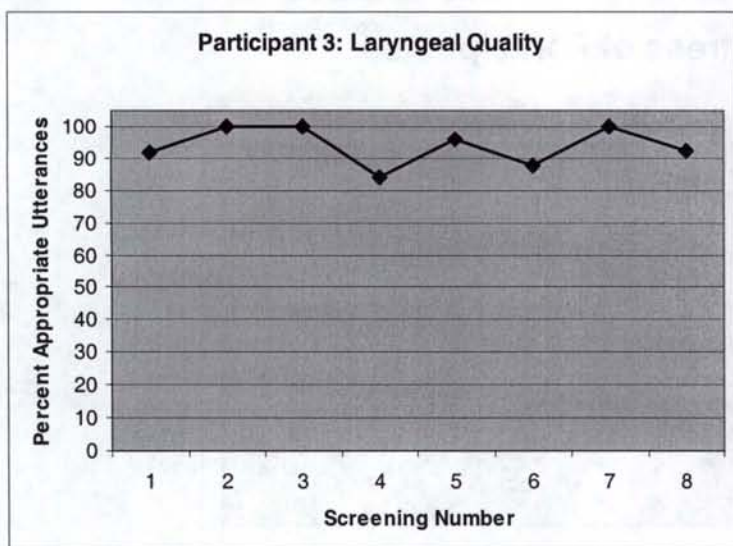


Figure A43: Laryngeal Quality Scores for Participant 4

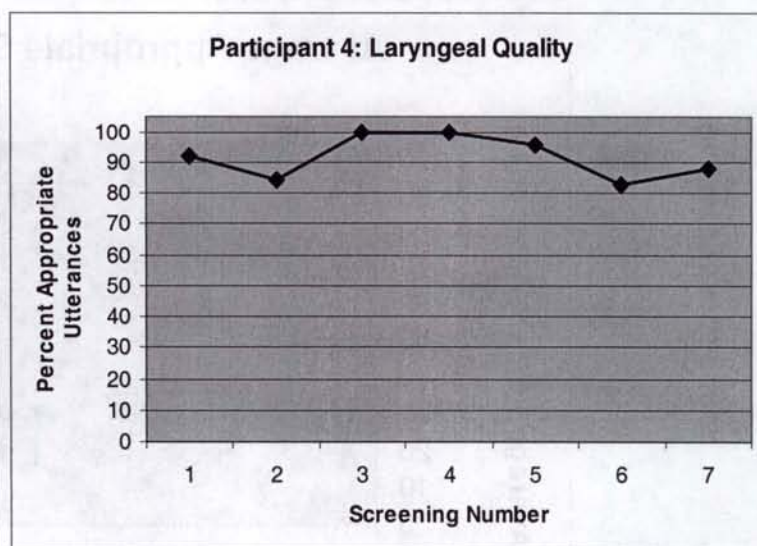


Figure A44: Laryngeal Quality Scores for Participant 5

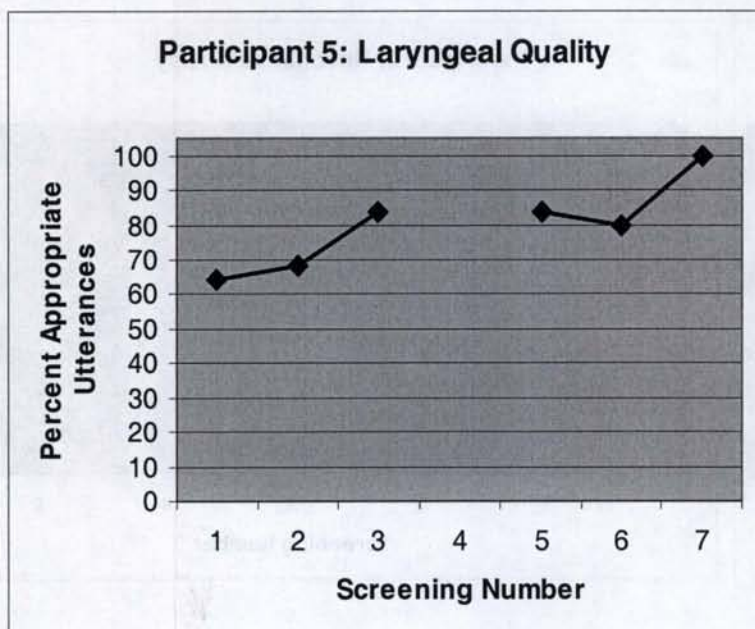


Figure A45: Laryngeal Quality Scores for Participant 6

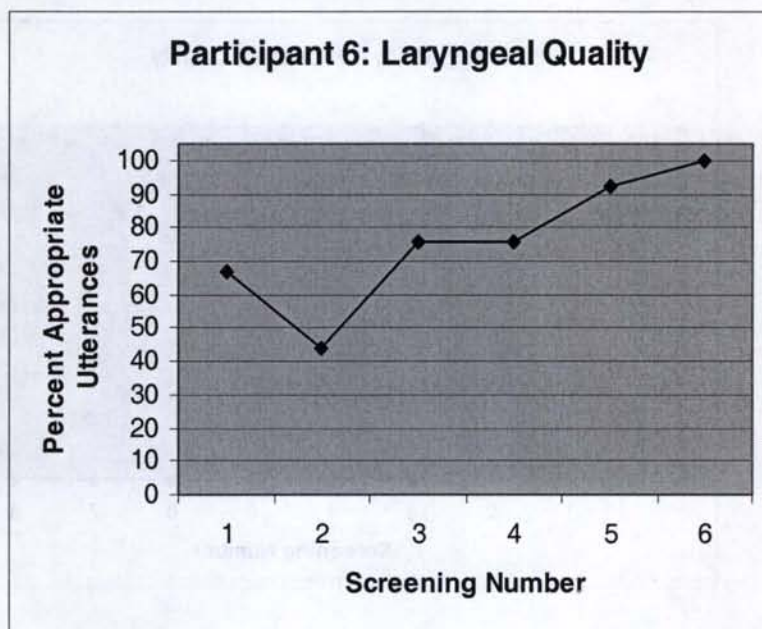


Figure A46: Average Laryngeal Quality Scores for All Participants

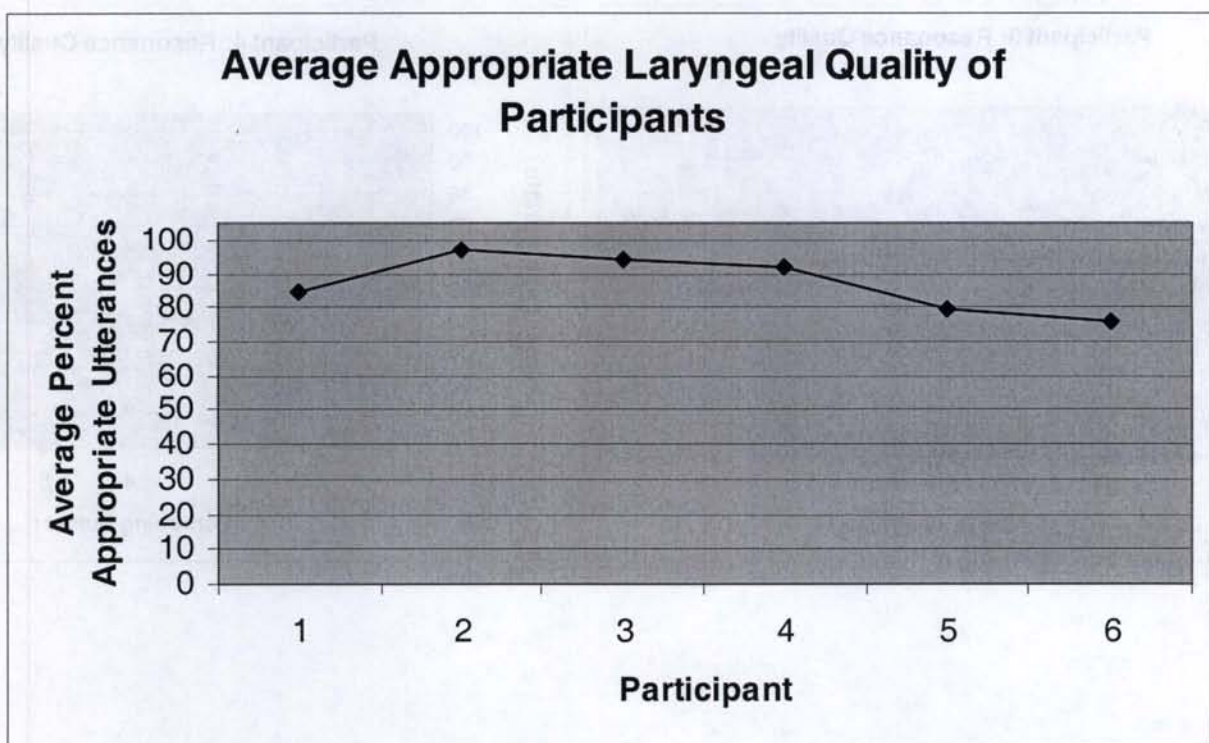


Figure A47: Resonance Quality Scores for Participant 1

Figure A48: Resonance Quality Scores for Participant 2

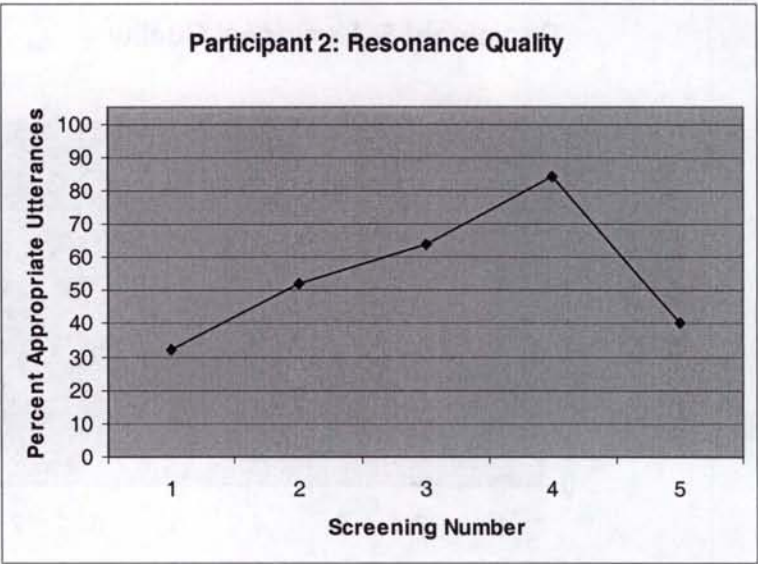
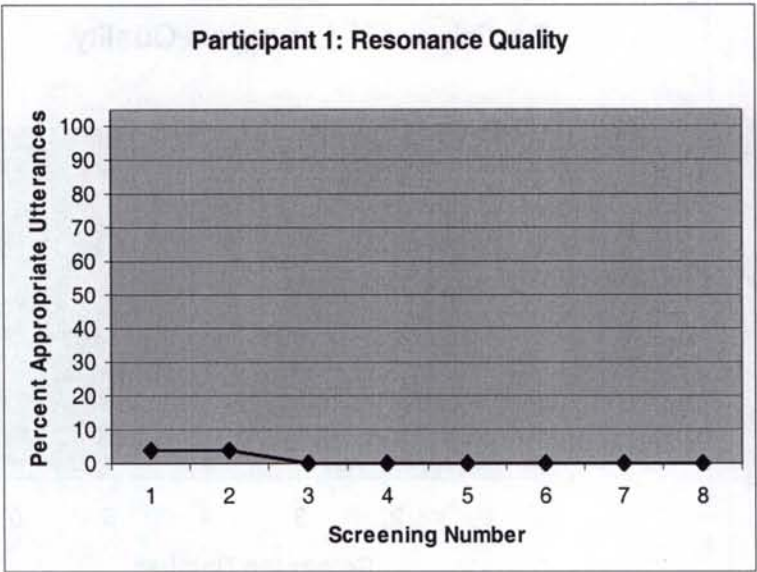


Figure A49: Resonance Quality Scores for Participant 3

Figure A50: Resonance Quality Scores for Participant 4

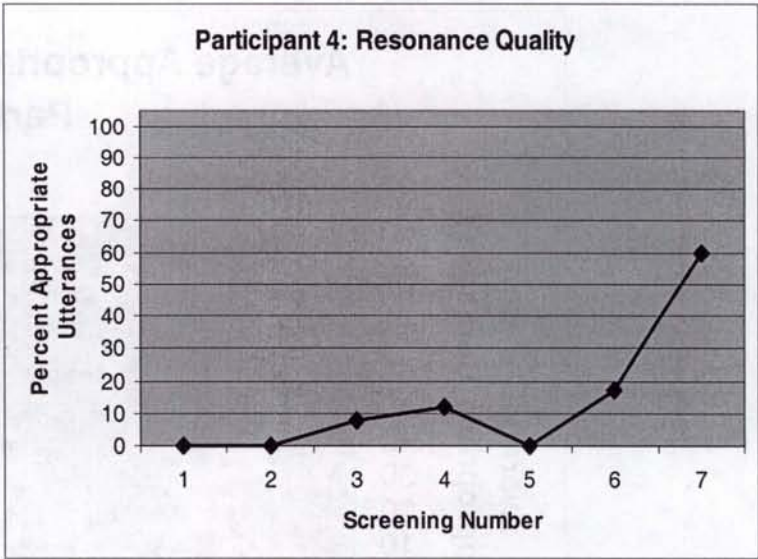
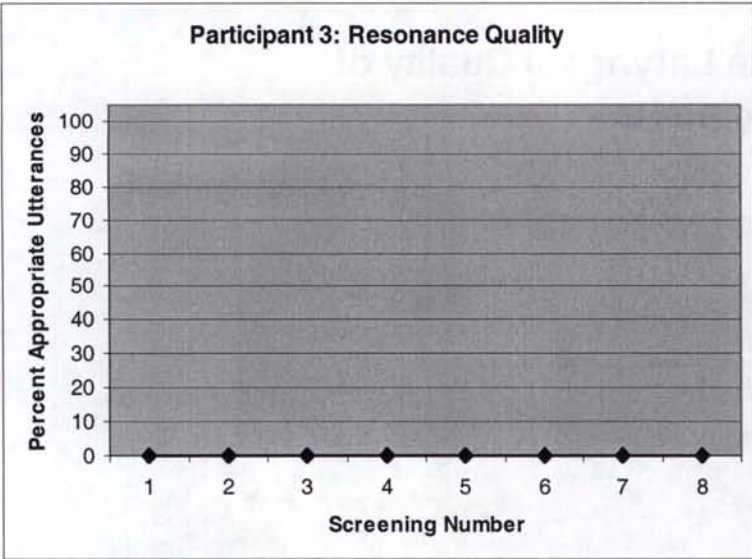


Figure A51: Resonance Quality Scores for Participant

Participant 5: Resonance Quality

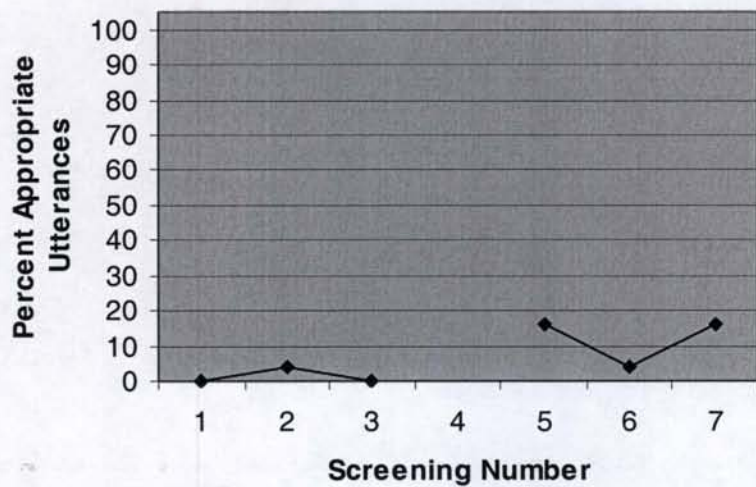


Figure A52: Resonance Quality Scores for Participant 6

Participant 6: Resonance Quality

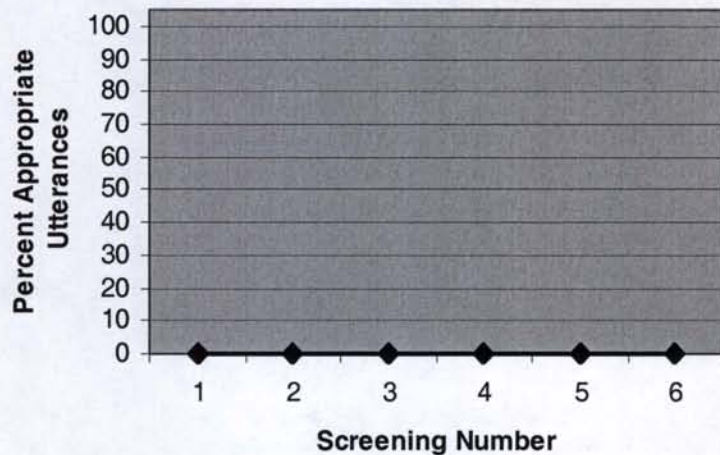


Figure A53: Average Resonance Quality Scores for All Participants

Average Appropriate Resonance Quality of Participants

