THE EFFECT OF INCREASING SPEAKING RATE ON ACOUSTIC AND PERCEPTUAL MEASURES OF NASALITY IN HEARING IMPAIRED SPEAKERS

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Abstract

Nasality is a common resonance disorder present in the speech of severely hearing impaired individuals (Hudgins, 1934). The likely cause has been attributed to structural or functional abnormalities of the velopharyngeal mechanism as well as deviations in pitch and loudness. In addition, hearing impaired individuals speak at a slower rate than normal hearing individuals which has been shown to exacerbate the presence of nasality in their speech (Colton & Cooker, 1968). The purpose of this study was to determine whether deliberate increases in speaking rate would serve to decrease the amount of nasality in the speech of severely hearing impaired individuals. The participants were 11 severe to profoundly hearing impaired students, ranging in age from 12 to 19 years (mean = 16 years). Each participant provided a baseline speech sample (R1) followed by three training sessions during which participants were trained to increase their speaking rate. Following the training sessions, a second speech sample was obtained (R2). Acoustic and perceptual analysis pf the speech samples obtained at R1 and R2 were undertaken. The acoustic analysis focused on changes in first and second formant frequency bandwidth (BW1 & BW2). The perceptual analysis involved 21 naïve listeners rating the speech samples (at R1 & R2) for perceived nasality. Findings indicated a significant increase in speaking rate at R2. In addition, a significantly narrower BW2 frequency and lower perceptual rating score was obtained at R2 across all participants, suggesting a considerable decrease in nasality as speaking rate increases. The influences of speaking rate changes on the functioning of the velopharyngeal mechanism are discussed. In addition, the clinical implications of the findings are explored.

Introduction

<u>Normal Speech Production</u>

The production of speech involves the complex motor coordination of respiratory, laryngeal and supralaryngeal structures (Bernthal & Bankson, 1998; Darley, Aronson, & Brown, 1975; Dworkin, Marunick, & Krouse, 2004; Fry, 1979; Hudgins, 1934; Hudgins & Numbers, 1942; Massengill, 1972). The respiratory system, which consists of the lungs, ribcage, diaphragm and airway, provides the air-supply required for the generation of sound. Inspiration and expiration is part of this process, with expiration being prolonged during the production of speech. Air passes from the lungs to the larynx, vibrating the vocal folds in order for voiced sounds of speech to be produced. When voiceless sounds are produced, air passes through the larynx to the oral and nasal cavities without vibrating the vocal folds. The velum (soft palate) separates the oral from the nasal cavities, enabling the air to be directed to the appropriate area. Once the sound is contained within the vocal tract, the tongue, jaw and lips (the articulators) shape it into meaningful speech.

Aside from the nasal consonants /m/, /n/, and /ŋ/, the production of consonants and vowels involves coordination of the velum and the pharynx to separate (i.e., seal off) the nasal cavity from the oral cavity. These two structures together form the velopharyngeal (VP) mechanism. Appropriate VP functioning is essential in regulating nasality in speech. The velum is situated at the juncture of the oropharynx and nasopharynx, dividing the oral from the nasal cavity (Dworkin et al., 2004; Mason & Helmick, 1979; Nickerson, 1975). Its function involves the regulation of airflow between the two cavities, as well as the regulation of pressure build-up required to produce most consonants. When non-nasal sounds are produced, the soft palate is elevated bringing the velum into contact with the posterior pharyngeal wall. This creates a seal, thus allowing most air to be released through the oral cavity. During the production of nasal consonants, the VP port remains open and most airflow is directed through the nasal cavity (Darley et al., 1975; Moll, 1962).

Speech consists of rapid sequential movements of the lips, tongue, teeth and jaw. As a result of these movements, on some occasions VP closure may not occur during normal speech production (Brancewicz & Reich, 1989; Lintz & Sherman, 1961; Moll, 1962; Nickerson, 1975). This, in combination with nasal consonants present in speech, is responsible for the natural presence of some degree of nasality in normal speech production (Mason & Helmick, 1979). The presence of excessive nasality in speech has been attributed to abnormal VP opening during non-nasal as well as nasal sounds (Lintz & Sherman, 1961; Massengill, 1972). Excessive airflow directed through the nasal cavity during the production of non-nasal and nasal consonants is termed hypernasality. Hypernasality represents a VP dysfunction, as a consequence of either a structural abnormality or functional breakdown without anatomical deformities (Dworkin et al., 2004; McClumpha, 1969).

Abnormal VP Functioning

Hypernasality is a common resonance disorder found in the speech of individuals with cleft palate. In this particular situation, the disorder is caused by structural deformities of the velum and soft palate, resulting in VP dysfunction. Excessive nasality is a hallmark characteristic of cleft palate speech and is a direct consequence of VP dysfunction (Mason & Helmick, 1979; Massengill, 1972; Murphy, 1964; Subtelny, Koepp-Baker, & Subtelny, 1961). Individuals with cleft palate are physically unable to maintain closure of the VP port, resulting in air escaping into the nasal cavity during the production of non-nasal as well as nasal consonants. Surgery is performed to repair the deformity, although many individuals still demonstrate VP insufficiency, as control over this mechanism is yet to be learned (Hudgins, 1934; Mason & Helmick, 1979; Seaver, Andrews, & Granata, 1980; Tatchell, Stewart, & Lapine, 1991). Access to auditory information is essential during this learning process, as the velum cannot be controlled through tactile means alone due to a limited number of nerve endings on the velar surface (Hudgins & Numbers, 1942; Nickerson, 1975; Rutherford, 1967). Furthermore, velar movement is not a visible gesture and is therefore not detectable by lip-reading (Nickerson, 1975; Rutherford, 1967). The absence of hypernasality during normal speech production does not necessarily suggest that a complete seal of the VP port has been achieved, as there are varying degrees of nasality observed across individuals. A VP gap of less than 3mm is considered to reflect the normal range of VP closure (Mason & Helmick, 1979). Those who are unable to achieve this degree of closure are likely to demonstrate some level of hypernasality. Overall intelligibility is compromised when persistent nasality or hypernasality is present in speech (Boone, 1966; Nickerson, 1975; Peterson, 1946).

VP Functioning and Hearing Impairment

Another disorder that is characterised by excessively nasal speech is that of hearing impairment (HI) (Colton & Cooker, 1968; Fletcher & Daly, 1976; Hudgins, 1934; Penn, 1955; Seaver et al., 1980). Hypernasality, in varying degrees, is one of many characteristics of the speech of HI individuals that contributes to reduced speech intelligibility. Others include breathy speech, irregular rhythm and speaking rate due to the insertion of syllables and prolonged pauses, unusual grouping of phonemes, prolonged vowels, and the incorrect use of adjoining consonants (Boone, 1966; Hood & Dixon, 1969; Hudgins, 1934; Hudgins & Numbers, 1942; John & Howarth, 1965; McHenry, 1999; Voelker, 1938). A distinction between the HI and cleft palate populations is known structural deformities of the VP mechanism in the latter population. A further distinction is the lack of auditory feedback available to HI individuals (Hudgins & Numbers, 1942; Seaver et al., 1980; Stevens, Nickerson, Boothroyd, & Rollins, 1976; Zimmerman & Rettaliata, 1981). Without auditory feedback, an individual may not learn the motor routines needed to separate the oral and nasal cavities, resulting in inadequate closure of the VP port. This is especially noticeable during the production of sounds that are visually similar (Hudgins, 1934). For example, the stops /b/, /d/ and /g/ cannot be visually distinguished from the nasal consonants /m/, /n/ and /ŋ/, respectively (Stevens et al., 1976). This often results in these non-nasal consonants being nasalized by HI individuals due to insufficient closure of the VP port.

The nasality present in the speech of HI individuals is noticeable to the everyday listener. This resonance disorder contributes to reduced intelligibility (Higgins, Carney, & Schulte, 1994; Hudgins & Numbers, 1942). There is debate whether increased nasality perceived in the speech of HI individuals is in fact due to (1) inadequate VP functioning, (2) structural differences or (3) other factors influencing listeners' perception of nasality. Each of these possibilities is reviewed below.

Nasality as a Functional Disorder

Hudgins (1934) suggested that the improper use of the VP mechanism is the primary cause of increased nasality in the speech of HI individuals. A detailed study of speech breathing and the time taken to repeat phrases of varying lengths in 87 HI and normal hearing individuals was undertaken. Results for the HI group were revealing of significantly more airflow during speech production compared to the normal hearing group. In addition, Hudgins found that post-lingually deafened individuals maintained speech rhythm analogous to individuals with normal hearing. This maintenance of rhythm, despite the loss of auditory feedback with which to regulate suprasegmentals, suggests an intact structural and functional motor mechanism in post-lingually deafened individuals.

Stevens et al. (1976) suggested that nasality present in the speech of HI individuals was due to inadequate velar timing resulting in inadequate VP functioning. They investigated the degree of nasality in the speech of 25 HI compared to normal hearing students using instrumental measures. Objective nasal accelerometer measures were used to calculate the amount of nasal airflow produced during both nasal and non-nasal consonants. Both naïve and experienced listeners judged nasality by assessing the adequacy of VP control for participants. The researchers found that 76% of participants in the HI group produced excessive nasal airflow and were judged to be excessively nasal in their speech. Participants demonstrated the most difficulty with correct VP functioning during the production of nasal-stop clusters, which require adequate VP functioning to be pronounced correctly. Stevens et al. (1976) concluded that the timing of the VP mechanism, due to inappropriate positioning of the velum, was disordered in the HI group. The nasality perceived by the listeners was therefore attributed to a functional problem rather than a structural deformity.

In a study conducted to compare the articulatory patterns of a HI individual to a normal hearing individual, Zimmerman and Rettaliata (1981) found movement and timing errors involving the back of the tongue (tongue dorsum) during speech production. The back of the tongue and the soft palate, which includes the velum, are connected via the palatoglossus muscle (Borden & Harris, 1984). If one of these structures is not functioning accurately it follows that the other will be affected in some way. The HI participant's speech was classified as mildly nasal and had adequate rhythm, with the exception of vowel prolongation. Opening and closing of the articulators were recorded using cinefluoroscopy and measurements of movement onset and offset, transition time between onset and offset, displacement and peak velocities were made. The profoundly HI individual demonstrated greater displacements and velocities of the articulators, longer transition times between phonemes, longer utterance duration and abnormal tongue dorsum movement than the normal hearing individual. Of particular significance was the difference in timing movements of the tongue dorsum relative to other articulators between the two individuals, which was suggestive of a functional anomaly of the VP mechanism.

Ysunza and Vazquez (1993) investigated VP functioning and anatomy in 53 HI individuals divided into two groups according to nasal resonance. Those considered normal or mildly hypernasal had adequate voice quality and good speech intelligibility, as rated by the researchers. Those HI individuals characterised as severely hypernasal demonstrated significant articulation errors. The researchers found that those participants considered severely hypernasal lacked VP strength and rhythm (i.e., the timing of opening and closing of the VP port), despite normal muscle action and anatomy. VP closure defects were also observed in the severely hypernasal group, as demonstrated by videofluoroscopy. The researchers concluded that the difference between the two HI groups was a functional disorder of the VP mechanism, specifically a lack of rhythm and strength. This may be attributed to the absence of auditory feedback needed to maintain its functional integrity. The reduction in strength of the VP structures observed may be attributed to a lack of correct use. This supports the conclusions made by Stevens et al. (1976), Zimmerman and Rettaliata (1981) that the increased degree of nasality may be a functional problem primarily due to inadequate positioning and timing of the velum and associated structures.

Nasality as a Structural Disorder

McClumpha (1969) evaluated VP functioning in five profoundly HI adults compared to normal hearing adults using cinefluoroscopy. Each participant was required to repeat seven sets of three syllables (/pi/, /pa/ & /pu/), while eight measurements of VP functioning were made. These included velar length, thickness, elevation, height, separation, nasopharyngeal depth, amount of VP contact, and the superior point of VP contact. Results showed that all normal hearing individuals maintained VP closure during the production of syllable sets. All HI participants displayed some degree of VP opening as seen on the fluoroscopic film. The HI participants' inability to monitor speech auditorily was suggested to influence the pattern of VP closure. Significant differences for velar length, nasopharyngeal depth and velar thickness were also reported. McClumpha concluded that the size of the speech production structures in HI individuals might differ from those of normal hearing individuals. She concluded that these structural differences could be due to two factors. Firstly, the VP mechanism may be structurally different due to a lack of use causing atrophy of the tissue. Secondly, the possibility exists that differences are due to a congenital deformation of the VP mechanism. Both of these structural factors would lead to velar insufficiency. The findings by McClumpha (1969) led to the conclusion that primarily structural differences may serve to increase the nasality present in the speech of HI individuals. The results of the study were limited, however, as no perceptual ratings of nasality were conducted. Consequently, it is not known whether these individuals studied were actually perceived as being hypernasal in their speech.

Nasality Due to Other Factors

Contrary to the findings of McClumpha (1969) are those of Seaver et al. (1980) who found that the majority of HI adults studied exhibited adequate VP closure during speech production. In spite of exhibiting VP closure, these individuals were still perceived as being hypernasal. The researchers employed radiographic methods with which to observe velar closure while participants read 13 sentences aloud. Nineteen of the 26 HI adults were judged to be hypernasal while speaking, as rated by students enrolled in a graduate speech-language pathology programme. Of these 19 individuals, 18 exhibited VP closure similar to those considered non-nasal. The results of this study suggested that the nasality perceived by listeners may not be related to VP insufficiency. They concluded that qualities of nasal speech in HI individuals are not analogous to the cleft palate population. In addition, no significant correlation was found between severity of hearing loss and perceived nasality, contrary to what might be expected. The conclusion reached by Seaver et al. (1980) is that listeners may be influenced by other factors while rating speech nasality, such as fundamental frequency (F_0), loudness, speaking rate and sentence context.

Lock and Seaver (1984) found no significant relationship between perceived nasality and VP opening during sentence production of five profoundly HI individuals. Cineradiographic films were taken for each participant during the production of nine sentences, each containing no nasal consonants. This was followed by listeners perceptually rating each sentence according to degree of nasality. All of the HI participants were perceived to be hypernasal in their speech. Interestingly, only two participants showed VP opening during sentence production with the remaining three displaying some degree of VP closure. These mixed results, and a lack of a significant relationship between perceived nasality and VP opening, implies that the perception of nasality may be influenced by other factors. In addition, Lock and Seaver found that perceived nasality was not strongly related to the severity of hearing loss, again suggesting that some other determinant plays a role in the perception of nasality.

In addition to the work by Seaver and colleagues (Lock & Seaver, 1984; Seaver et al., 1980), a number of researchers have suggested that the perceived nasality in HI speech may not simply reflect structural or functional aspects of the VP mechanism (Brancewicz & Reich, 1989; Fletcher & Higgins, 1980; Lintz & Sherman, 1961; Nickerson, 1975; Sherman, 1954; Spriestersbach, 1955; Stevens et al., 1976). However, missing from most past studies is an evaluation of the acoustic characteristics of nasality in HI speech. For example, the presence of nasality in speech can be determined acoustically by measuring first (F_1) and second (F_2) formant frequency bandwidth. The general effect of nasalization is to broaden and flatten the spectral peaks in speech (House & Stevens, 1956; Kataoka, Warren, Zajac, Mayo, & Lutz, 2001). Acoustic measures of vowels produced by HI and normal hearing individuals were compared by Chen (1995). The specific factors of interest were (1) whether HI speakers had a widening of first formant bandwidth (BW1) and (2) whether an extra peak in the vicinity of F_1 would be present in the spectra of the HI individuals' speech. Chen found a trend that as BW1 widened, the perception of nasality increased, although the effect was less noticeable when BW1 was already large.

Summary of VP Functioning and Hearing Impairment

There is debate whether structural anomalies or functional difficulties account for the presence of nasality in the speech of HI individuals. In addition, perceptual studies have returned conflicting results as it has become evident that a variety of factors can influence both naïve and experienced listeners when making judgements of nasality. Furthermore, there is a paucity of research examining the acoustic correlates of nasality in the HI population. Acoustical analysis, coupled with perceptual information, could provide additional insight in to the nature of nasalization in the speech of HI individuals.

Effect of Speaking Rate on Normal VP Functioning

Speaking rate can affect the functioning of the VP mechanism in both normal hearing and HI individuals. Hudgins (1934) and others (Brancewicz & Reich, 1989; Goberman, Selby, & Gilbert, 2001) have suggested that during the production of "slow" speech the velum fails to make sufficient contact with the posterior pharyngeal wall, thereby allowing airflow to be directed through the nasal cavity. Consequently, an increase in nasalization is evident in slow speech. Colton and Cooker (1968) and McClumpha (1969) presented evidence that suggested a break in VP contact when speaking rate was reduced in normal hearing individuals. Colton and Cooker (1968) found that listeners rated the speech of normal hearing individuals as being more nasal when read in a word-by-word fashion when compared to a more habitual speaking rate. The results suggested that speaking rate may influence the perception of nasality in individuals with intact VP mechanisms. Furthermore, Bzoch (1968), found that at slower speaking rates some degree of VP opening existed when observing the VP functioning of normal hearing individuals.

Thompson and Hixon (1979) assessed VP functioning of normal hearing individuals using instrumental measures. Of the 113 participants, 112 produced no nasal airflow during the production of non-nasal syllables. These researchers re-measured nasal airflows of six participants when repeating the same non-nasal syllables at a reduced speaking rate and found that two of the participants exhibited some nasal airflow.

Reduced speaking rate and its effect on both instrumental and perceptual measures of nasality was examined by Brancewicz and Reich (1989). Ten normal hearing adults attempted to reduce their speaking rate in two different conditions; self-paced and computer-paced. Experienced listeners rated the speech samples for degree of nasality. Instrumental measures were recorded using nasal and voice accelerometry. No significant rate effect on accelometric measures of nasality was noticeable and the researchers found that speech rate was a poor predictor of nasal resonance. In addition, no correlation between instrumental and perceptual measures of nasality was found, suggesting that judges may have responded to other factors such as the slower rate, rhythm or prosody. Despite this, a small but significant relationship was found between speaking rate and perceived nasality. As speech rate decreased in both the self-paced and computer-paced reduction technique conditions, the measure of perceived nasality increased. Of importance to note, however, is the effect of the rate reduction technique used in this study on the perception of nasality. Speech rate can be slowed by either increasing the pause time between each syllable or by prolonging word segments of a sentence. During the computer-paced condition the word segments were prolonged, while the self-paced approach could have included either technique.

Similarly, Goberman et al. (2001) examined the effect of speaking rate on both instrumental and perceived measures of nasality in 20 normal hearing individuals. Each participant was required to repeat a non-nasal sentence at three different speeds (normal, slow, fast) in two conditions; self-controlled and metronome-controlled. Significantly higher perceived nasality scores were found for the slow speaking rate when compared to the normal and fast rates. Judges perceived less nasality at faster speaking rates. Nasal resonance, measured by percentage of nasal airflow present, was significantly higher for the slow speaking rate condition, supporting the results found by Hudgins (1934). Similar to Brancewicz and Reich (1989), Goberman et al. (2001) found no strong relationship between instrumental and perceptual measures of nasality. Goberman et al. found that individuals were consistently perceived as more nasal in the metronome-paced condition, which may have been due to the loss of natural rhythm and prosody while attempting to match a speech rate that is slower than average. The non-significant relationship between instrumental and perceptual measures of nasality found by Goberman et al. has been demonstrated by other studies conducted over the years (Karnell, 1995; Keuning, Wieneke, & Dejonckere, 2004; Keuning, Wieneke, van Wijngaarden, & Dejonckere, 2002; Watterson, McFarlane, & Wright, 1993), suggesting that measuring nasalance (nasal airflow) may not be the most accurate method for detecting the presence of nasality in speech. Contained within the literature, however, are studies supporting a strong correlation between perceived nasality and nasality measured using nasal airflow (Dalston & Warren, 1986; Dalston, Warren, & Dalston, 1991; Fletcher, 1972; Hardin, Van Demark, Morris, & Payne, 1992). There seems to be some debate, therefore, as to the strength of the relationship between these two measures.

Effect of Hearing Impairment on Speaking Rate and VP Functioning

There is a considerable body of research suggesting that individuals with HI speak more slowly than normal hearing speakers (Boone, 1966; Colton & Cooker, 1968; Fletcher & Daly, 1976; Fletcher, Mahfuzh, & Hendarmin, 1999; Hood & Dixon, 1969; John & Howarth, 1965; Nickerson, 1975; Robb, Hughes, & Frese, 1985; Voelker, 1938). In addition, within the population of HI speakers, it has been shown that individuals with a severe HI speak at a slower rate compared to mild to moderate HI individuals (Boone, 1966; Hudgins, 1934; Hudgins & Numbers, 1942; Robb et al., 1985). McClumpha (1969) noted that HI speakers took considerably longer to repeat syllable sets compared to normal hearing speakers. She concluded that the nasality present in the speech of the HI group may be influenced by their rate of speech. Hood and Dixon (1969) observed that the most pronounced difference between that of the HI and normal individuals they studied was speaking rate. The HI speakers took at least 1.5 times longer to produce a variety of stimulus sentences. Their results also indicated that the speech rhythm of the HI individuals was significantly related to speech intelligibility, thereby suggesting that speech intelligibility could be enhanced if speaking rate and rhythm were improved.

To assess the effect of speaking rate on VP functioning in HI individuals, Gilbert and Hoodin (1984) used instrumental means to measure the amount of nasal airflow at varying rates of speech. Eight individuals were required to speak at their habitual speaking rate and at a rate of three syllables per second. In each case, nasal flow rates were greater at slower speaking rates than faster, although the researchers did not validate these findings with perceptual or acoustic data. The above findings support those of Hudgins (1934), Bzoch (1968) and McClumpha (1969) whereby speaking rate has an effect on VP functioning.

Effect of Speaking Rate on Perceptions of Nasality

Nasality is a common resonance error present in the speech of HI individuals that contributes to reduced speech intelligibility (Hudgins, 1934; Hudgins & Numbers, 1942). Inadequate timing aspects of speech (i.e., speaking rate & rhythm) have been found to contribute to diminished intelligibility in the speech of HI individuals (Hood & Dixon, 1969; Hudgins, 1934; Hudgins & Numbers, 1942; John & Howarth, 1965; McHenry, 1999; Wilson & McReynolds, 1973). John and Howarth (1965) found that intelligibility improved when HI children were trained to focus on the speech patterns (rhythm & stress) of their utterances.

There is limited literature directly studying the effect of speaking rate on individuals' perceptions of nasality in the speech of HI individuals. Perceptual rating tasks have proven to be difficult in the past, as both naïve and experienced listeners' ratings of nasality are influenced by such factors as speaking rate, F_0, loudness, and articulation errors (Brancewicz & Reich, 1989; Fletcher & Higgins, 1980; Lock & Seaver, 1984; Nickerson, 1975; Sherman, 1954; Spriestersbach, 1955; Stevens et al., 1976). To date, the most comprehensive study to evaluate the perception of nasality in HI speakers was performed by Colton and Cooker (1968). They undertook a study to assess the degree of nasality present in the speech of 28 profoundly HI individuals. As a means of minimizing possible influencing variables, the researchers presented samples of speech to listeners played in reverse. The samples contained examples of speech from both normal-hearing and HI speakers. The listeners were required to perform ratings of nasality for both types of speech samples. The HI speakers were rated as significantly more nasal than normal hearing individuals in spite of the samples being played in reverse. The researchers concluded that a lack of VP control directly contributed to the increased nasality in HI speech.

Summary of the Effect of Speaking Rate on Perceptions of Nasality

A major drawback with the research conducted by Colton and Cooker (1968) is that, although they were able to control for a number of variables interfering with nasality judgements, they were unable to control for speaking rate. Speaking rate is significantly reduced in the speech of HI individuals which may serve to increase the presence of nasality due to inadequate VP closure. No studies have yet been conducted on the effect of speaking rate on the perception of nasality in the speech of HI individuals. Assuming the VP mechanism is anatomically intact in HI individuals (Seaver et al., 1980; Ysunza & Vazquez, 1993), the increased nasality present in their speech may be attributed to a reduced speaking rate and subsequent inadequate velar control. The possibility therefore exists that by increasing the speaking rate of an HI individual, a corresponding decrease in the perception of nasality will occur.

Statement of the Problem

Past research has shown that nasality is present in the speech of HI individuals, which contributes to an overall reduced intelligibility of speech (Boone, 1966; Colton & Cooker, 1968; Fletcher, 1976; Hudgins & Numbers, 1942; Lock & Seaver, 1984; Nickerson, 1975; Seaver et al., 1980; Stevens et al., 1976). Yet, there is still some debate as to whether this nasality can be attributed to structural deformities or functional problems. Three common approaches to assessing nasality involve instrumental, acoustic or perceptual techniques. While instrumental measures have been revealing of nasality in HI speakers, results of perceptual studies have proved inconclusive. Furthermore, there are few studies which have sought to measure nasality acoustically in HI speakers. In addition, speaking rate can effect VP functioning and therefore influence the presence of nasality in both normal and HI individuals (Brancewicz & Reich, 1989; Colton & Cooker, 1968; Gilbert & Hoodin, 1984; Goberman et al., 2001; Hudgins, 1934; McClumpha, 1969). Interestingly, no studies have been conducted that directly evaluate the effect of speaking rate on both acoustical and perceptual measures of nasality in the speech of HI individuals. The purpose of the present study was to observe the effect of changes in speaking rate on acoustical and perceptual measures of nasality in the speech of HI individuals. The following hypothesis was proposed:

> *An increase in the speaking rate of HI speakers will be accompanied by a significant decrease in nasality.*

To test this hypothesis, the following research questions were developed.

1. A statistically significant decrease in BW1 will occur as a function of increased speaking rate.

2. A statistically significant decrease in BW2 will occur as a function of increased speaking rate.
3. HI speakers will be rated as significantly less nasal when a paired comparison perceptual task was undertaken.
4. HI speakers will be rated as significantly less nasal when a sliding severity rating scale of nasality was used.

Method

<u>Participants</u>

Hearing Impaired Speakers.

The HI group consisted of 11 individuals (7 males & 4 females), aged between 12 and 19 years, with a mean age of 16 years. The participants were enrolled at Van Asch Deaf Education Centre (VADEC), located in Christchurch, New Zealand. The VADEC is the major residential special school for deaf children located in the South Island and also serves as a resource centre for mainstreamed HI students and their teachers. Approval for this study was obtained from the University of Canterbury Human Ethics Committee and is contained within Appendix I. The general characteristics of the participants are listed in Table 1. To be included in the project, each participant was required to meet the following criteria:

1. Severe to profound bilateral hearing loss as determined using behavioural pure-tone audiometry. Each participants' pure-tone average was 70 dB HL or greater. Audiograms for the HI participants are contained in Appendix II.
2. The hearing loss was congenital or pre-lingual. This information was obtained from the parental history contained on file at VADEC.
3. The primary mode of communication was either oral or simultaneous (i.e., oral & signed). None of the participants used sign language as their sole form of communication.
4. All students were either hearing aid or cochlear implant users at some period in their lives. Not all participants were aided at the time of data collection.

5. Based on prior educational and medical history, none of the participants demonstrated cognitive or physical impairments, other than spoken and written communication difficulties.

Perceptual Judges.

A group of 21 adults were recruited from the general public. The judges ranged in age from 18 to 59, with a mean age of 32 years. Each judge displayed normal hearing, as determined by either pure-tone audiometry or self-report. All judges were native speakers of English. For participation in the perceptual analysis component of the project, the judges were considered naïve listeners with no prior experience with deaf speech or in the evaluation of speech disorders. In addition, all perceptual judges had no prior knowledge of the purpose of the study.

Speech Sample

Oral reading samples were obtained from each HI participant. The sample consisted of an Aesop's fable entitled, '*The Fox and the Crow*' (Avery, 2000). The text consisted of 142 words and is aimed at a reading level of seven years of age. This particular text was selected to ensure that reading level and "word attack" abilities would not be confounding factors in the assessment of speaking rate. The entire text of the fable is contained in Appendix III. Prior to collection of the speech samples, each participant underwent a 45-minute practice session, during which the text was placed on an overhead projector and interpreted using New Zealand Sign Language. The session was held so that all participants were equally familiar with the text. Words that were assumed to be unfamiliar to the participants, such as "advice" and "flatterers" were defined. Each participant was given the opportunity to practice reading the text aloud during this session.

Table 1: General characteristics of individual participants including age (years), sex, mode of communication, and type and use of hearing aid.* denotes whether the individual communicates primarily via spoken English or New Zealand Sign Language (NZSL).

Participant	*Age*	*Sex*	*Pure-tone Average*	*Language*	*Type of Aid*	*Use*
1	12	Female	105 dBHL	Spoken English, NZSL*	Hearing Aids	Regular
2	18	Male	100 dBHL	Spoken English, NZSL*	Hearing Aids	Regular
3	16	Female	100 dBHL	Spoken English*, NZSL	Cochlear Implant	Regular
4	17	Male	110 dBHL	Spoken English, NZSL*	Hearing Aids	Regular
5	14	Male	100 dBHL	Spoken English, NZSL*	Hearing Aids	N/A
6	18	Male	85 dBHL	Spoken English*, NZSL	Hearing Aids	Regular
7	15	Male	85 dBHL	Spoken English*, NZSL	Hearing Aids	Regular
8	17	Female	110 dBHL	Spoken English, NZSL*	Hearing Aids	Regular
9	16	Male	95 dBHL	Spoken English, NZSL*	Hearing Aids	Regular
10	17	Female	120 dBHL	Spoken English, NZSL*	Hearing Aids	Regular
11	16	Male	110 dBHL	Spoken English, NZSL*	Cochlear Implant	N/A

Audio recording

The speech samples were audio-recorded using a Compaq laptop computer and a DSE PC desktop microphone. A sampling rate of 44 kHz with 16 bits of quantisation was used. All samples were normalised for volume to an average RMS power of -24 dB (relative to 100% of the available dynamic range), using Sound Forge 6.0 (Sonic Foundry, 2002). The RMS level was calculated on all samples above -45 dB using an equal loudness contour to approximate the frequency sensitivity of the human ear. Previous research has shown that variations in loudness can influence perceptual ratings of nasality (Hanson, 1964; Sherman, 1954). The microphone was placed approximately 25 centimetres from each participant's mouth during recordings. All recordings were obtained in a sound-treated room at VADEC. The ambient noise level was recorded at 25 dBA.

Speech Rate Training

Each participant underwent three training sessions conducted within a one-week period. The focus of the training sessions was to instruct participants to increase their speaking rate. A flow diagram of the order of the speech rate training sessions is displayed in Figure 1. The format of each session involved a brief period of conversational discourse between the participant and researcher followed by speech rate training. Following the completion of the conversational discourse, each participant was positioned in front of a computer monitor for speech rate training. The training activity involved each word of *The Fox and the Crow* reading passage being highlighted in a sequential manner. The participant was required to match verbally the specific rate accordingly (i.e., karaoke style). The rate at which the highlighted words were displayed on the monitor could be adjusted from slow (1 word per second) to fast (6 words per second). A screen print of the speech rate trainer used in the present study can be seen in Figure 2. It was assumed that all participants were physically capable of increasing their speaking rate.

Past research has focused on increasing the speaking rate abilities of HI speakers using a variety of different training devices. For example, Boone (1966) suggested the use of a metronome or some other timing device to aid HI individuals with increasing their speaking rate. Wilson and McReynolds (1973) trained four moderate to severely HI children to read sentences in time with a vibrotactile oscillator for the purpose of increasing their speaking rate. This method was employed so that the children did not have to attend visually to a metronome while attempting to read sentences. On average, the reading rate of the individuals was doubled. Results also indicated that the increase in speaking rate generalised to unfamiliar words and sentences. Wilson and McReynolds concluded that HI individuals can be trained, using a vibrotactile device, to increase their oral reading rate and that in some cases this rate is maintained and can be generalised to unfamiliar material. While past studies have varied in the approach to increasing speaking rate, the goal has been the same, namely to facilitate an increase in speaking rate. The approach in the present study was an attempt to use a modern, computer-based, approach to increasing speaking rate – one that might be easily transferred to an educational setting.

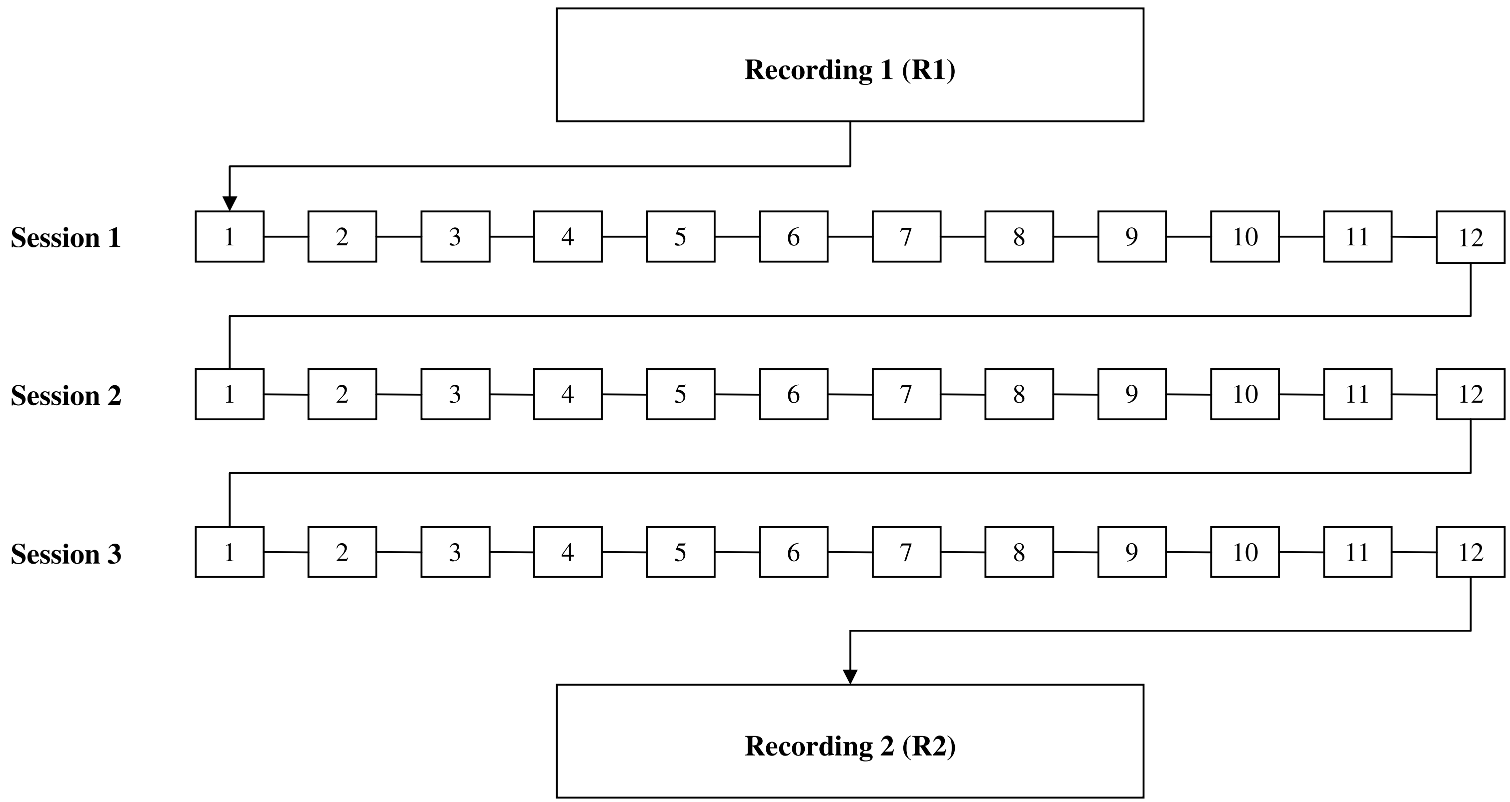


Figure 1: Schematic representation of speech sampling. Each session contained three practices at four different speaking rates (12 practices per session). Audio recordings were obtained prior to Session 1 (R1) and at the completion of Session 3 (R2).

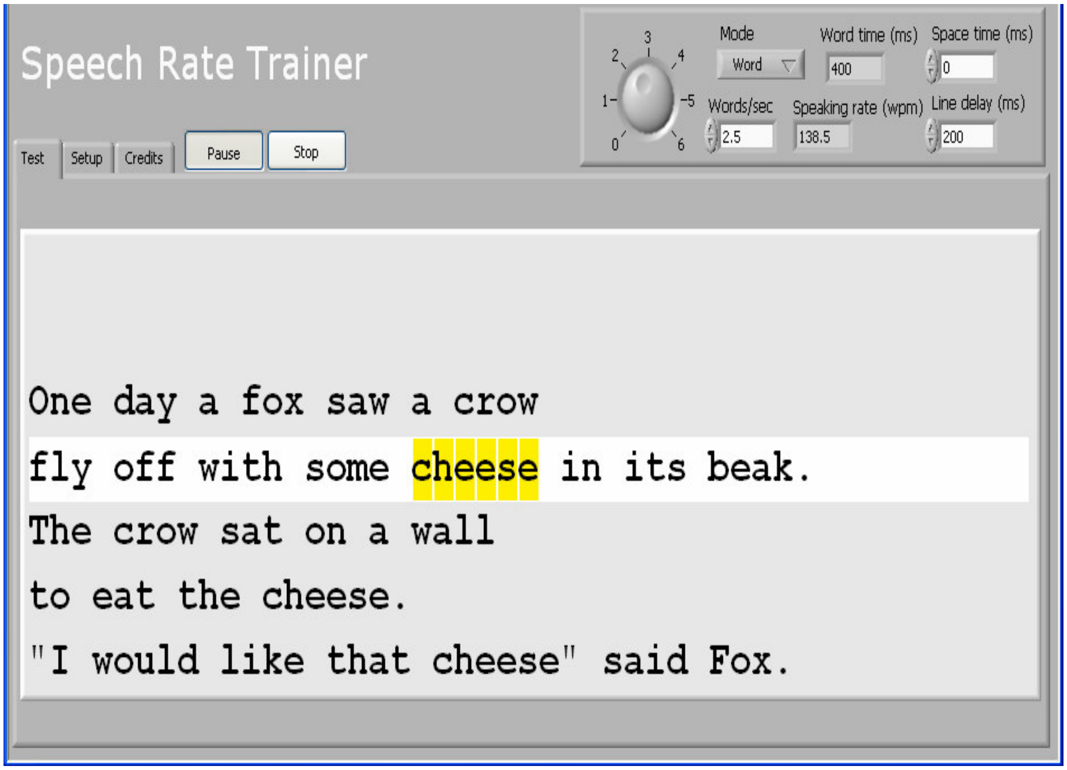


Figure 2: Screen print of the karaoke-style speech rate trainer used during the speech training sessions. The speaking rate setting (words per second) is visible in the top right corner.

The same speech rate training procedures were used during each session in the current study. Following the conversational discourse activity, a baseline audio recording (R1) was made of each participant's reading of the test passage. All participants were required to read the passage aloud, before any attempt at increasing their speaking rate was made. The instructions to the participants for R1 were as follows:

> "*I want you to read this story about a fox and a crow. Please read this like you would normally read, like you practiced, and as smoothly as possible. Your speech will be recorded during this task."*

Following the baseline recording, participants were then required to practice reading the passage three times at 4 different speaking rates (12 readings in total), with each subsequent rate being faster than the previous. Research by Walker (1988) indicates that normal speaking rate is approximately 3.14 words per second (wps). Using this value as a reference of normalcy, and taking into account each participant's approximate rate during the discourse activity, the initial rate targeted was 1.5 wps. It was left to the discretion of the researcher, however, to increase this initial rate to 2.0 or 2.5 wps after the passage was read for the first time using the speech rate trainer, depending on individual ability. The instructions to the participants were as follows:

> *"Now I want you to read the same story again, this time try and follow the highlighted word as you speak. Try to keep up with the highlighted word, and try not to leave any words out. If you cannot keep up, please just keep reading. No recording will be made."*

Upon completion of three readings of the passage at a designated speaking rate, the researcher increased the setting of the speech rate trainer. The amount of increase in speaking rate was determined by the researcher and depended on individual participant ability, as some participants adjusted easier to the increases in rate than others. The final rate achieved using the speech rate trainer differed between the participants; however, the number of practice readings per participant was consistent across the group. Measurable increases in each participant's speaking rate were considered more important than the actual speed at which they spoke. The instructions provided to the participants at the onset of each new speaking rate were as follows:

> *"Now I want you to read the story as smoothly as possible, like you practiced, but this time the highlighted word is going to move faster. Try to keep up with the highlighted word and try not to leave any words out. No recording will be made."*

At the conclusion of the final speech rate training session, each participant was instructed to read the passage 'as fast as possible' and a second audio recording was made (R2). The instructions given to the participants were as follows:

> *"Now I would like you to read the same story again, but this time as fast as possible. During this task I will be recording your speech."*

Acoustic Analysis

The audio recordings of the test passage obtained at the beginning and conclusion of the training sessions were submitted for acoustic analysis of speaking rate. First and second formant frequencies (F_1 & F_2) and first and second formant bandwidth frequencies (BW1 & BW2) were measured. The primary acoustic measures of interest were BW1 and BW2. Past research has clearly documented that measures of formant bandwidth provide a reliable estimate of the rate at which sound energy is absorbed, as well as sound damping within the vocal tract (House & Stevens, 1956; Robb, Chen,

& Gilbert, 1997) In general, any corresponding decrease in speech nasality would be revealed by a decrease in formant frequency bandwidths.

A commercially available speech analysis system (Kay Elemetrics, 1994) was used for the acoustic data analysis in the present study. The sentence *"The crow liked being called the queen of all birds"* was selected for acoustic analysis. This sentence was at the approximate midpoint of *The Fox and the Crow* reading passage. The midpoint location was chosen for two reasons. Firstly, it represented the point where maximum speaking rate was likely to be achieved. Secondly, the particular sentence contained ten vowel samples which represented various points of articulation within the vocal tract. The specific measurements performed were as follows:

Speaking Rate. Using the protocols from Robb et al. (2003), the sentence was displayed on a computer monitor as an amplitude-by-time waveform. Using this display, a vertical cursor was placed at the onset of the first syllable of the sentence and a second cursor placed at the offset of the last syllable of the sentence. Syllable onset was taken to be the point on the display where acoustic energy was first detected. Offset of the last syllable was taken at the point at which acoustic energy was no longer detected. The time interval between the two cursors, including silences, was recorded as the total sentence duration. The total number of syllables produced in the passage was perceptually tabulated and divided by the total sentence duration to derive speaking rate. The unit of measure for speaking rate used was number of syllables produced per second (sps).

Formant Frequency and Formant Bandwidth. The F_1 and F_2 frequencies, as well as the BW1 and BW2 values were obtained for each vowel produced in the target sentence. This was done by examining the amplitude-by-time waveform and positioning a time window at the approximate midpoint of each vowel. The F_1 and F_2

values were obtained using linear predictive coding (LPC) autocorrelation analysis. The LPC settings included a frame length of 50 or 30 ms, using a Blackman window and a filter order of 36 coefficients. To guide in the identification of formants, the LPC derived values were compared to norms taken from Peterson and Barney (1952). In those instances where reliable formant bandwidth values could not be obtained, the window was repositioned to another location in the vowel. For the male and female speakers, the time windows used were 50 ms and 30 ms respectively. The variable length of the time window accounted for known differences in F_0 between men and women. Assuming an average F_0 of approximately 100 Hz for the male speakers, with a period of 0.01s ($T = 1/f$) the time window contained approximately five glottal periods for estimates of F_0, formant and bandwidth values ($0.05/0.01 = 5$). Assuming an average F_0 of approximately 200 Hz for the female speakers, with a period of 0.005s, the time window contained approximately six glottal periods for estimates of formant and bandwidth values ($0.03/0.005 = 6$). Bandwidths were computed automatically on the LPC spectrum by the CSL software and numeric results were provided in Hertz (Hz).

Perceptual Evaluation

Twenty-one naïve listeners served as perceptual judges. In total, 22 samples were evaluated (2 per HI participant), that were taken from R1 and R2. The sample chosen from the Fox and the Crow reading passage for perceptual evaluation was '*You are the queen of all birds. I am sure that you sing well too. Will you sing a little song for me? The crow liked being called the queen of all birds. She lifted her head and began to sing."* Contained within this phrase was the sentence that was analysed acoustically for BW1 and BW2 (underlined above). The sample used for perceptual evaluation was selected for the same reasons as those for acoustic analysis. However, the sample was slightly longer to provide the listeners with an ample speech sample to make a perceptual judgement.

In an attempt to eliminate the effect of rate of speech on the judgements of nasality, two adjustments to the R1 speech sample were made. Firstly, long pauses (i.e., silent periods) in the speech sample were reduced to a maximum length of 250 ms. This was done so that the total duration of the baseline (R1) recording closely approximated the duration of the R2 recording. Following the editing of pauses, a further adjustment of R1 was performed. The further adjustment involved time-compression of the overall speech sample to the exact duration of the sample collected at R2. The original and adjusted speech sample waveforms are displayed in Figure 3. The original and adjusted sample durations for the 11 HI participants are contained within Table 2.

The 22 speech samples used for the perceptual evaluation were temporally reversed using CSL software. Sherman (1954) found that by using samples of speech played in reverse, listeners were less influenced by irrelevant factors, such as articulation and intelligibility, when making judgements on the severity of nasality. She concluded that judgements made on speech played in reverse were more valid that than those made on forward-played speech. Colton and Cooker (1968) used a similar procedure when samples of speech were rated for nasality. In the present study, all reversed samples were presented in a randomised order at a comfortable loudness level (approximately 60 dBHL). An example of the temporally reversed speech samples is provided in Figure 4.

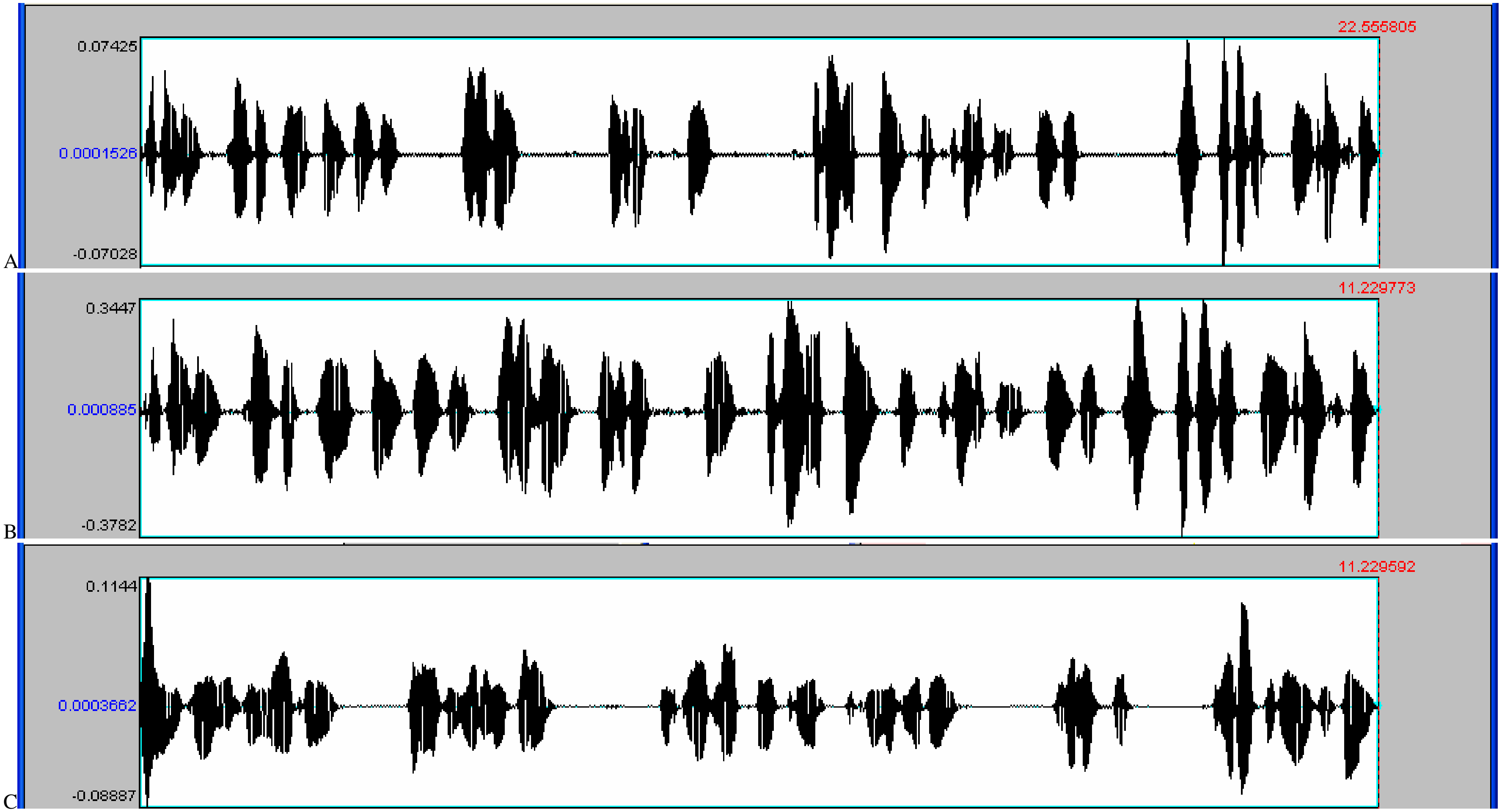


Figure 3: Panel A provides a display of the forward-played amplitude-by-time waveform of the speech sample produced by Participant 6 at R1. The original duration at R1 was 22.55s. Panel B is the same signal produced by Participant 6 at R1 once trimmed and compressed to duration of 11.22s. Panel C is the forward-played amplitude-by-time waveform of the speech sample produced by Participant 6 at R2. The duration of R2 was 11.22s.

Table 2: Mean (M), standard deviation (SD) and range (R) values, in seconds, for the original duration of the speech sample used in the perceptual task at Recording 1 (R1), the duration once pauses had been removed, and the duration at Recording 2 (R2).

	R1			R2
	Original duration (sec)	**Duration following pauses removed (sec)**	**Duration following compression (sec)**	**Duration (sec)**
Participant				
1	20.66	15.27	13.68	13.68
2	21.33	15.35	10.61	10.61
3	11.03	9.64	5.73	5.73
4	14.73	12.82	10.64	10.64
5	15.94	14.51	10.99	10.99
6	22.55	16.77	11.22	11.22
7	17.16	11.78	8.10	8.10
8	29.36	22.99	15.23	15.23
9	18.41	13.79	11.63	11.63
10	16.14	13.57	12.15	12.15
11	19.75	15.84	12.01	12.01
M	**18.81**	**14.76**	**11.09**	**11.09**
SD	**4.77**	**3.38**	**2.53**	**2.53**
R	**11-29**	**9.64 - 22.99**	**5.73 – 15.23**	**5.73 - 15.23**

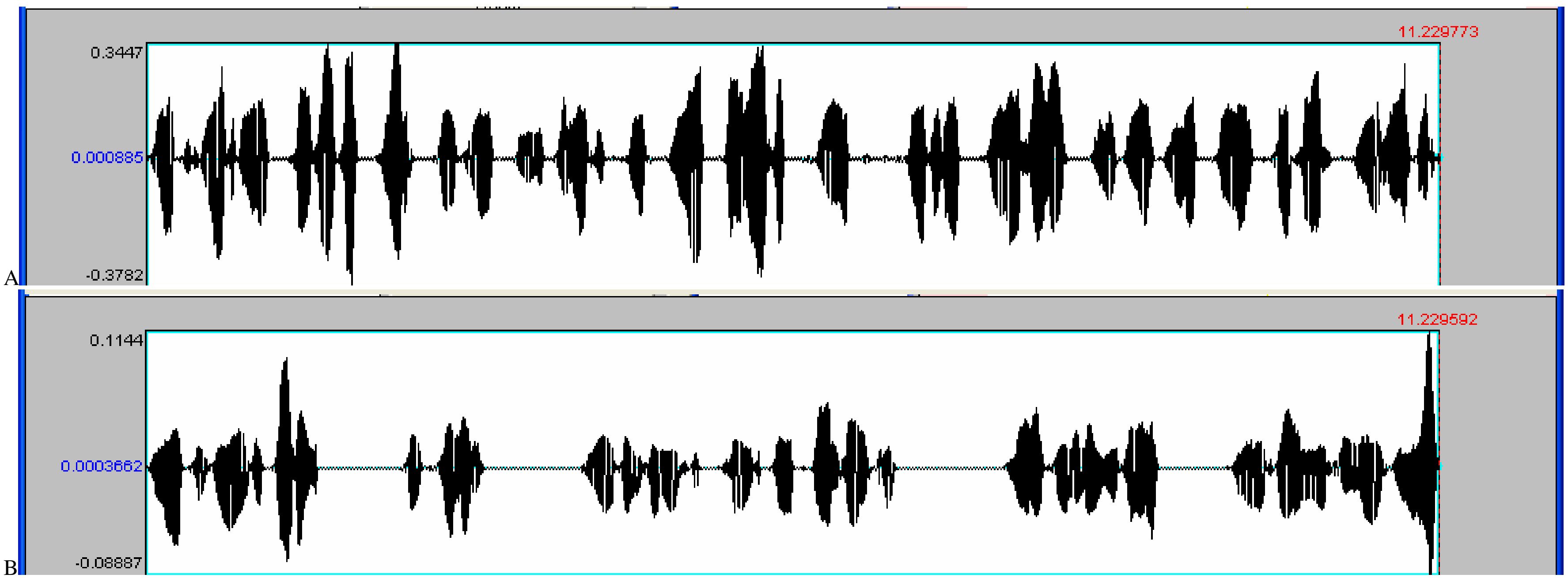


Figure 4: Panel A provides an example of temporally reversed amplitude-by-time waveform of the speech sample produced by Participant 6 at R1 once trimmed and compressed. Panel B is an example of backward-played amplitude-by-time waveform of the speech sample produced by Participant 6 at R2. The duration of both R1 and R2 samples is 11.22s.

Using headphones, judges were required to complete two perceptual tasks. The first task was a forced-choice paired comparison task during which listeners were required to listen to R1 and R2 and rate one sample as being more nasal than the other. The ordering of the R1 and R2 pairs was randomised and was separated by a two-second pause. Participants were allowed to listen to the paired samples as many times as required before making a judgement. A screen print of the paired comparison task is displayed in Figure 5. The second perceptual task required the listeners to evaluate each sample for degree of nasality using a visual analogue sliding scale of zero (no nasality) through to 10 (extreme nasality) (Dromey, 2003). The entire sample of 22 sentences (R1 & R2) was randomised and presented individually to the listeners. The listeners were instructed to focus on the nasal quality of the speech samples and assign a number corresponding to the degree of nasality perceived. Listeners could elect to repeat the sample as many times as necessary before making a judgement. A screen print of the sliding scale task is displayed in Figure 6. For all judges, the paired comparison task preceded the sliding scale task. The rationale for doing so involved the assumption that the paired comparison task was the easier of the two tasks. By completing the easier task first, it was thought that the listeners would become better accustomed to the speech samples before the more difficult sliding scale task was attempted.

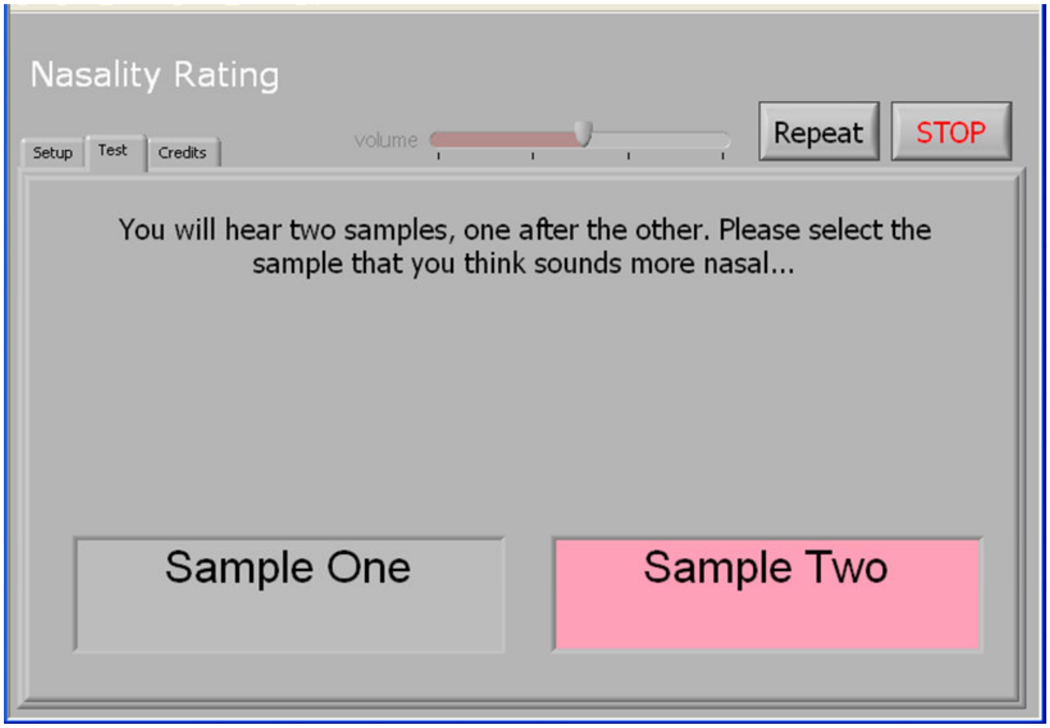


Figure 5: Screen print of the forced-choice paired comparison nasality rating task completed by the perceptual judges. Listeners made the choice by clicking on either Sample 1 or Sample 2.

Figure 6: Screen print of the sliding scale task completed by the perceptual judges, showing the visual analogue sliding scale of zero (no nasality) to 10 (extreme nasality). Listeners rated the degree of nasality by clicking on a number between these values.

<u>Measurement Reliability</u>

To assess intra-judge reliability of the acoustic measurements, speech samples from two of the HI individuals, chosen at random, were re-measured by the researcher. Speaking rate, F_1, F_2, BW1 and BW2 were re-measured for this purpose and the values obtained were compared to the original measurements. Pearson product-moment correlation coefficients, Mann-Whitney Rank Sum Tests and absolute mean differences for overall speaking rate, F_1, F_2, BW1 and BW2 between the first and second measurements were calculated. The resulting correlation coefficient calculated for speaking rate was r = 0.99. A Mann-Whitney Rank Sum Test was run to compare the median values of the original (median = 2.814s) and re-measured (median = 2.814) values. No significant difference was found ($t = 150$, $p = 0.977$). The absolute difference between the original and re-measured mean values was 0.05 ms.

The correlation coefficient for re-measurement of F_1 and F_2 was 0.913 and 0.809, respectively. For F_1, no significant difference was found between the median value of the original (372.5 Hz) and repeated (369.5 Hz) measures ($t = 12402.5$, $p = 0.601$). No significant difference was found between the original F_2 (1448 Hz) and re-measured (1475 Hz) F_2 values ($t = 12719$, $p = 0.830$). The absolute difference between the mean of F_1 and F_2 were 17 and 74 Hz, respectively. The correlation coefficients for re-measurement of BW1 and BW2 were 0.833 and 0.693, respectively. For BW1, no significant difference was found between the median value of the original (209.5 Hz) and re-measured (204.5 Hz) values (t = 12555.5, $p = 0.397$). No significant difference was found between the original (216 Hz) and re-measured (214.5 Hz) BW2 values (t = 11986.5, p = 0.639). The absolute difference between the mean of BW1 and BW2 was 48 and 59 Hz, respectively.

To assess intra-judge reliability for the paired comparison perceptual task, each of the 21 listeners had to re-judge two randomly selected samples played at the end of the original task. A comparison of the original judgement to the subsequent judgement indicated an average agreement of 83%. In addition, intra-judge reliability was assessed for the sliding scale task. Listeners were required to re-evaluate the degree of nasality for 20% of the speech samples presented. The correlation between listeners' initial and subsequent ratings was 0.78. A t-test was performed to determine whether the initial and subsequent ratings differed significantly. No significant difference was found [$t(40) = 0.130$, $p > 0.05$]. The mean absolute difference between initial and subsequent ratings of degree of nasality was 1.25.

Statistical Analysis

The data were analysed using a combination of correlation and inferential statistics to describe relationships and differences between the data, respectively (SPSS Inc, 1992). A combination of group testing between R1 and R2, as well as individual participant testing between R1 and R2 was conducted. A series of t-tests were used to determine if the various acoustic and perceptual measures differed significantly between R1 and R2. When performing individual participant t-testing, the p-value was adjusted using the Bonferroni procedure to reduce the possibility of making a Type I error ($p = 0.05/11 = 0.004$) (Schiavetti & Metz, 2002). In addition, a series of correlational analyses were performed to evaluate the relationship between perceptual ratings at R1 and R2 and the corresponding acoustic measures.

Results

The results are presented in three sections. The first section contains the results concerning the acoustic analysis of the speech samples collected at R1 and R2. The second section contains the results pertaining to the perceptual estimates of the speech samples at R1 and R2. The third section provides the results of several correlational analyses examining the relationship between the various acoustic and perceptual measures.

Acoustic Results

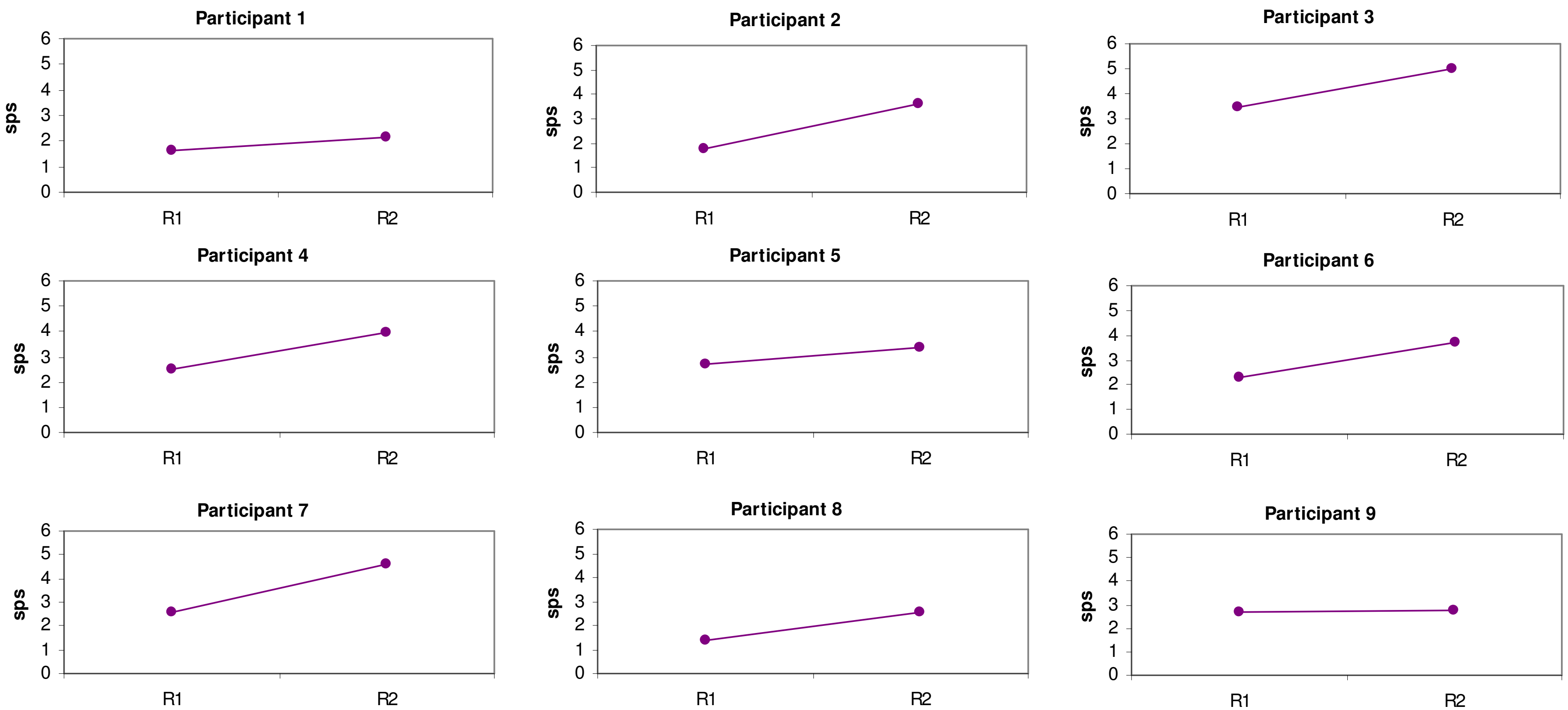
Speaking Rate. Speaking rate values for all participants across R1 and R2 are listed in Table 3 and Figure 7. The mean speaking rate at R1 was 2.27 sps and ranged from 1.41 to 3.48 sps. The mean speaking rate at R2 was 3.39 sps and ranged from 2.14 to 4.98 sps. A t-test was performed to determine if speaking rate differed between R1 and R2. The test was significant [$t(10) = -6.046$, $p < 0.001$], indicating a faster rate at R2. The mean percentage change for speaking rate between R1 and R2 was 55.55% and ranged from 4.90 – 99.44% across participants.

First Formant Bandwidth. The BW1 values for all participants across R1 and R2 are listed in Table 4 and Figure 8. The mean BW1 frequency at R1 was 236 Hz and ranged from 159 – 348 Hz. The mean BW1 frequency at R2 was 237 Hz and ranged from 164 -345 Hz. The group results for BW1 are displayed in Figure 9. A t-test was performed to determine if BW1 frequencies were significantly different between the R1 and R2 sampling periods. No significant difference was found [$t(10)= -0.096$, $p= 0.925$], indicating little change in bandwidth frequency from R1 to R2. A series of alpha-adjusted paired t-tests were performed to determine if any significant differences for BW1 between R1 and R2 were present among the 11 HI participants. No significant differences were obtained across R1 and R2 for each participant, confirming the results obtained from the group analysis.

Second Formant Bandwidth. The BW2 values for all participants across R1 and R2 are listed in Table 5 and Figure 10. The mean BW2 frequency at R1 was 352 Hz with a range of 210 to 424 Hz. The mean BW2 frequency at R2 was 287 Hz with a range of 176 to 423 Hz. The overall group mean values for BW2 are displayed in Figure 11. A t-test was performed to determine if BW2 values were significantly different across R1 and R2. The test was significant [$t(10)= 2.615$, $p= 0.026$], indicating a narrower F_2 bandwidth at R2. A series of alpha-adjusted paired t-tests were performed to determine if BW2 values across R1 and R2 differed significantly among the individual participants. No significant differences were found when the adjusted p-value was used ($p < 0.004$).

Table 3: Speaking rate (SR), measured in syllables per second (sps) and the percentage change in SR that occurred from Recording 1 (R1) to Recording 2 (R2).

Participant	*R1*	*R2*	*Percentage Change*
1	1.66	2.14	28.91
2	1.80	3.59	99.44
3	3.48	4.98	43.10
4	2.49	3.94	58.23
5	2.68	3.39	26.49
6	2.29	3.69	61.13
7	2.56	4.61	80.07
8	1.41	2.56	81.56
9	2.65	2.78	4.90
11	2.14	3.03	41.58
12	1.85	2.62	41.62
Mean	**2.27 (0.58)**	**3.39 (0.88)**	**51.55 (27.80)**



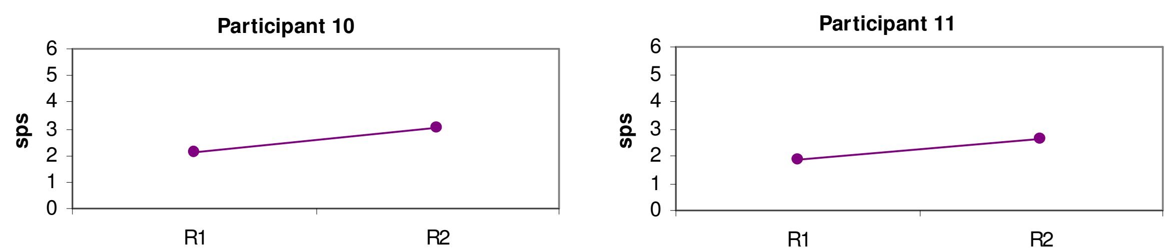
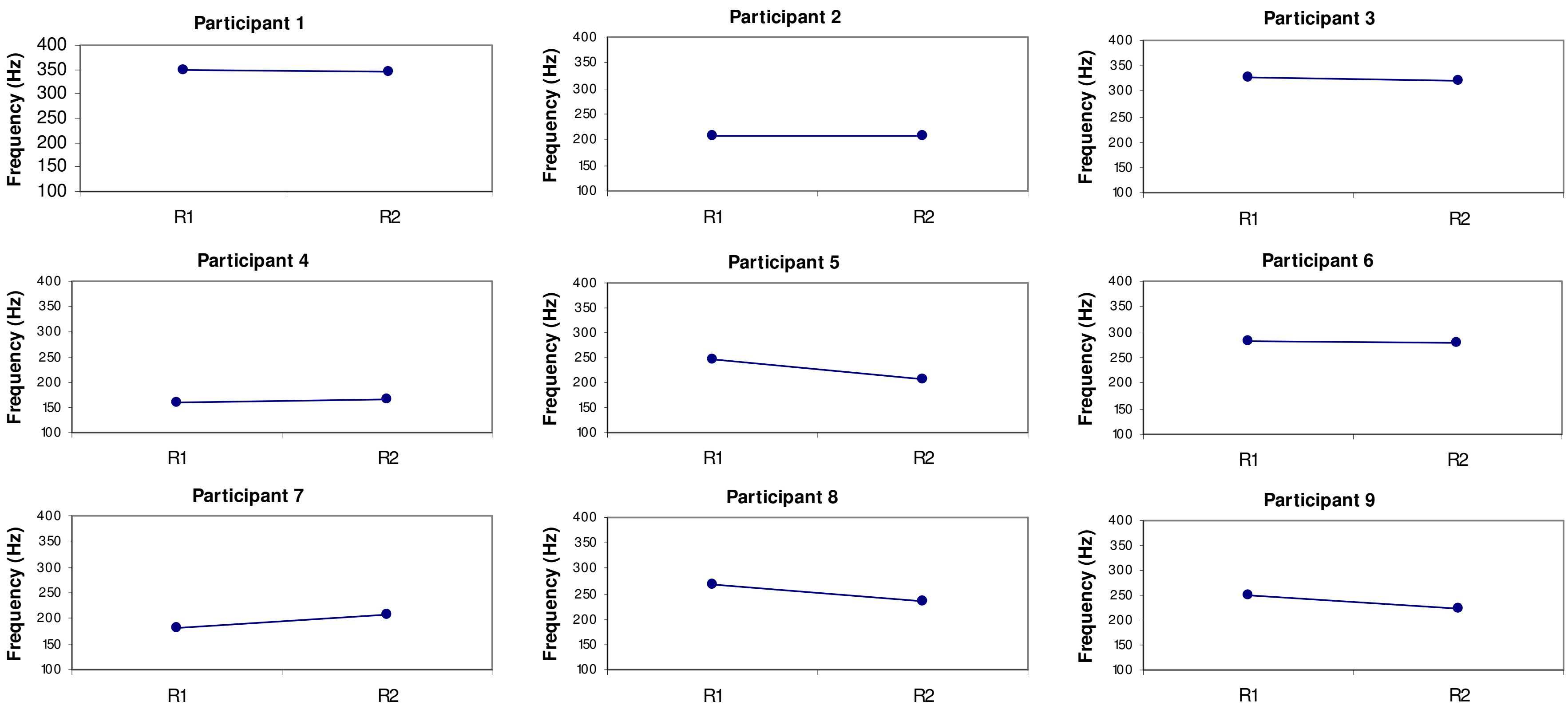


Figure 7: Individual results showing speaking rate, in syllables per second (sps), at Recording 1 (R1) and Recording 2 (R2).

Table 4: Mean (m), standard deviation (SD) and range (R) of first formant bandwidth (BW1) values for each participant at Recording 1 (R1) and Recording 2 (R2). All values are reported in Hertz.

	BW1					
	R1			**R2**		
Participant	***m***	***SD***	***R***	***m***	***SD***	***R***
1	348	269.62	110-892	345	120.36	190-561
2	208	149.72	46-452	207	164.61	70-628
3	328	115.87	169-526	322	165.58	188-691
4	159	193.19	34-613	164	115.81	26-394
5	248	81.73	186-439	207	95.71	65-377
6	281	189.87	59-661	279	229.02	60-643
7	180	120.03	47-408	206	136.99	72-476
8	269	128.34	126-480	233	105.61	93-412
9	251	141.50	63-446	223	131.40	53-474
10	159	110.31	63-438	244	149.31	80-545
11	173	79.17	81-317	184	109.56	39-312
Grand Mean	**236**	**66**		**237**	**56**	



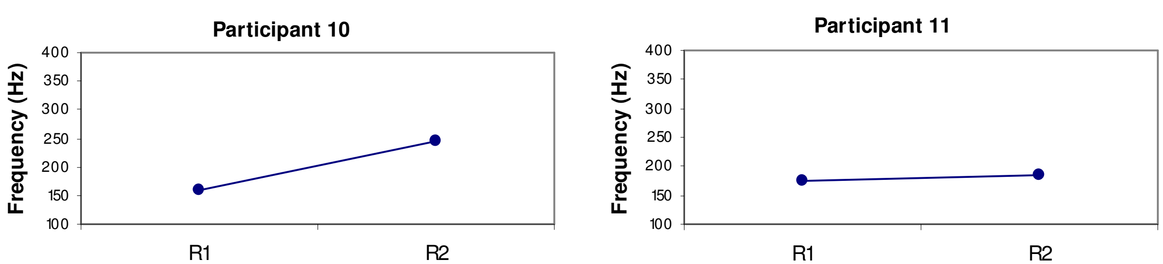


Figure 8: Individual results showing BW1 frequency values, in Hertz, at Recording 1 (R1) and Recording 2 (R2).

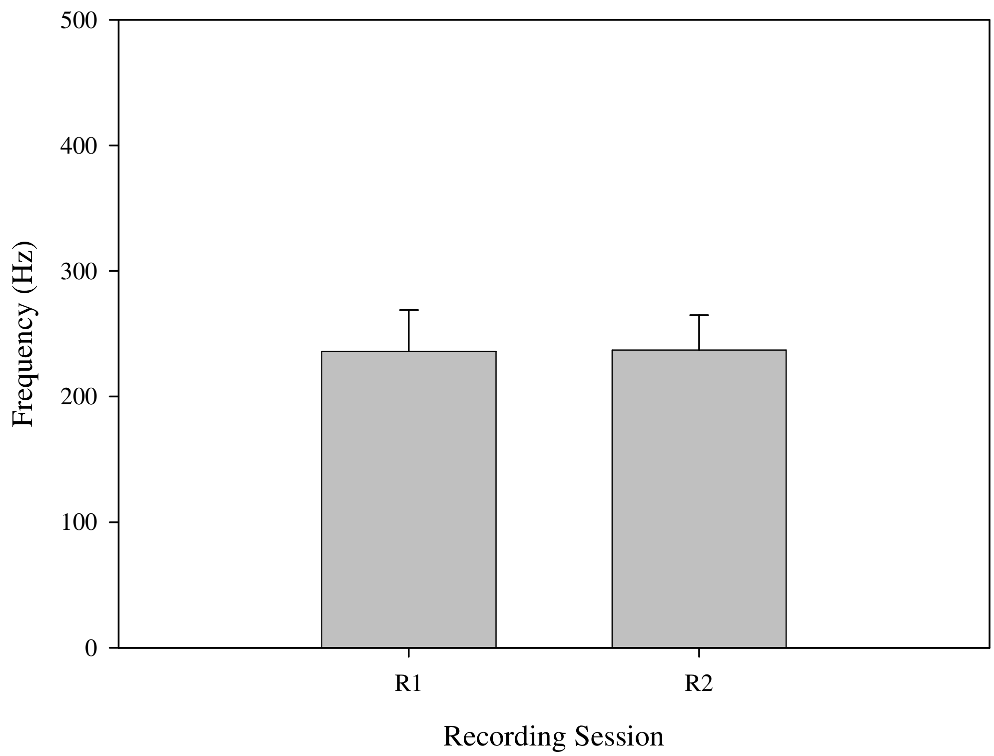
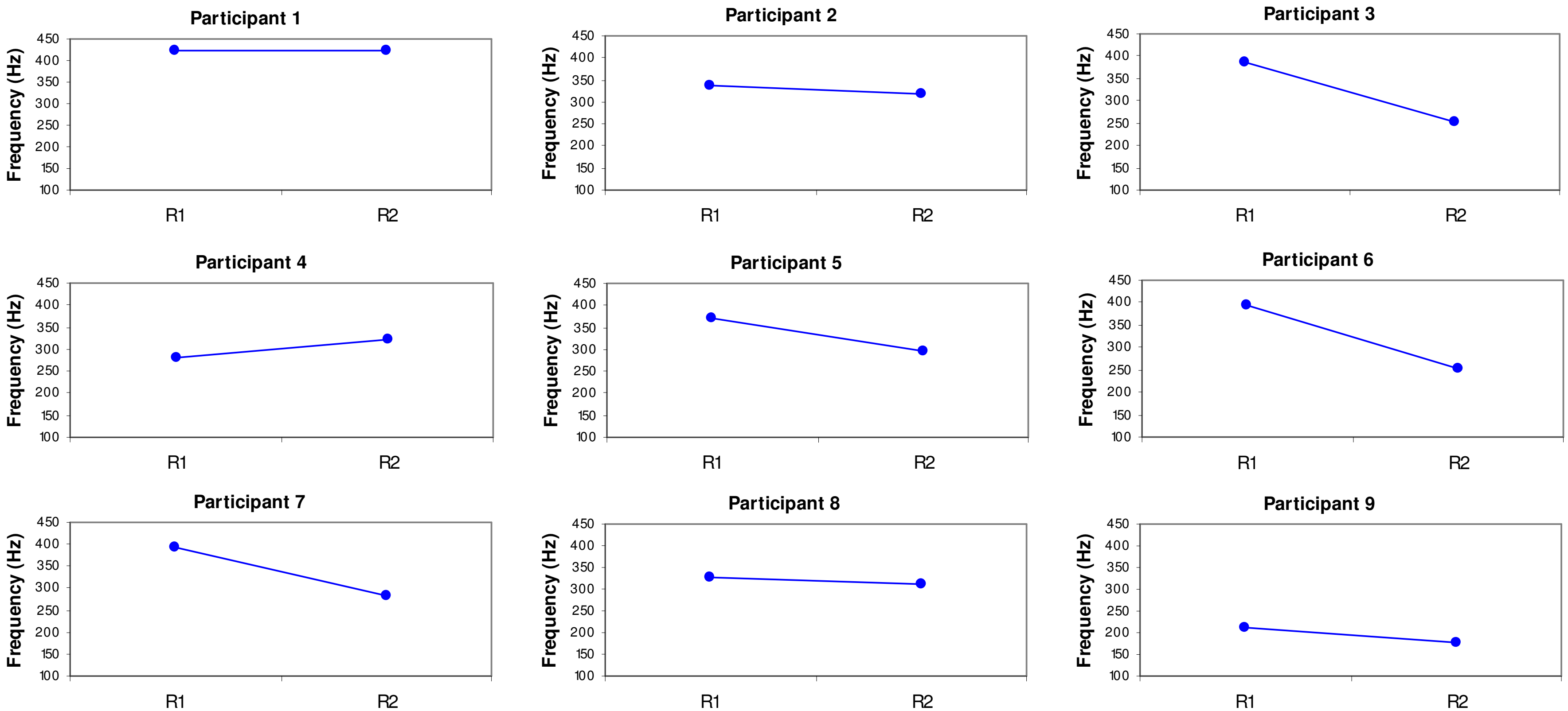


Figure 9: Mean first formant bandwidth values (BW1), in Hertz, for all participants at Recording 1 (R1) and Recording 2 (R2).

Table 5: Mean (m), standard deviation (SD) and range (R) of second formant bandwidth (BW2) values for each participant at Recording 1 (R1) and Recording 2 (R2). All values are reported in Hertz.

	BW2					
	R1			R2		
Participant	***m***	***SD***	***R***	***m***	***SD***	***R***
1	424	189.40	197-700	423	196.51	189-667
2	337	242.47	81-747	319	143.51	111-512
3	385	248.14	119-876	253	135.25	118-561
4	281	175.90	83-614	322	165.91	100-616
5	370	295.19	120-1007	295	175.57	112-712
6	395	196.89	206-843	254	128.69	137-443
7	391	207.30	120-657	284	153.47	93-585
8	327	157.49	112-559	311	168.99	118-619
9	210	145.27	56-507	177	125.28	72-475
10	344	246.15	131-861	347	119.84	190-558
11	417	332.54	77-1086	176	110.93	62-384
Grand Mean	**352**	**63**		**287**	**71**	



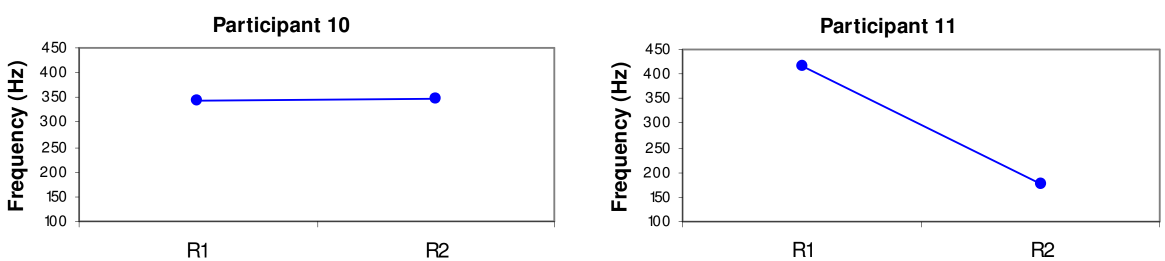


Figure 10: Individual results showing BW2 frequency values, in Hertz, at Recording 1 (R1) and Recording 2 (R2).

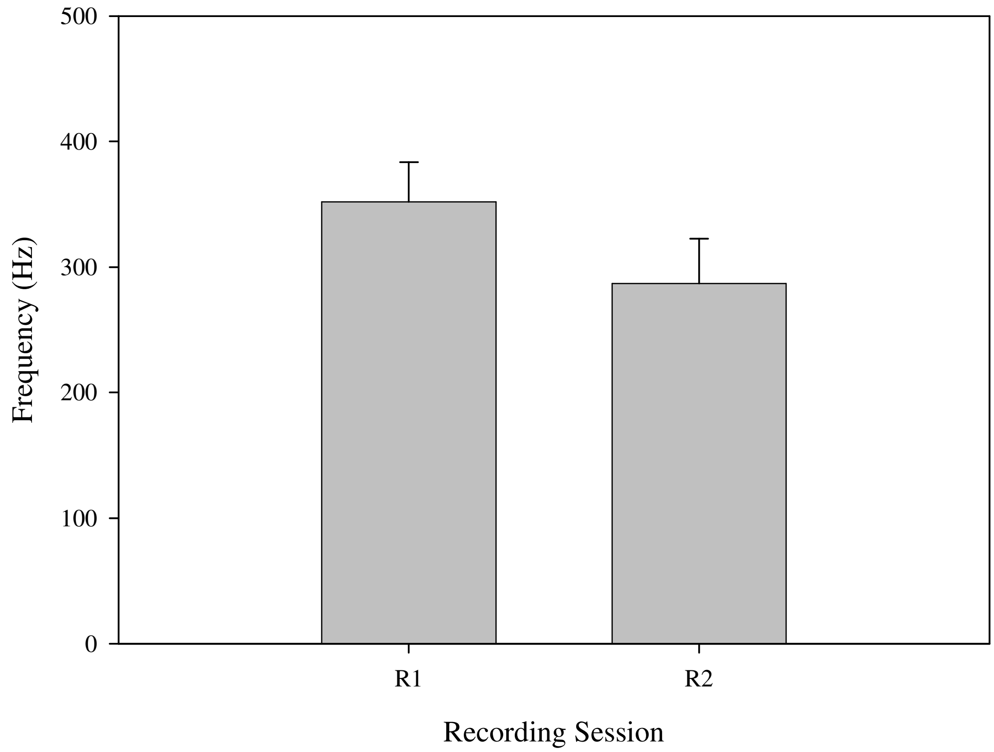


Figure 11: Mean second formant bandwidth values (BW2), in Hertz, for all participants at Recording 1 (R1) and Recording 2 (R2).

Perceptual Results

Paired Comparison Task. The mean percentage of R1 correctly being rated as more nasal than R2 (R1>R2) and incorrectly rated as less nasal than R2 (R1<R2) for all participants is displayed in Figure 12. The mean percentage for R1>R2 was 57% indicating that more than half of the R1 samples were correctly rated as more nasal than the faster speaking rate recordings at R2. The mean percentage for R1<R2 was 43%. A t-test was performed to determine whether R1 was rated as significantly more nasal than R2. Prior to performing the test, the percentage values were converted to arcsin values. Results showed a significant difference [$t(20)= 2.23$, $p= 0.0372$], indicating a change in perception of nasality from R1 to R2. The perceptual ratings specific to each of the HI participants are listed in Table 6 and Figure 13.

Sliding scale task. Mean perceptual rating values for the HI participants across R1 and R2 are listed in Table 7 and Figure 14. The mean rating value at R1 was 5.99 with a range of 0 – 10. The mean rating value at R2 was 5.34 with a range of 0 – 10. A t-test was conducted to assess whether the ratings at R2 changed significantly from the ratings at R1. Results showed a significant difference between the two measures [$t(10) = 3.284$, $p= 0.008$], indicating a lower nasality score at R2. The overall group mean values for perceptual rating are displayed in Figure 15. In addition, a series of alpha-adjusted paired t-tests were conducted to determine if any significant differences were present in the ratings between R1 and R2 for each individual. No significant differences were found for the HI participants, with the exception of Participant 7 [$t(20)= 4.333$, $p= <0.001$], when the adjusted p-value was used.

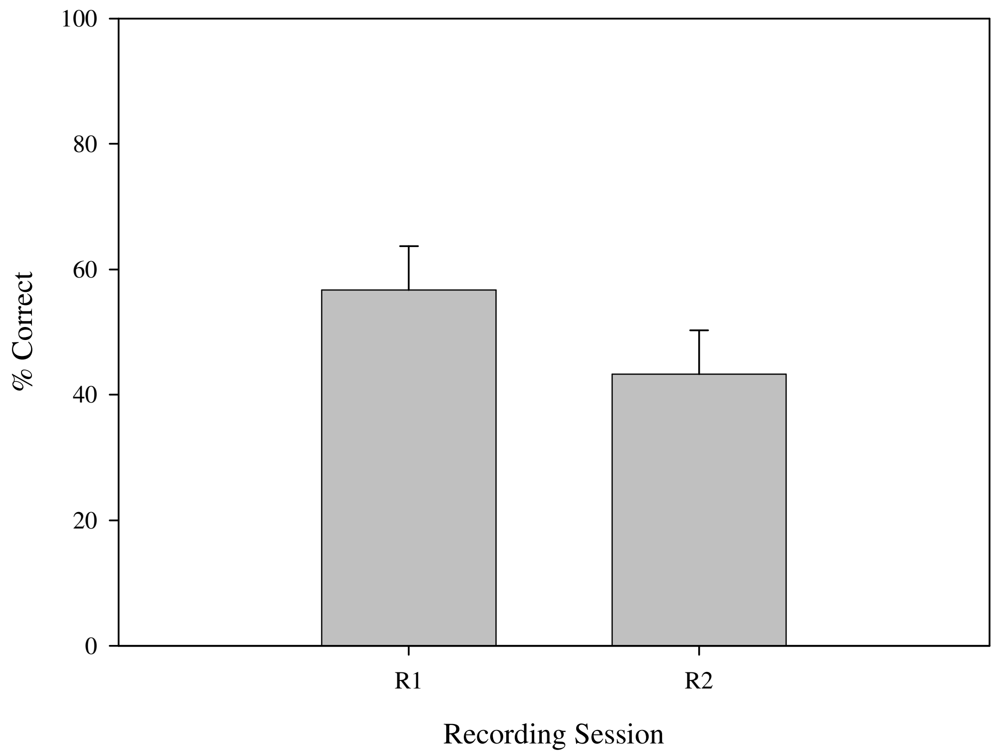


Figure 12: Percentage correct scores for Recording 1 (R1) being rated as more nasal than Recording 2 (R2) (R1>R2), for all participants.

Table 6: Mean percentage score for Recording 1 (R1) being correctly rated as more nasal than Recording 2 (R2), R1>R2, and for R1 being rated as less nasal than R2 (R1<R2), with corresponding arcsin values, for all participants.

	Percentage Correct Score			
	R1>R2	***Arcsin Value***	***R1<R2***	***Arcsin Value***
Participant				
1	66.67	1.9177	33.33	1.2239
2	71.43	2.0042	28.57	1.1374
3	28.57	1.1374	71.43	2.0042
4	42.86	1.4303	57.14	1.7113
5	61.90	1.8132	38.10	1.3284
6	57.14	1.7113	42.86	1.4303
7	52.38	1.6108	47.62	1.5308
8	52.38	1.6108	47.62	1.5308
9	80.95	2.2395	19.05	0.9021
10	52.38	1.6108	47.62	1.5308
11	57.14	1.7113	42.86	1.4303
Mean	**56.71(14.04)**	**1.7088(0.29)**	**43.29(14.04)**	**1.4327(0.29)**

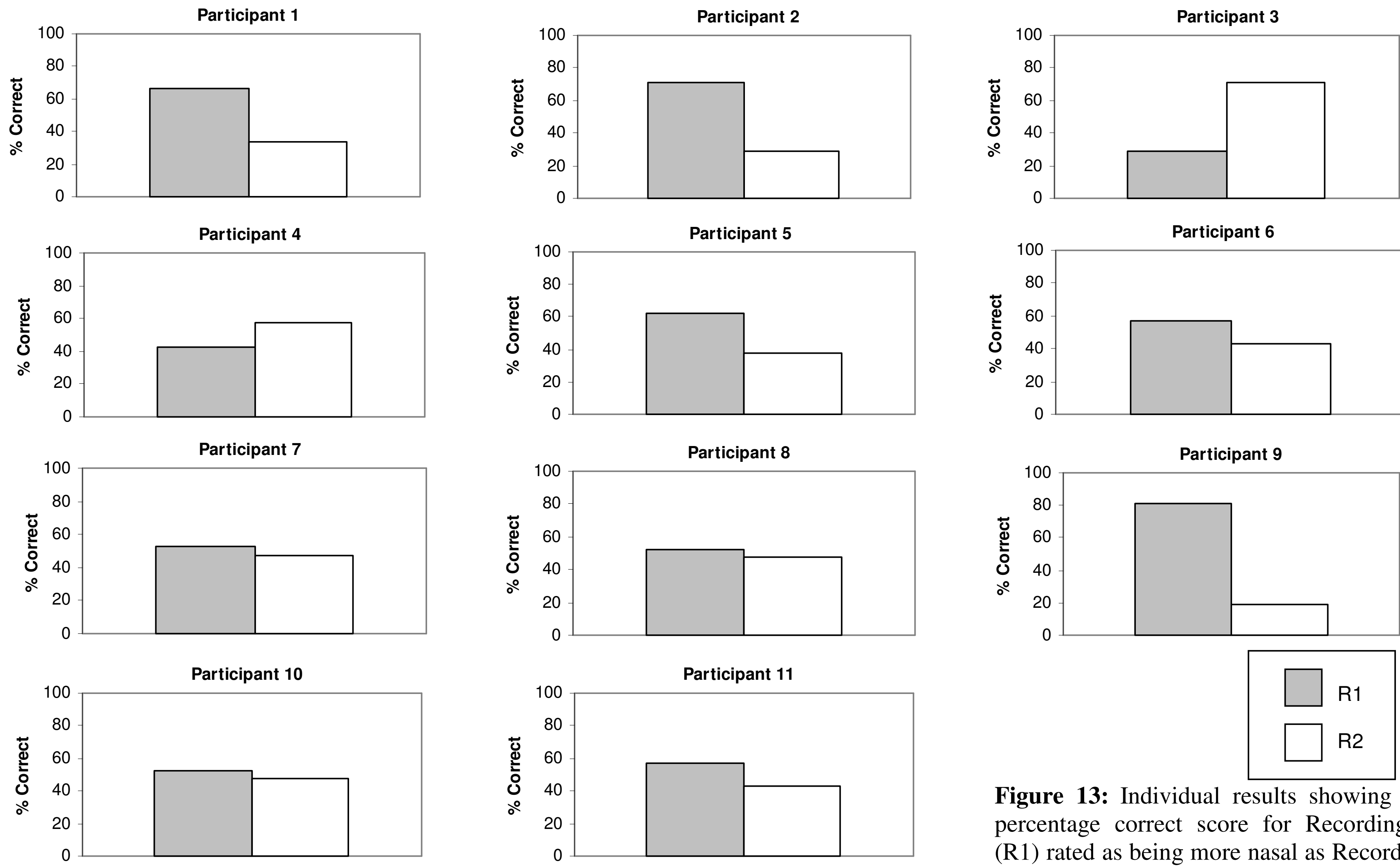
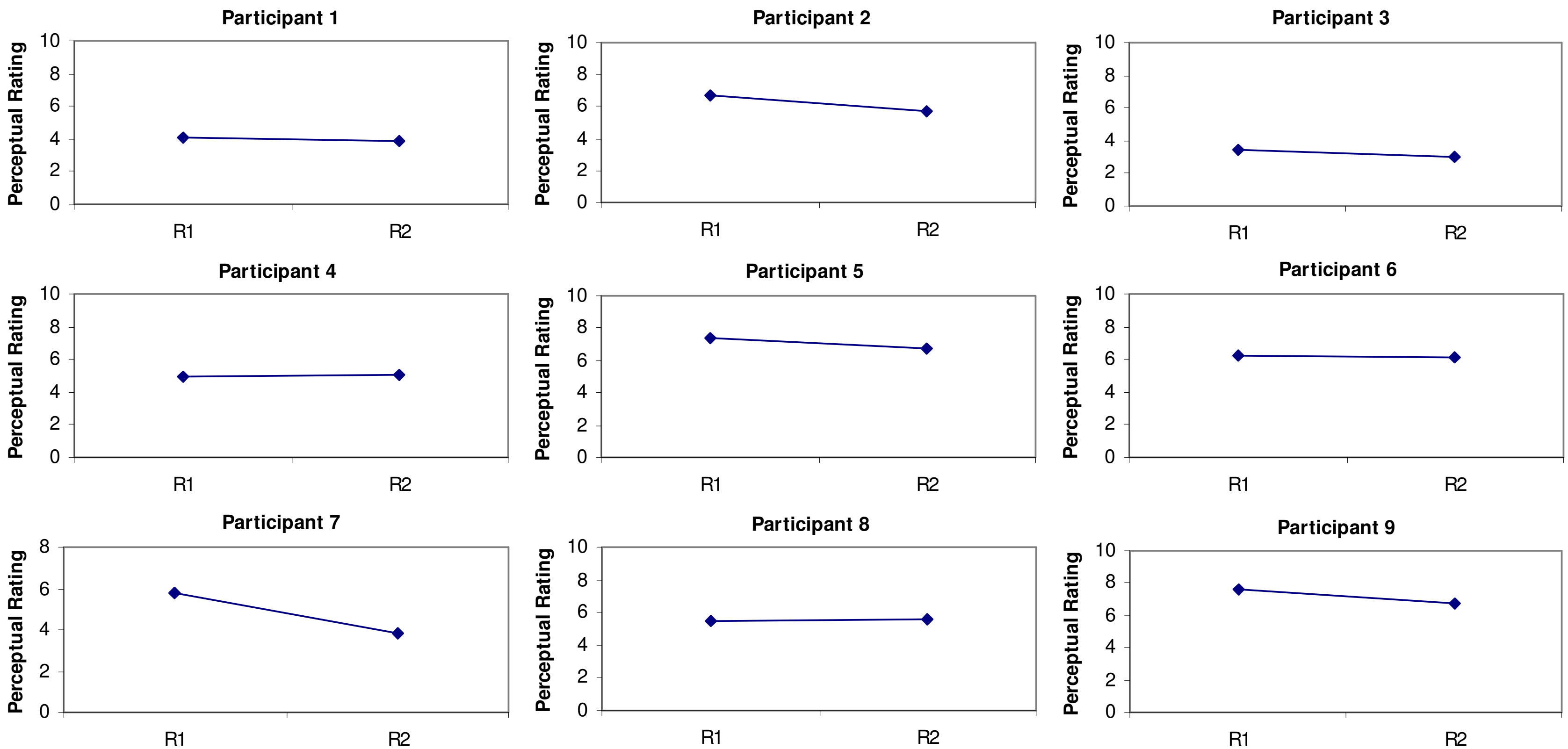


Figure 13: Individual results showing the percentage correct score for Recording 1 (R1) rated as being more nasal as Recording 2 (R2).

Table 7: Mean (m), standard deviation (SD), and range (R) for perceptual rating values of all participants at Recording 1 (R1) and Recording 2 (R2). A score of 0 reflected no nasality whereas a score of 10 reflected extreme nasality.

	Perceptual Rating					
	R1			**R2**		
Participant	***m***	***SD***	***R***	***m***	***SD***	***R***
1	4.04	2.42	0.65 – 9.40	3.83	2.43	0.96 – 9.48
2	6.71	2.21	2.96 – 9.60	5.72	2.40	0.62 – 10
3	3.41	2.51	0.00 – 9.57	2.97	1.80	0.00 – 6.06
4	4.97	2.64	1.19 – 10	5.04	2.57	0.66 – 9.20
5	7.37	2.26	1.16 – 10	6.76	2.32	1.93 – 10
6	6.25	2.23	0.96 – 10	6.12	2.91	0.00 – 9.71
7	5.80	2.35	1.02 – 9.45	3.84	2.17	0.00 – 8.23
8	5.45	2.63	1.19 – 9.00	5.59	2.51	0.96 – 8.97
9	7.64	1.77	3.64 – 10	6.78	2.19	1.56 – 10
10	7.02	2.62	0.91 – 10	6.40	2.70	0.59 – 9.08
11	7.27	2.40	1.19 - 10	5.68	2.17	1.96 – 8.74
Grand Mean	**5.99**	**1.40**		**5.34**	**1.27**	



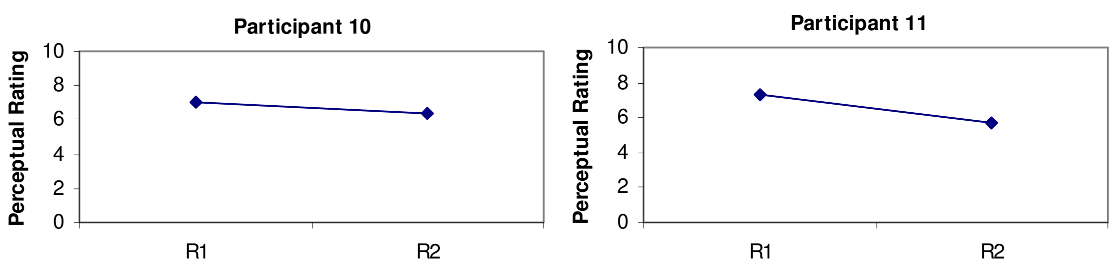


Figure 14: Individual results showing the mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) at Recording 1 (R1) and Recording 2 (R2).

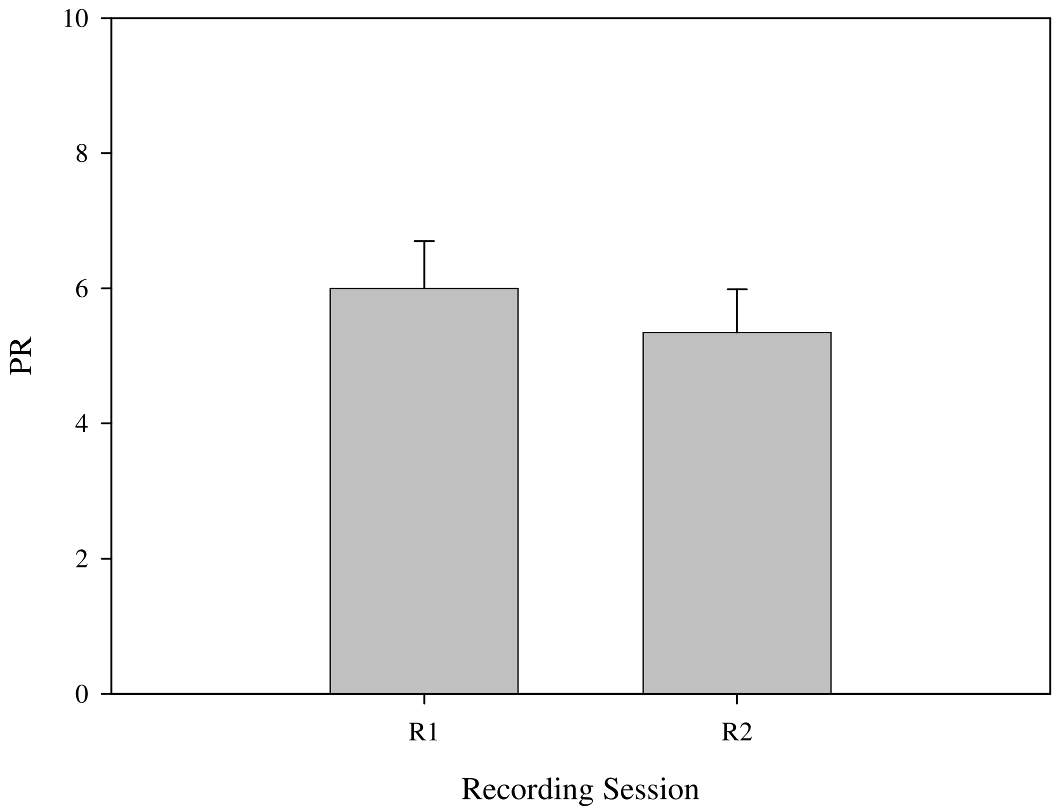


Figure 15: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) for all participants at Recording 1 (R1) and Recording 2 (R2).

Correlational Analysis

Speaking Rate and BW1. A Pearson product-moment correlation was performed to examine the relationship between speaking rate and BW1 at R1 and R2. No significant relationship was found between these variables at either R1 (r= 0.11, p= 0.752) or R2 (r= -0.04, p= 0.898). The relationship between BW1 and speaking rate at R1 and R2 is displayed in Figures 16 and 17, respectively.

Speaking Rate and BW2. A Pearson product-moment correlation was performed to examine the relationship between speaking rate and BW2 at R1 and R2. Results showed no significant relationship between these variables at either R1 (r= -0.14, p = 0.691) or R2 (r= -0.16, p= 0.637). BW2 frequency values and speaking rate for all participants at R1 and R2 are displayed in Figures 18 and 19, respectively.

Perceptual Rating and BW1. To investigate the relationship between BW1 and perceptual rating a Pearson product-moment correlation was conducted at R1 and R2. Results indicated no significant relationship between these variables at either R1 (r= -0.55, p= 0.083) or R2 (r= -0.48, p= 0.131). The relationship between BW1 and perceptual rating at R1 and R2 is displayed in Figures 20 and 21, respectively.

Perceptual Rating and BW2. A Pearson product-moment correlation was conducted between BW2 and perceptual rating at R1 and R2 to investigate the relationship between these variables. No strong relationship was found between BW2 and rating values at either R1 (r= -0.32, p= 0.343) or R2 (r= -0.28, p= 0.402). The relationship between BW2 and perceptual rating at R1 and R2 is displayed in Figures 22 and 23, respectively.

Perceptual Rating and Speaking Rate. A Pearson product-moment correlation was performed to examine the relationship between perceptual rating and speaking rate for all participants at R1 and R2. Results indicated no significant relationship between these two variables at either R1 (r= -0.19, p= 0.575) or R2 (r=-0.47, p= 0.147). The relationship between speaking rate and rating values at R1 and R2 is displayed in Figures 24 and 25, respectively.

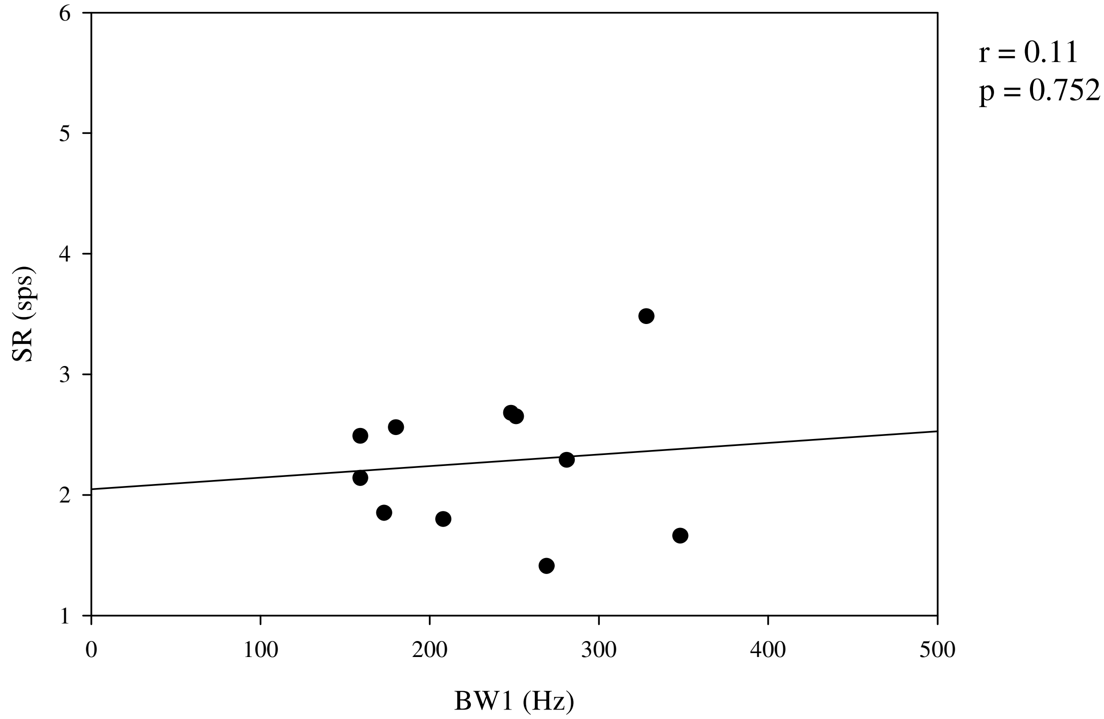


Figure 16: Mean first formant bandwidth frequency (BW1), in Hertz, and speaking rate (SR), in syllables per second (sps), for all participants at Recording 1 (R1).

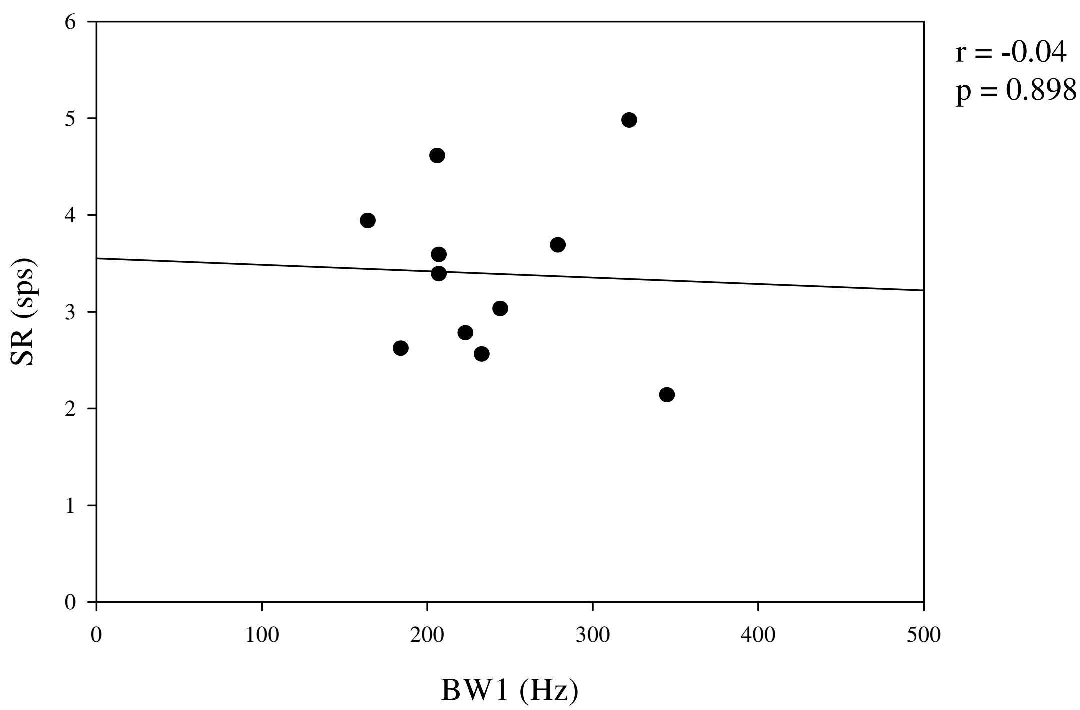


Figure 17: Mean first formant bandwidth frequency (BW1), in Hertz, and speaking rate (SR), in syllables per second (sps), for all participants at Recording 2 (R2).

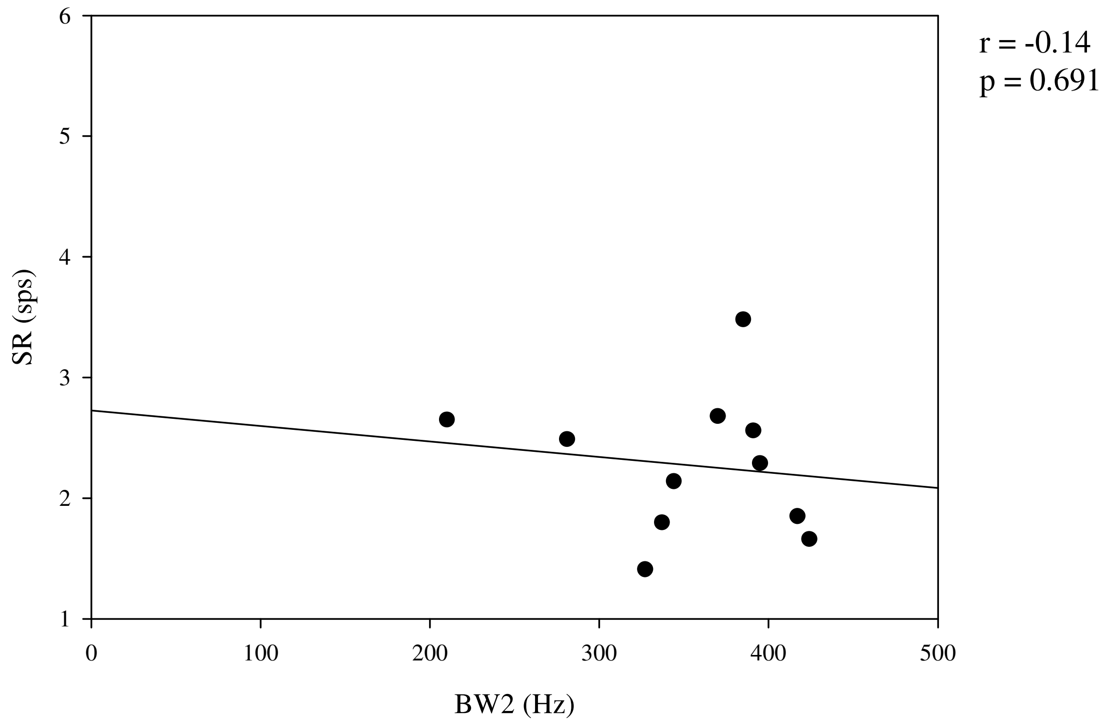


Figure 18: Mean second formant bandwidth (BW2) values, in Hertz, and speaking rate (SR), in syllables per second (sps), for all participants at Recording 1 (R1).

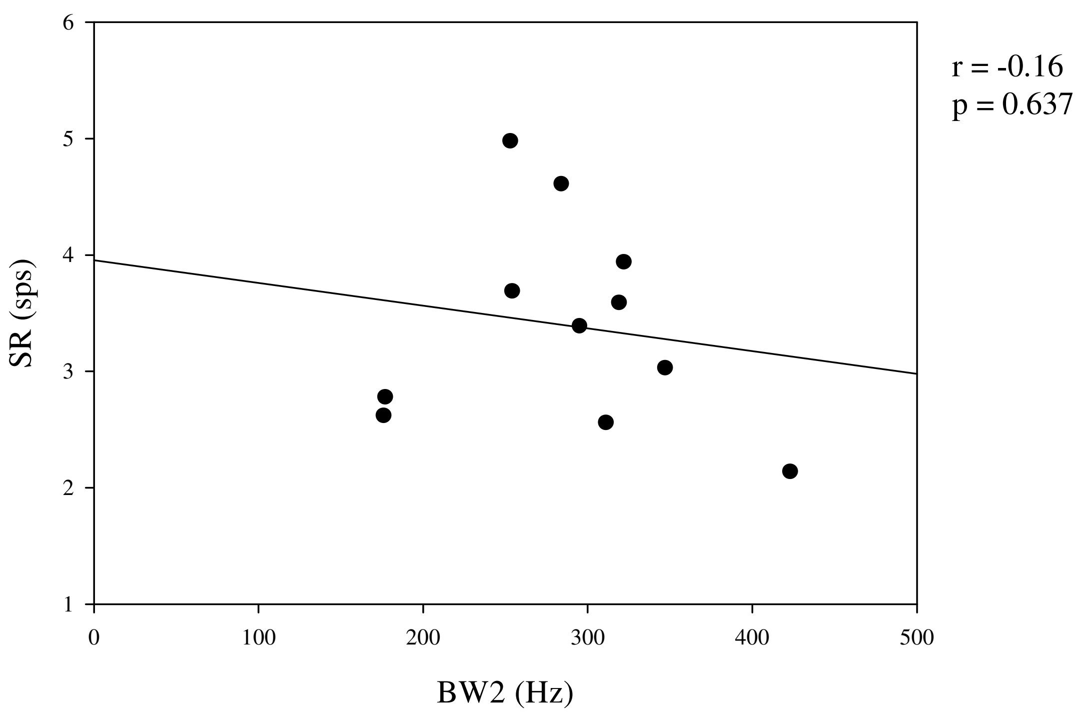


Figure 19: Mean second formant bandwidth values (BW2), in Hertz, and speaking rate (SR), in syllables per second (sps), for all participants at Recording 2 (R2).

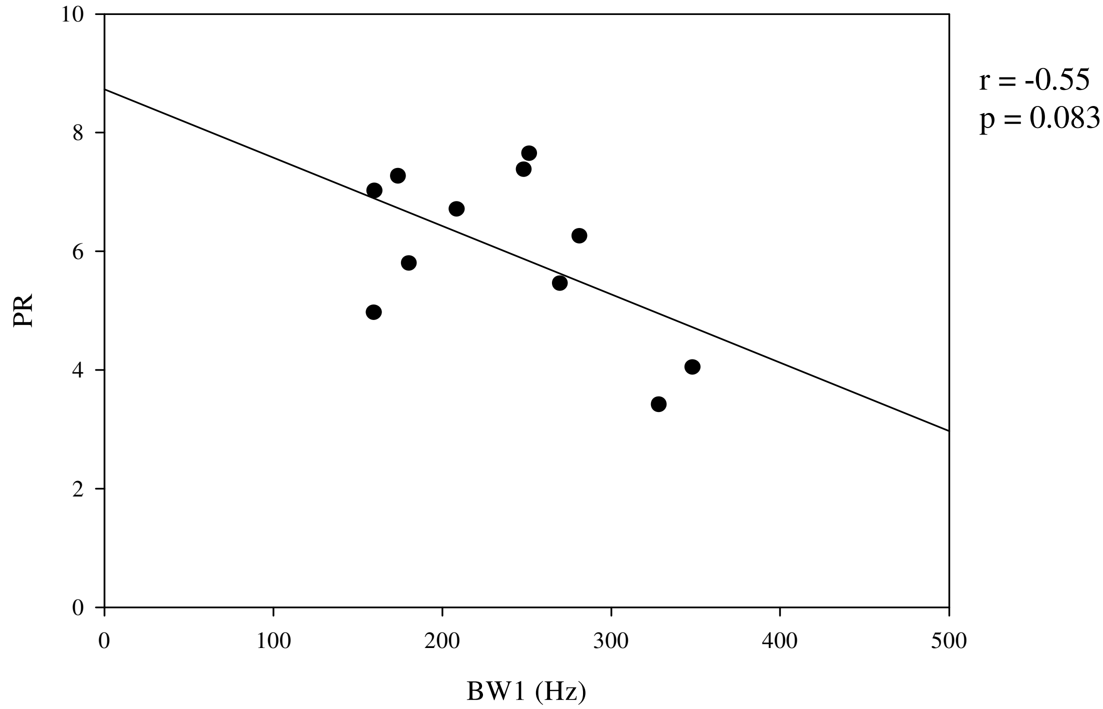


Figure 20: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) and first formant bandwidth frequency (BW1), in Hertz (Hz), for all participants at Recording 1 (R1).

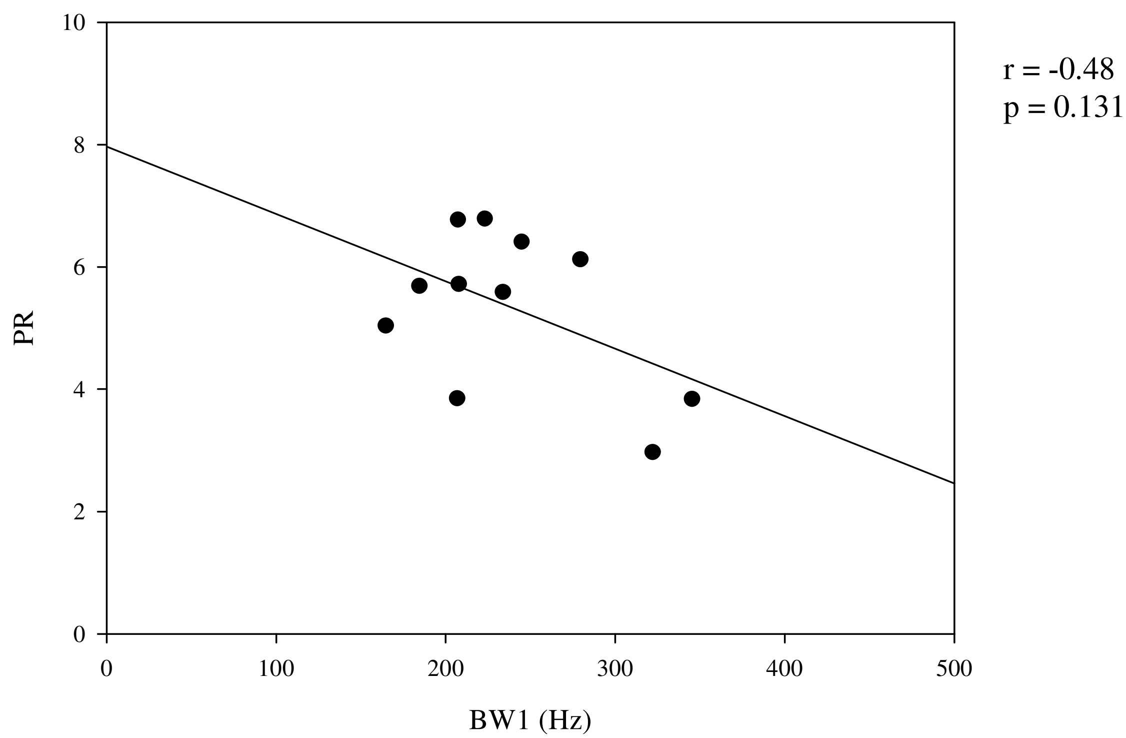


Figure 21: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) and first formant bandwidth frequency (BW1), in Hertz (Hz), for all participants at Recording 2 (R2).

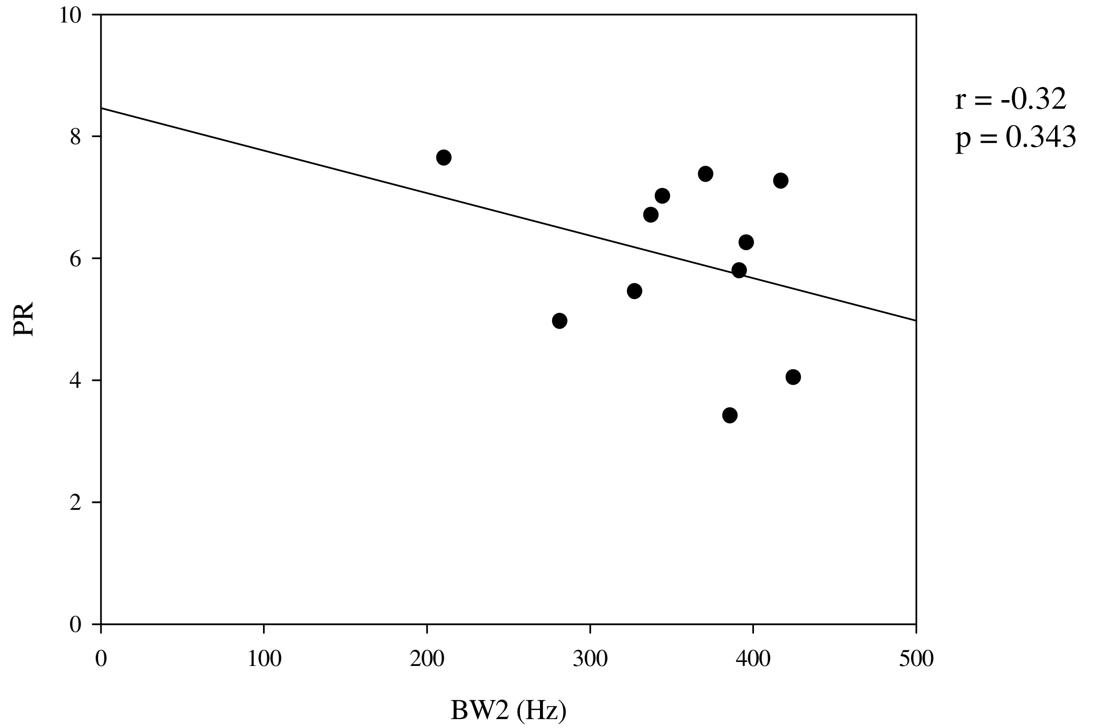


Figure 22: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) and second formant bandwidth (BW2) values, in Hertz (Hz), for all participants at Recording 1 (R1).

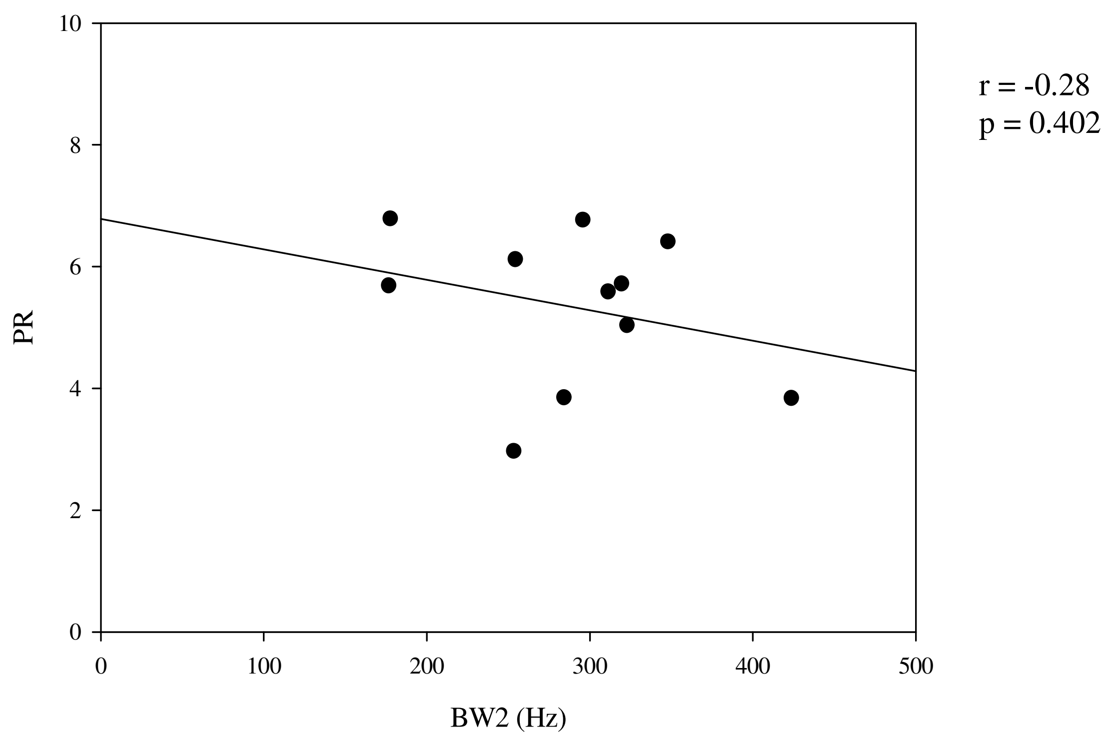


Figure 23: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) and second formant bandwidth (BW2) frequency, in Hertz, for all participants at Recording 2 (R2).

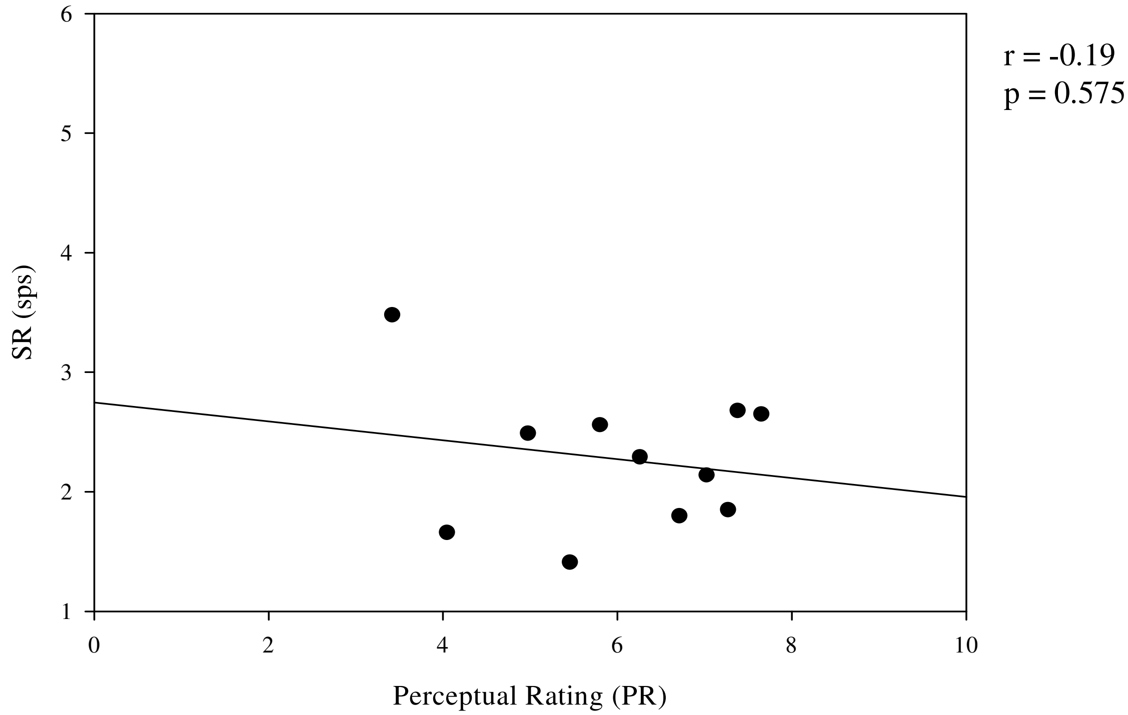


Figure 24: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) and speaking rate (SR), in syllables per second (sps), for all participants at Recording 1 (R1).

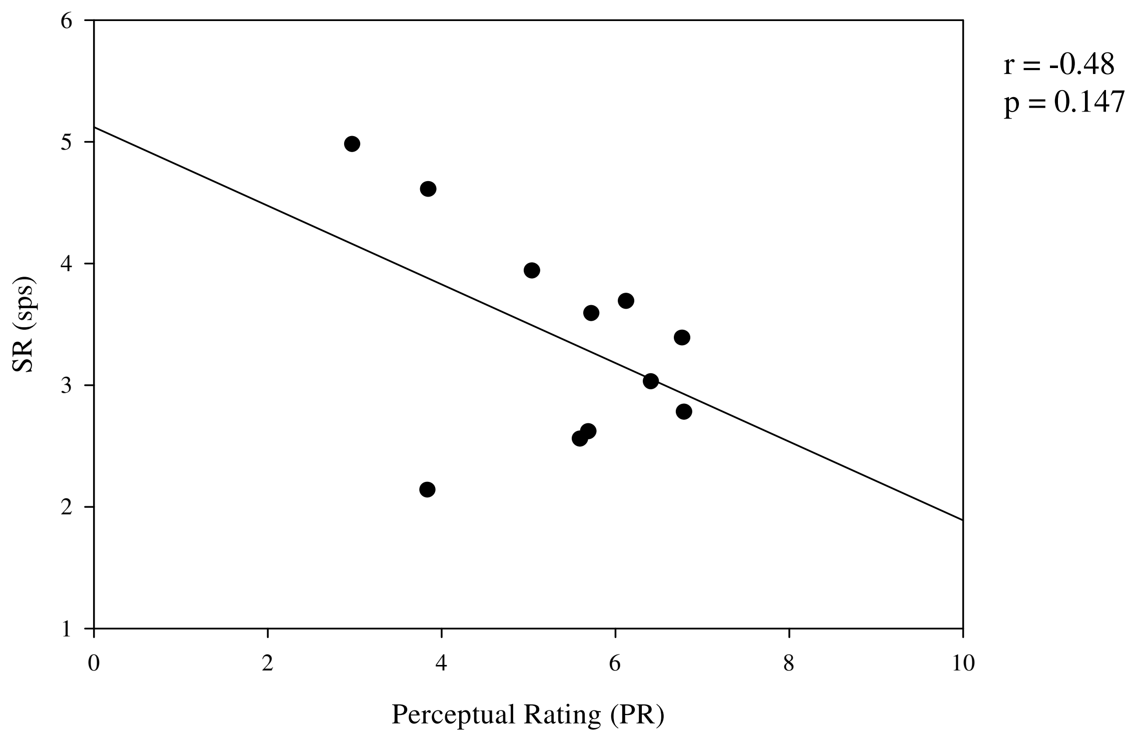


Figure 25: Mean perceptual rating (PR) values (0 = no nasality, 10 = extreme nasality) and speaking rate (SR), in syllables per second (sps), for all participants at Recording 2 (R2).

Discussion

The purpose of the present study was to evaluate the effect of deliberate increases in speaking rate on the presence of nasality in the speech of HI individuals. It was proposed that increases in speaking rate would result in significant decreases in both acoustic and perceptual measures of nasality. The following discussion will address this hypothesis with regards to acoustic results, perceptual results and the correlational analysis conducted.

Acoustic Results

Speaking Rate. Results indicated that all HI participants increased their speaking rate across R1 and R2. There was a considerable range of speaking rate change across the participants, ranging from a 4% increase (Participant 9) to 99% increase (Participant 2) at R2. However, a majority of the participants (n = 8) were able to increase their rate by greater than 40% of the original rate. These results are consistent with the findings of Boone (1966), and Wilson and McReynolds (1973) who successfully trained HI individuals to increase their oral reading rate using a timing device such as a metronome or vibrotactile oscillator. The instrumentation used in the present study differed from past studies in that a computer-based software system was used to increase speaking rate. The instrument was selected because it was considered a more current timing device than those used in previous studies. It was also considered more applicable to the HI students who took part in the study, as all the participants use computers as part of their education at VADEC. In spite of the differences in instrumentation between the present and past studies, the goal was the same; namely to increase speaking rate. It is important to note therefore that it is possible to train HI individuals to increase their speaking rate across a short training period.

BW1 and BW2. The results obtained for the measurement of BW1 and BW2 were mixed. Across the two recording sessions, BW1 remained essentially unchanged. Examination of the individual results for the participants (Table 4) indicated that seven of the 11 HI participants demonstrated a lower BW1 at R2. However, the magnitude of the decrease ranged from only 1 Hz (Participant 2) to 41 Hz (Participant 5). Although past research of HI speakers has indicated that nasality is likely to decrease with increases in speaking rate (Gilbert & Hoodin, 1984), there have been few, if any, studies which have specifically evaluated nasality according to formant frequency bandwidth. Several possibilities are offered as to why BW1 did not change noticeably with increases in speaking rate. First, it is possible that the measurement of BW1 could have been influenced adversely by the presence of nasality in HI participants' speech. Researchers have reported the presence of a low frequency resonance (i.e., murmur) just below F_1 that is introduced into the sound spectrum when vowels are nasalized (Chen, 1995; Dickson, 1962; House & Stevens, 1956). This nasal resonance may have influenced the accuracy of the LPC measurement system in the present study. Therefore, the lack of change in BW1 between R1 and R2 may have simply resulted from a strong nasal murmur that remained in the speech spectra. It is interesting to note that past studies evaluating changes in vocal tract development have similarly found minimal change in BW1. Robb et al. (1997) evaluated children between the ages of four and 25 months and found that decreases in nasality were more closely associated with changes in BW2 rather than BW1 frequencies.

A second possibility regarding the lack of change in BW1 concerns the anatomical correlates of BW1. In the model prepared by House and Stevens (1956), the F_1 frequency is assumed to reflect pharyngeal resonance (i.e., closest to the larynx), while F_2 resonance is more anterior in the vocal tract. Such being the case, it is likely that BW1 in the present study was unable to capture the nasalance in the signal of the HI participants' speech, as it may have been too low in the vocal tract. Another consideration is that of the speaking rate obtained by the HI individuals. Speaking rate of young adults with normal hearing is 4.66 sps (Robb, MacLagan, & Chen, 2004). In the present study, the fastest rate obtained by the HI speakers was approximately 3.39 sps. This rate was still considerably slower than what is found for normally hearing individuals. The average speed at which the participants spoke may not have been fast enough to achieve the amount of VP closure required to have a noticeable effect on BW1 frequencies. This again could be attributed to the location of the F_1 resonance in the vocal tract.

Contrary to the results found for BW1, there was a significant decrease in BW2 frequency across recording sessions indicating less nasality at the faster speaking rate. The observed differences are consistent with previous work suggesting that nasality in HI speakers decreases with increased speaking rate (Gilbert & Hoodin, 1984; Hood & Dixon, 1969; Hudgins, 1934; McClumpha, 1969). More specifically, it supports the research by Robb et al. (1997) who found, at least developmentally, that more pronounced changes occurred to BW2 frequencies than BW1 frequencies as nasality decreased. Contrary to the findings of Robb et al (1997) and those of the present study, are those of Dickson (1962) and House and Stevens (1956). Dickson noted decreases in formant bandwidth frequencies for both F_1 and F_2 as nasality decreased in functionally hypernasal speakers and individuals with cleft palate. House and Stevens developed an acoustic analogue of the vocal tract in order to study the acoustic properties that occur in the speech spectrum when vowels become nasalized. House and Stevens found the most pronounced changes occurred in the region of F_1 when vowels were nasalized. They also reported changes in BW2 frequencies as vowels became nasalized, although these were not as pronounced as changes in BW1 frequencies. House and Stevens concluded that changes in the region of F_1 may be of importance in determining the presence of nasality in speech. The primary difference between the present study and that conducted by House and Stevens is that the present study looked at HI speakers and directly measured their speech for nasality. House and Stevens developed a mathematical model of nasality and observed changes to formant bandwidth frequencies. This methodological difference may have led to these contradictory results. Thus, there is still controversy over whether BW1 or BW2 frequencies more accurately reflect the presence of nasality in speech. Whether more noticeable changes occur in BW1 or BW2 frequencies in the speech spectrum of HI individuals is yet to be determined. Based on the results obtained for measurement of BW2 in the present study, support is provided for the original hypothesis that nasality decreases when speaking rate is increased.

Perceptual Results

Two tasks were conducted to evaluate whether increases in speaking rate would be accompanied by perceived decreases in the nasality of HI individuals' speech. The first task required a group of naïve listeners with normal hearing to compare paired samples of HI speech and to decide which of the samples sounded more nasal. The second task involved the same listeners individually rating a large randomised sample of HI individuals' speech, according to the degree of nasality, using a sliding severity rating scale of 0 to 10 (0 = no nasality & 10 = extreme nasality). The paired comparison task allowed for a direct examination of perceived changes in nasality for each HI participant at R1 and R2. The sliding scale task allowed for an overall comparison and evaluation of the degree of nasality present in the speech of the HI participants, when all speech samples, containing varying degrees of nasality, were presented to perceptual judges in the one task. Results obtained from both perceptual tasks were revealing of significant decreases in nasality from R1 to R2. Therefore, the perceptual results of the present study support the hypothesis that an increase in speaking rate will lead to a decrease in nasality in the speech of HI individuals.

These results confirm past findings for participants with normal hearing. Brancewicz and Reich (1989) demonstrated that perceived nasality in normal hearing speakers decreases as speaking rate increases. Similarly, Goberman et al. (2001) recorded significantly lower perceived nasality scores when individuals with normal hearing spoke at a normal or fast rate when compared to a slow speaking rate.

The decrease in nasality found in the present study may be indicative of the VP mechanism working more efficiently at faster speaking rates. Previous research has shown that at slower speaking rates the velum fails to make sufficient contact with the posterior pharyngeal wall resulting in excessively nasal speech (Brancewicz & Reich, 1989; Bzoch, 1968; Goberman et al., 2001; Hudgins, 1934). Past explanations for nasality present in the speech of HI individuals have focussed on either functional or structural abnormalities of the VP mechanism. Furthermore, HI individuals in particular speak at slower speaking rates which may serve to intensify the presence of nasality in their speech. McClumpha (1969) concluded that structural abnormalities may exacerbate the presence of nasality in HI speakers. The present study did not address structural deformities of the VP mechanism, as no imaging observing VP competency at slow and faster speaking rates was conducted. The results obtained in the present study suggest that VP functionality can be improved and is therefore amenable to change. However, the fact that the average nasality score at R2 was 5.34 would indicate that nasality was still persistent the speech of the HI participants. If the nasality at R2 had been judged to be closer to zero, it could be argued that nasality was primarily a result of a functional abnormality. In light of the nasality still present in the speech of the HI participants; one cannot entirely rule-out the possibility of a structural influence on the presence of nasality in the speech of HI individuals. Even so, the contention that nasality in the speech of HI individuals may be partly due to a functional inadequacy of the VP mechanism is supported, as significant decreases in nasality at the faster speaking rate did occur in the present study. These results support the suggestions by Hudgins (1934), Stevens et al. (1976), Zimmerman and Rettaliata (1981) and Ysunza and Vazquez (1993) that nasality present in the speech of HI individuals is due to a functional abnormality of the VP mechanism.

<u>Correlational Analysis</u>

A series of correlational analyses were used to determine whether any of the acoustic and perceptual variables of nasality were significantly related. Results of the correlational analysis between perceptual ratings, speaking rate and other acoustical measures (BW1 & BW2) indicated that no specific variables of nasality were related to one another. Although changes in speaking rate occurred across sessions, and a decrease in nasality was observed (both perceptually and acoustically), these variables were not correlated. Similarly, research by Dickson (1962) found no relationship between acoustic and perceptual measures of nasality. Contrary to the findings of the present study are those of Brancewicz and Reich (1989) who found a small but significant relationship between speaking rate and perceived nasality; however, these researchers looked at individuals with normal hearing.

Two explanations are offered for the lack of correlation between acoustic and perceptual measures of nasality. Previous research has shown that many variables, such as speaking rate, loudness, F_0, and articulation errors, can influence the presence of nasality in the speech of HI individuals (Fletcher & Higgins, 1980; Lintz & Sherman, 1961; Lock & Seaver, 1984; Nickerson, 1975; Sherman, 1954; Stevens et al., 1976). The present study was designed to control for speaking rate, loudness and articulation errors. A variable not considered was that of F_0. Past studies have shown that the F_0 of HI individuals is generally higher when compared to that of normal hearing individuals (Boone, 1966; Gilbert & Campbell, 1980; Horii, 1982; Nickerson, 1975). Researchers have also shown that insufficient F_0 changes, resulting in monotonic speech, can occur in HI speakers (Calvert, 1962; Horii, 1982; Martony, 1968; Voelker, 1935), while others have reported excessive variation of F_0 in the speech of HI individuals (Giusti, Padovani, Behlau, & Granato, 2001; Higgins et al., 1994; Martony, 1968). In addition, variations in F_0 are thought to influence perceptual ratings of nasality in speakers with VP dysfunction such as cleft palate (Lintz & Sherman, 1961; Sherman, 1954; Spriestersbach, 1955). Furthermore, Kataoka et al. (2001) demonstrated that changes in the amplitude of F_0 in either direction serve to increase ratings of nasality in children with cleft palate and those with velar insufficiency. It follows that ratings of nasality in HI individuals are influenced by factors such as F_0, speaking rate and articulation errors. Accordingly, in the present study, changes in F_0 that may have occurred with an increase in speaking rate could have played a role in the perception of nasality. It remains to be determined whether F_0 is a significant correlate of perceptual ratings of nasality.

An alternate explanation for the lack of significant relationship between perceptual and acoustic measures of nasality may be due to a measurement issue. Kataoka et al. (2001) used a 1/3 octave band analysis method to determine acoustic measures of nasality in 32 children with cleft palate and 5 children without cleft palate. The 1/3 octave analysis method was chosen because the bandwidth closely approximated the critical bandwidth analysis system of the human ear (Pols, Van Der Kamp, & Plomp, 1969). In addition, this method was considered compatible to the formant analysis traditionally used (Bakkum, Plomp, & Pols, 1995). When comparisons between the nasal and non-nasal groups were made, researchers found increased amplitudes between F_1 and F_2 and decreased amplitudes within the F_2 region. Furthermore, correlational analysis revealed a strong relationship between these acoustic measures and the perceptual ratings of nasality obtained, suggesting that this method may be a more reliable way of determining the presence of nasality acoustically.

Chen (1995) reported the presence of several acoustic parameters present in the spectrum of nasalized vowels produced by HI speakers. She evaluated the speech spectra of 16 HI individuals between the ages of 11 and 17 years and found that as BW1 widened the perception of nasality increased. Contrary to present findings, a strong correlation was found between A1-P1 (the difference between the amplitude of F_1 and the resonance peak between the first two formants) and perceptual ratings of nasality in the speech of the HI participants. In addition, a correction factor was developed to eliminate the effect of the low frequency resonance present when vowels were nasalized. When this low frequency resonance was taken into account, correlations between acoustic measures and judgements of nasality were stronger.

Clinical Implications

Based on the results obtained in the present study, several clinical implications regarding increasing speaking rate are worth considering. It is well documented that nasality contributes to reduced intelligibility in the speech of HI individuals (Boone, 1966; Hudgins, 1934; Leder & Spitzer, 1990; Nickerson, 1975; Peterson, 1946). It is therefore noteworthy to consider that increasing the speaking rate of HI individuals may serve to improve overall speech intelligibility. The results of the present study demonstrate that severely HI individuals are capable of increasing their speaking rate. In addition, this change in speaking rate was accompanied by a decrease in nasality, both acoustically and perceptually. Therefore, it follows that instructing HI individuals to increase their speaking rate should help to improve speech intelligibility. However, it is important to note that attempting to increase an individual's speaking rate too much could be counterintuitive. Attempting to speak at a fast rate may adversely affect articulation such as the deletion of word-final consonants (Ohde & Sharf, 1992). A carefully controlled balance therefore needs to be observed if such training were to be incorporated into therapy sessions.

Based on anecdotal reports from teachers at VADEC, teachers of the deaf are trained to speak slowly to HI students to ensure adequate articulation of all consonants and vowels. It is possible that this technique, in combination with the existing difficulties that HI individuals encounter when speaking, contributes to the observed nasality of HI speech. It is therefore noteworthy for teachers of the deaf to consider the implications of speaking slowly to their students. If teachers of the deaf were to implement speaking at a faster rate when in the classroom, a careful balance between speaking too slowly and speaking too fast would need to be maintained. Speaking at too fast a rate would possibly be detrimental to HI students' learning, as they may miss part or all of what is being said.

Results of the correlational analysis suggest that something more than just nasality may be contributing to reduced intelligibility. Focusing on just one aspect of HI individuals' speech therefore may not be very useful during therapy. It may be more beneficial to HI individuals if the various factors that contribute towards reduced intelligibility are worked on in combination. For example, the effect of fluctuating F_0 on the perception of nasality may be an important factor affecting speech intelligibility. If speaking rate is successfully increased and maintained in HI speakers, but their F_0 continues to fluctuate, individuals may still be considered nasal or less intelligible. Teaching individuals to maintain normal pitch changes, in combination with rate and rhythm training, may be more useful in the clinical setting. Ling (1978), in his article concerning speech development in HI children, emphasized that speech patterns should not be taught in isolation, but in context spanning several articulatory events. Furthermore, increases in speaking rate may not generalise to HI individuals' everyday speech, as training can be very contrived and specific to the clinical setting. Speech rate training therefore could focus on more real-world situations and should be conducted for longer periods, even ongoing, for the changes to be longstanding.

Limitations

This study used 11 HI participants and, although parametric statistics were used, the small sample size resulted in low statistical power (Schiavetti & Metz, 2002). The number of HI participants in previous studies has ranged from one (Zimmerman & Rettaliata, 1981) to 53 (Ysunza & Vazquez, 1993) and the possibility exists that a larger sample size may have yielded different results. Future research with larger sample sizes would increase the statistical power of the results, therefore allowing for greater generalisation of findings.

Naïve listeners were used in the present study to make judgements on the nasality present in the speech of the HI participants. Previous research has revealed mixed results when comparing the performance of naïve versus experienced listeners on the ratings of nasality and intelligibility for HI speakers (Lewis, Watterson, & Houghton, 2003; McGarr, 1983; Mencke, Ochsner, & Testut, 1983). Lewis et al. (2003) reported that listeners who had experience rating nasality in cleft palate speech were more reliable than non-experienced listeners were. Contrary to the findings of Lewis et al. were those of Mencke et al. (1983) and McGarr (1983) who found minimal differences between naïve and experienced listeners when perceptual ratings of nasality were conducted. Based on these findings it appears there is some controversy regarding the use of experienced versus non-experienced listeners when making judgements concerning speech nasality. Even so, by using experienced listeners in the present study different perceptual judgements may have surfaced.

Limitations due to the ordering of the perceptual tasks may have influenced the rating results in the present study. The paired comparison perceptual task was presented to the listeners first as it was considered to be the easier of the two tasks, particularly considering naïve listeners were used as perceptual judges. It is possible that a learning (i.e., ordering) effect may have occurred thereby influencing the listeners' judgements concerning the rating of nasality.

Research observing the effect of vowel type on perceptual ratings of nasality has shown that nasality judgements can vary among vowel types and context (Lintz & Sherman, 1961; Moll, 1962). The present study did not consider vowel types independently and their effect on nasality; however, a wide range of vowels was sampled across each participant. Future attempts to balance vowels when conducting perceptual and acoustic measures of nasality may yield more sensitive information regarding HI speech.

In an attempt to control for speaking rate in the R1 samples presented to perceptual judges, long pauses were reduced to a maximum length of 250 ms. In addition to the editing of pauses, the samples were time-compressed to match the duration of the corresponding R2 speech sample. An alternative to compressing R1 samples to match the duration of R2 samples would have been to do the opposite. That is, R2 samples could have been temporally expanded to match the duration of the R1 samples. Leeper, Nieuwesteeg, Bishop, Lass and Beckwith (1980) used time-expanded speech in judgements of nasality and found that as time expansion increased ratings of nasality increased. It remains to be seen whether this alternative method would have had an effect on ratings of nasality. By expanding the R1 samples in the present study, a higher average nasality rating may have been obtained.

Finally, audiological characteristics, such as type of hearing aid, years of hearing aid use and severity of hearing loss, were not taken into account in the present study, due to the small sample size. It is possible that differences in nasality among the group of HI participants may have been apparent if these audiological factors, particularly severity of hearing loss, were considered.

Directions for Future Research

The present study demonstrated that increases in speaking rate resulted in subsequent decreases in both acoustic and perceptual measures of nasality. Future research should consider investigating the effect of fluctuations in F_0 present in the speech of HI individuals on the perception of nasality. Once F_0, in addition to other factors influencing perceived nasality are controlled, the effect of speaking rate may be isolated more effectively. Studies assessing the effect of increasing HI individuals' speaking rate on the newly constructed nasality severity index (NSI) (Van Lierde, Wuyts, Bonte, & Van Cauwenberge, 2006) should be undertaken. The NSI was recently developed as an objective and efficient way of quantifying nasality in speech, with researchers reporting a sensitivity of 88% and a specificity of 95%. Whether a strong relationship between the NSI, speaking rate and perceptual measures of nasality in HI individuals' speech exists should be investigated.

Nasality is one component affecting the speech intelligibility of HI speakers. The present study has shown that speech nasality can be decreased by increasing the speaking rate of HI individuals. However, this study did not address improvements in speech intelligibility of HI individuals with increases in speaking rate. John and Howarth (1965) evaluated overall speech intelligibility of 29 HI children after training was conducted to improve their speech patterns (i.e., rhythm & stress). The researchers reported a mean increase in intelligibility of 56% once children had been trained to focus on the continuity of their speech. John and Howarth concluded that timing aspects were critical in the interpretation of speech that is grossly misarticulated. A follow-up to the present study, assessing changes in speech intelligibility as speaking rate increases, using forward-played speech samples should therefore be considered.

Studies also need to consider whether the effects of increasing speaking rate will generalise to the everyday speech of HI individuals. Targeting common conversations with the intention of generalising changes achieved during therapy to others areas of spoken communication could be of benefit. In addition, speech training could be undertaken not only in the clinical setting but also at home and at school so that improvements are more likely to generalise to their everyday spoken communication (Ling, 1978; Perigoe & Ling, 1986). Improvements in HI individuals' speech production, as well as the generalisation of speech skills, have been achieved by those HI individuals enrolled in programmes that focused on speech training in combination with auditory training (Paul & Quigley, 1990) Individuals could therefore benefit from comprehensive treatment that includes aspects such as improving speaking rate and speech rhythm. Furthermore, Ling (1978) and Paul and Quigley (1990) advocate for early intervention so that adequate speech and language skills, particularly spoken language, are developed in HI individuals. Studies have shown that intensive, comprehensive and early oral intervention programmes are effective in achieving longstanding improvements in the overall intelligibility of HI individuals' speech (Long, Fitzgerald, Sutton, & Rollins, 1983; Novelli-Olmstead & Ling, 1984; Perigoe & Ling, 1986). Future studies could integrate speech rate training into the speech education of HI individuals from a young age to assess whether this would have an effect on nasality. Follow-up studies, particularly those involving observation of individuals in their natural speaking environment, to assess whether the training has had long-term effects should be considered. In addition, the training of HI individuals to improve their rate of speech, with the intention of decreasing nasality, could be implemented into a treatment plan in the clinical setting and independently evaluated as to the clinical usefulness of such a technique.

Finally, studies should be designed to evaluate the effect of cognitive processing on HI individuals' speaking rate. Past research has suggested that HI individuals take longer to access spoken language than normal hearing individuals (Fletcher, Smith, & Hasegawa, 1985). These researchers compared the verbal response times of 16 normal hearing and 25 HI individuals. They found that as the phonetic complexity of the task increased, verbal response times for the HI individuals decreased. While conducting the present research, it was noted that the HI individuals struggled initially with increases in speaking rate due to the unfamiliarity, and therefore complexity, of the text they were required to read. This initially made small increases in speaking rate difficult for the participants. However, once the text became familiar to them, and therefore less complex, participants became more adept at achieving the increases in speaking rate required. Familiarity of the text was therefore essential in this study, so that cognitive processing did not play a significant role. Even so, this factor was not directly controlled for nor directly evaluated. Future studies aimed at assessing the role HI individuals' access to language plays in increasing their speaking rate, particularly if some cognitive delay is present, may be of benefit.

Conclusion

As hypothesised, nasality in the speech of HI individuals was reduced, both acoustically and perceptually, when these same individuals were trained to increase their speaking rate. Although significant changes in nasality were found as speaking rate increased, no significant relationships between variables on their own existed. Despite this, the overall speech signal demonstrated an effect due to increases in speaking rate, suggesting that these factors in combination, or some other factor such as F_0, could be contributing towards the perception of nasality in HI speakers. In addition, the findings demonstrated that VP functioning is amenable to change when speaking rate was increased. The subsequent significant decrease in nasality may be indicative of improved VP mechanism efficiency. Even so, nasality was not entirely eliminated in the speech of the HI participants at the faster rate. Furthermore, no imaging of the VP structures at slow and fast speaking rates was undertaken. A structural abnormality of the VP mechanism is therefore still possible in this population of HI individuals. Future research evaluating the effect of increasing speaking rate on the overall speech intelligibility of HI speakers may provide interesting results. Furthermore, focusing on all factors that contribute to nasality in the speech of HI individuals during speech training sessions may serve to improve overall intelligibility in these individuals.

References

Avery, D. (2000). *Coyote, fox and wolf tales: A collection of traditional tales*. Auckland: Shortland Publications Incorporated.

Bakkum, M. J., Plomp, R., & Pols, L. C. W. (1995). Objective analysis versus subjective assessment of vowels pronounced by deaf and normal-hearing children. *Journal of the Acoustical Society of America, 98*(2), 745-762.

Bernthal, J. E., & Bankson, N. W. (Eds.). (1998). *Articulation and phonological disorders* (4th ed.). Boston: Allyn and Bacon.

Boone, D. R. (1966). Modification of the voices of deaf children. *Volta Review, 68*(9), 686-692.

Borden, G. J., & Harris, K. S. (1984). *Speech science primer: Physiology, acoustics and perception of speech* (2nd ed.). Baltimore: Williams & Wilkins.

Brancewicz, T. M., & Reich, A. R. (1989). Speech rate reduction and "nasality" in normal speakers. *Journal of Speech and Hearing Research, 32*(4), 837-848.

Bzoch, K. R. (1968). Variations in velopharyngeal valving: The factor of vowel changes. *Cleft Palate Journal, 5*, 211-218.

Calvert, D. R. (1962). Speech sound duration and the surd-sonant error. *The Volta Review, 64*, 401-403.

Chen, M. Y. (1995). Acoustic parameters of nasalized vowels in hearing-impaired and normal-hearing speakers. *Journal of the Acoustical Society of America, 98*(5), 2443-2453.

Colton, R. H., & Cooker, H. S. (1968). Perceived nasality in the speech of the deaf. *Journal of Speech and Hearing Research, 11*(3), 553-559.

Dalston, R. M., & Warren, D. W. (1986). Comparison of Tonar II, pressure-flow, and listener judgments of hypernasality in the assessment of velopharyngeal function. *Cleft Palate Journal, 23*(2), 108-115.

Dalston, R. M., Warren, D. W., & Dalston, E. T. (1991). Use of nasometry as a diagnostic tool for identifying patients with velopharyngeal impairment. *Cleft Palate Craniofacial Journal, 28*(2), 184-188.

Darley, F. L., Aronson, A. E., & Brown, J. R. (1975). *Motor speech disorders*. Philadelphia: W.B. Saunders Company.

Dickson, D. R. (1962). An acoustic study of nasality. *Journal of Speech and Hearing Research, 5*(2), 103-112.

Dromey, C. (2003). Spectral measures and perceptual ratings of hypokinetic dysarthria. *Journal of Medical Speech Language Pathology, 11*, 85-94.

Dworkin, J., Paul., Marunick, M., T. , & Krouse, J., H. . (2004). Velopharyngeal dysfunction: Speech characteristics, variable etiologies, evaluation techniques, and differential treatments. *Language, Speech & Hearing Services in Schools, 35*(4), 333.

Fletcher, S. G. (1972). Contingencies for bioelectronic modification of nasality. *Journal of Speech and Hearing Disorders, 37*(3), 329-346.

Fletcher, S. G. (1976). "Nasalance" vs. listener judgements of nasality. *Cleft Palate Journal, 13*, 31-44.

Fletcher, S. G., & Daly, D. A. (1976). Nasalance in utterances of hearing-impaired speakers. *Journal of Communication Disorders, 9*(1), 63-73.

Fletcher, S. G., & Higgins, M. B. (1980). Performance of children with severe to profound auditory impairment in instrumentally guided reduction of nasal resonance. *Journal of Speech and Hearing Disorders, 45*, 181-194.

Fletcher, S. G., Mahfuzh, F., & Hendarmin, H. (1999). Nasalance in the speech of children with normal hearing and children with hearing loss. *American Journal of Speech-Language Pathology, 8*(3), 241-248.

Fletcher, S. G., Smith, S. C., & Hasegawa, A. (1985). Vocal/verbal response-times of normal-hearing and hearing-impaired children. *Journal of Speech and Hearing Research, 28*(4), 548-555.

Fry, D. B. (1979). *The physics of speech*. Cambridge: Cambridge University Press.

Gilbert, H. R., & Campbell, M. I. (1980). Speaking fundamental frequency in three groups of hearing impaired individuals. *Journal of Communication Disorders, 13*(3), 195-205.

Gilbert, H. R., & Hoodin, R. B. (1984). Effect of speaking rate on nasal airflows in hearing-impaired speakers. *Folia Phoniatrica et Logopaedica, 36*(4), 183-189.

Giusti, M. C., Padovani, M. M. P., Behlau, M., & Granato, L. (2001). The hearing-impaired children voice. *Revista Brasileira de Otorrinolaringologia, 67*(1), 29-35.

Goberman, A. M., Selby, J. C., & Gilbert, H. R. (2001). The effects of changes in speaking rate on nasal airflow and the perception of nasality. *Folia Phoniatrica et Logopaedica 53*(4), 222-230.

Hanson, G. (1964). A study of velopharyngeal competence in children with repaired cleft palate. *Cleft Palate Journal, 1*, 217-231.

Hardin, M. A., Van Demark, D. R., Morris, H. L., & Payne, M. M. (1992). Correspondence between nasalance scores and listener judgments of hypernasality and hyponasality. *Cleft Palate Craniofacial Journal, 29*(4), 346-351.

Higgins, M. B., Carney, A. E., & Schulte, L. (1994). Physiological assessment of speech and voice production of adults with hearing loss. *Journal of Speech and Hearing Research, 37*(3), 510-521.

Hood, R. B., & Dixon, R. F. (1969). Physical characteristics of speech rhythm of deaf and normal-hearing speakers. *Journal of Communication Disorders, 2*, 20-28.

Horii, Y. (1982). Some voice fundamental frequency characteristics of oral reading and spontaneous speech by hard-of-hearing young women. *Journal of Speech and Hearing Research, 25*(4), 608-610.

House, A. S., & Stevens, K. N. (1956). Analog studies of the nasalization of vowels. *Journal of Speech and Hearing Disorders, 21*(2), 218-232.

Hudgins, C. V. (1934). A comparative study of the speech coordinations of deaf and normal subjects. *Journal of Genetic Psychology, 44*, 1-48.

Hudgins, C. V., & Numbers, F. C. (1942). An investigation of the intelligibility of the speech of the deaf. *Genetic Psychology Monographs, 25*, 289-392.

John, J. E., & Howarth, J. N. (1965). The effect of time distortions on the intelligibility of deaf children's speech. *Language and Speech, 8*, 127-134.

Karnell, M. P. (1995). Nasometric discrimination of hypernasality and turbulent nasal airflow. *Cleft Palate-Craniofacial Journal, 32*, 145-148.

Kataoka, R., Warren, D. W., Zajac, D. J., Mayo, R., & Lutz, R. W. (2001). The relationship between spectral characteristics and perceived hypernasality in children. *Journal of the Acoustical Society of America, 109*(5), 2181-2189.

Kay Elemetrics. (1994). CSL 4300B (Version 5.X) [Computer Programme]. Lincoln Park, IL: Kay Elemetrics Corporation.

Keuning, K. H. D. M., Wieneke, G. H., & Dejonckere, P. H. (2004). Correlation between the perceptual rating of speech in Dutch patients with velopharyngeal insufficiency and composite measures derived from mean nasalance scores. *Folia Phoniatrica et Logopaedica, 56*(3), 157-164.

Keuning, K. H. D. M., Wieneke, G. H., van Wijngaarden, H. A., & Dejonckere, P. H. (2002). The correlation between nasalance and a differentiated perceptual rating of speech in Dutch patients with velopharyngeal insufficiency. *Cleft Palate-Craniofacial Journal, 39*(3), 277-284.

Leder, S. B., & Spitzer, J. B. (1990). A perceptual evaluation of the speech of adventitiously deaf adult males. *Ear and Hearing, 11*(3), 169-175.

Leeper JR, H. A., Nieuwesteeg, Y., Bishop, L., Lass, N. J., & Beckwith, S. (1980). The use of time-expanded speech in judgements of hypernasality. *Journal of Communication Disorders, 13*, 335-339.

Lewis, K. E., Watterson, T. L., & Houghton, S. M. (2003). The influence of listener experience and academic training on ratings of nasality. *Journal of Communication Disorders, 36*(1), 49-58.

Ling, D. (1978). Speech development in hearing-impaired children. *Journal of Communication Disorders, 11*(2-3), 119-124.

Lintz, L. B., & Sherman, D. (1961). Phonetic elements and perception of nasality. *Journal of Speech and Hearing Research, 4*(4), 381-396.

Lock, R. B., & Seaver, E. J. (1984). Nasality and velopharyngeal function in five hearing impaired adults. *Journal of Communication Disorders, 17*(1), 47-64.

Long, N., Fitzgerald, C., Sutton, K., & Rollins, J. (1983). The auditory-verbal approach. *The Volta Review, 85*(27-30, 35), 27-30, 35.

Martony, J. (1968). On the correction of the voice pitch level for severely hard of hearing subjects. *American Annals of the Deaf, 113*, 195-202.

Mason, R. M., & Helmick, J. W. (1979). Residual hypernasality in repaired cleft palate. *Journal of Communication Disorders, 12*(5), 431-438.

Massengill, R. (1972). *Hypernasality*. Springfield: Charles C Thomas.

McClumpha, S. L. (1969). Cinefluorographic investigation of velopharyngeal function in selected deaf speakers. *Folia Phoniatrica et Logopaedica, 21*, 368-374.

McGarr, N. S. (1983). The intelligibility of deaf speech to experienced and inexperienced listeners. *Journal of Speech and Hearing Research, 26*, 451-458.

McHenry, M. A. (1999). Aerodynamic, acoustic, and perceptual measures of nasality following traumatic brain injury. *Brain Injury, 13*(4), 281-290.

Mencke, E. O., Ochsner, G. J., & Testut, E. W. (1983). Listener judges and the speech intelligibility of deaf children. *Journal of Communication Disorders, 16*(3), 175-180.

Moll, K. L. (1962). Velopharyngeal closure on vowels. *Journal of Speech and Hearing Research, 5*(1), 30-37.

Murphy, A. T. (Ed.). (1964). *Functional voice disorders*. Englewood Cliffs: Prentice-Hall Incorporated.

Nickerson, R. S. (1975). Characteristics of the speech of deaf persons. *Volta Review, 77*(6), 342-362.

Novelli-Olmstead, T., & Ling, D. (1984). Speech production and discrimination by hearing-impaired children. *The Volta Review, 86*, 72-80.

Ohde, R. N., & Sharf, D. J. (1992). *Phonetic analysis of normal and abnormal speech.* New York: Maxwell Macmillan International.

Paul, P. V., & Quigley, S. P. (1990). *Education and deafness*. New York: Longman.

Penn, J. P. (1955). Voice and speech patterns of the hard of hearing. *Acta Otolaryngology Supplement, 124*, 1-69.

Perigoe, C., & Ling, D. (1986). Generalization of speech skills in hearing-impaired children. *The Volta Review, 88*(351-366).

Peterson, G. E. (1946). Influence of voice quality. *The Volta Review, 48*, 640-641.

Peterson, G. E., & Barney, H. L. (1952). Control methods used in the study of the vowels. *The Journal of the Acoustical Society of America, 24*(2), 175-184.

Pols, L. C. W., Van Der Kamp, L. J. T., & Plomp, R. (1969). Perceptual and physical space of vowel sounds. *Journal of the Acoustical Society of America, 46*(2), 458-467.

Robb, M. P., Chen, Y., & Gilbert, H. R. (1997). Developmental aspects of formant frequency and bandwidth in infants and toddlers. *Folia Phoniatrica et Logopaedica, 49*, 88-95.

Robb, M. P., Hughes, M. C., & Frese, D. J. (1985). Oral diadochokinesis in hearing-impaired adolescents. *Journal of Communication Disorders, 18*(2), 79-89.

Robb, M. P., MacLagan, M. A., & Chen, Y. (2004). Speaking rates of American and New Zealand varieties of English. *Clinical Linguistics and Phonetics, 18*(1), 1-15.

Rutherford, D. (1967). Auditory-motor learning and the acquisition of speech. *American Journal of Physical Medicine, 46*(1), 245-251.

Schiavetti, N., & Metz, D. (2002). *Evaluating research in communicative disorders* (4th ed.). Boston: Allyn and Bacon.

Seaver, E. J., Andrews, J. R., & Granata, J. J. (1980). A radiographic investigation of velar positioning in hearing-impaired young-adults. *Journal of Communication Disorders, 13*(3), 239-247.

Sherman, D. (1954). The merits of backward playing of connected speech in the scaling of voice quality disorders. *Journal of Speech and Hearing Disorders, 19*, 312-321.

Sonic Foundry. (2002). Sound Forge (Version 6.0) [Computer Software]. Madison, WI: Sony Media Software.

Spriestersbach, D. C. (1955). Assessing nasal quality in cleft palate speech of children. *Journal of Speech and Hearing Disorders, 20*, 266-270.

SPSS Inc. (1992). SigmaStat (Version 2.03) [Computer Programme]. Chicago, IL: SYSTAT Software Incorporated.

Stevens, K. N., Nickerson, R. S., Boothroyd, A., & Rollins, A. M. (1976). Assessment of nasalization in the speech of deaf children. *Journal of Speech and Hearing Research, 19*(2), 393-416.

Subtelny, J. D., Koepp-Baker, H., & Subtelny, J. D. (1961). Palatal function and cleft palate speech. *Journal of Speech and Hearing Disorders, 26*(3), 213-224.

Tatchell, J. A., Stewart, M., & Lapine, P. R. (1991). Nasalance measurements in hearing-impaired children. *Journal of Communication Disorders, 24*(4), 275-285.

Thompson, A. E., & Hixon, T. J. (1979). Nasal airflow during normal speech production. *Cleft Palate Journal, 16*, 412-420.

Van Lierde, K. M., Wuyts, F. L., Bonte, K., & Van Cauwenberge, P. (2006). The nasality severity index: An objective measure of hypernasality based on a multiparameter approach; a pilot study. *Folia Phoniatrica et Logopaedica, 59*(1), 31.

Voelker, C. H. (1935). A preliminary strobophotoscopic study of the speech of the deaf. *Annals of the Deaf, 80*, 243-259.

Voelker, C. H. (1938). An experimental study of the comparative rate of utterance of deaf and normal hearing speakers. *American Annals of the Deaf, 83*, 274-283.

Walker, V. G. (1988). Durational characteristics of young adults during speaking and reading tasks. *Folia Phoniatrica et Logopaedica, 40*, 15.

Watterson, T., McFarlane, S. C., & Wright, D. S. (1993). The relationship between nasalance and nasality in children with cleft palate. *Journal of Communication Disorders, 26*(1), 13-28.

Wilson, M. D., & McReynolds, L. V. (1973). A procedure for increasing oral reading rate in hard-of-hearing children. *Journal of Applied Behaviour Analysis, 6*(2), 231-239.

Ysunza, A., & Vazquez, M. C. (1993). Velopharyngeal sphincter physiology in deaf individuals. *Cleft Palate-Craniofacial Journal, 30*(2), 141-143.

Zimmerman, G., & Rettaliata, P. (1981). Articulatory patterns of an adventitiously deaf speaker: Implications for the role of auditory information in speech production. *Journal of Speech and Hearing Research, 24*, 169-178.

Appendices

Appendix I

Human Ethics Committee approval letter, parent information letter, project information sheets, and consent forms.

HEC Ref: 2006/23

18 September 2007

Ms Claire Dwyer
Communication Disorders
UNIVERSITY OF CANTERBURY

Dear Claire

The Human Ethics Committee advises that your research proposal “Perceived nasality, as influenced by speaking rate, in the speech of hearing impaired individuals” has been considered and approved.

Yours sincerely

Dr Alison Loveridge
Chair, Human Ethics Committee

Department of Communication Disorders

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

18 May 2006

Dear Parents:

I am a Master of Audiology student currently enrolled at the University of Canterbury, in Christchurch. As part of the course, we are required to conduct a research study during the year.

As part of this study, I will require participants who have a hearing impairment. The study involves using a computer-based programme in an attempt to train children to increase the speed at which they talk (also known as speaking rate). This training programme will involve three sessions, each lasting approximately 30 to 45 minutes. I would greatly appreciate your consent, as well as your child's, for participation in this study. I would also request permission to access information relating to your child's hearing impairment that is held within the Audiology Department at Van Asch Deaf Education Centre. All information obtained will be held in the strictest confidence within the Department of Communication Disorders at the University of Canterbury. Attached is an information sheet that describes the study in more detail, as well as a consent form.
If you have any further questions about the research project, please do not hesitate to contact either my supervisor or myself at the University of Canterbury. Thank you once again.

Sincerely,

Claire Dwyer B.Sc.
Master of Audiology Student
Ph: 356 2851
Mob: 0212 252 473
Email: chd21@student.canterbury.ac.nz

Professor Michael Robb
Head of Department
Communication Disorders
Ph: 364 2401
Email: michael.robb@canterbury.ac.nz

Department of Communication Disorders

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Project Information Sheet

PARENT INFORMATION

Your child is invited to participate in the research project *Perceived Nasality, as Influenced by Speaking Rate, in the Speech of Hearing Impaired Individuals.*

The aim of this project is to evaluate the nasal quality of hearing impaired students, and how this nasality changes when a student increases his/her speaking rate.

Your child's involvement in this project will involve three sessions, each lasting approximately 30 – 45 minutes, whereby your child will be required to read phrases presented on a computer monitor at various speeds. Your child has the right to withdraw from the project at any time, including withdrawal of any information provided.

The results of the project may be published, but your child may be assured of the complete confidentiality of data gathered in this investigation: the identity of participants will not be made public without their consent. To ensure anonymity and confidentiality, the information gathered will be assigned a number and all identifiable information removed. Data will be kept in a locked filing cabinet within a lockable room in the Department of Communication Disorders.

The project is being carried out as a requirement for a Masters of Audiology by Claire Dwyer under the supervision of Professor Michael Robb, who can be contacted at the University of Canterbury on 364 2401. They will be pleased to discuss any concerns you may have about participation in the project.

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

Department of Communication Disorders

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Project Information Sheet

STUDENT INFORMATION

You are invited to participate in the research project entitled *Perceived Nasality, as Influenced by Speaking Rate, in the Speech of Hearing Impaired Individuals.*

The aim of this project is to evaluate the nasal quality of hearing impaired students, and how this nasality changes when a student increases his/her speaking rate.

Your involvement in this project will involve three sessions, each lasting approximately 30 – 45 minutes, whereby you will be required to read phrases presented on a computer monitor at various speeds. You have the right to withdraw from the project at any time, including withdrawal of any information provided.

The results of the project may be published, but you may be assured of the complete confidentiality of data gathered in this investigation: the identity of participants will not be made public without their consent. To ensure anonymity and confidentiality, the information gathered will be assigned a number and all identifiable information removed. Data will be kept in a locked filing cabinet within a lockable room in the Department of Communication Disorders.

The project is being carried out as a requirement for a Masters of Audiology by Claire Dwyer under the supervision of Professor Michael Robb, who can be contacted at the University of Canterbury on 364 2401. They will be pleased to discuss any concerns you may have about participation in the project.

The project has been reviewed ***and approved*** by the University of Canterbury Human Ethics Committee.

Department of Communication Disorders

Claire Dwyer
Department of Communication Disorders
University of Canterbury
Creyke Road
Ilam
18 May 2006

Consent Form - Parent

Perceived Nasality, as Influenced by Speaking Rate, in the Speech of Hearing Impaired Individuals.

I have read and understood the description of the above-named project. On this basis, I agree to my child's participation in the project, and I consent to publication of the results of the project with the understanding that anonymity will be preserved.

I understand also that my child may at any time withdraw from the project, including withdrawal of any information my child or I have provided.

NAME (please print): ……………………………………………………………….

CHILD'S NAME:…………………………………………………………………..

Parent's Signature:

Date:

Department of Communication Disorders

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Claire Dwyer
Department of Communication Disorders
University of Canterbury
Creyke Road
Ilam
18 May 2006

Consent Form - Student

Perceived Nasality, as Influenced by Speaking Rate, in the Speech of Hearing Impaired Individuals.

I have read and understood the description of the above-named project. On this basis, I agree to take part as a participant in the project, and I consent to publication of the results of the project with the understanding that anonymity will be preserved.

I understand also that I may at any time withdraw from the project, including withdrawal of any information I have provided.

NAME (please print): …………………………………………………………….

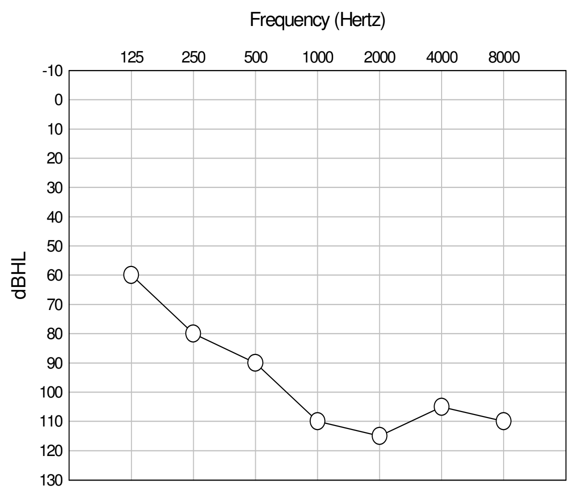
Signature:

Date:

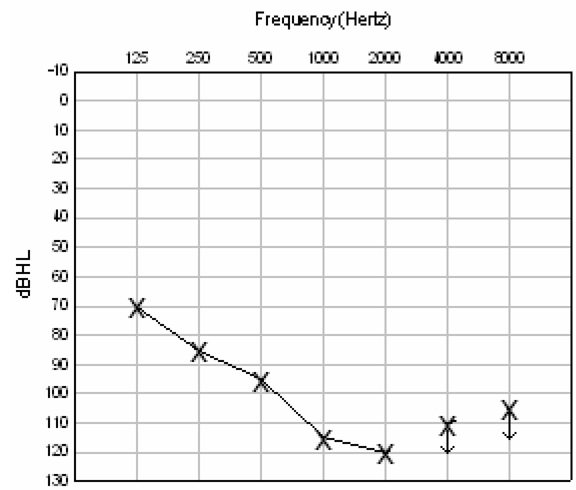
Appendix II

Audiograms

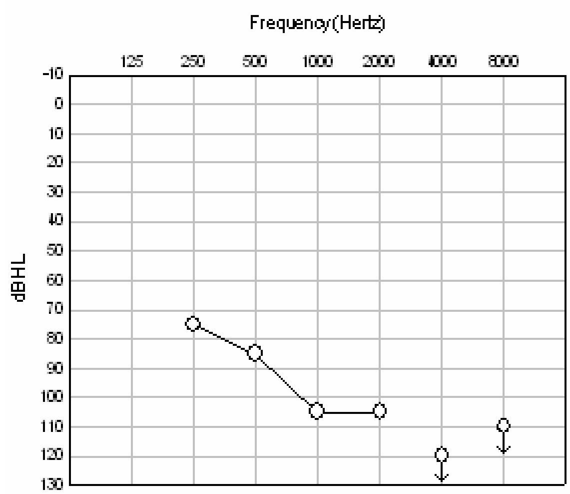
Participant 1 - Right Ear



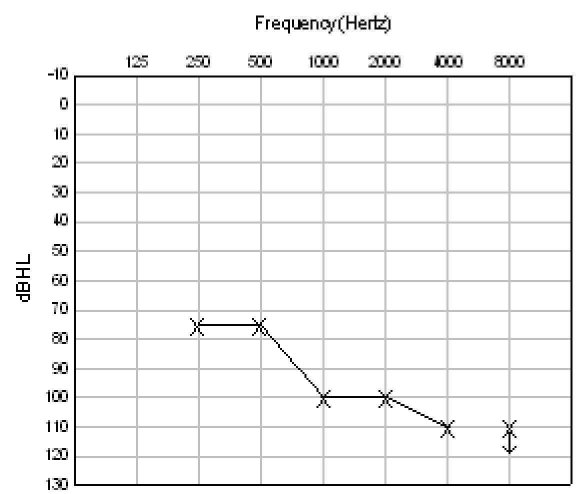
Participant 1 - Left Ear



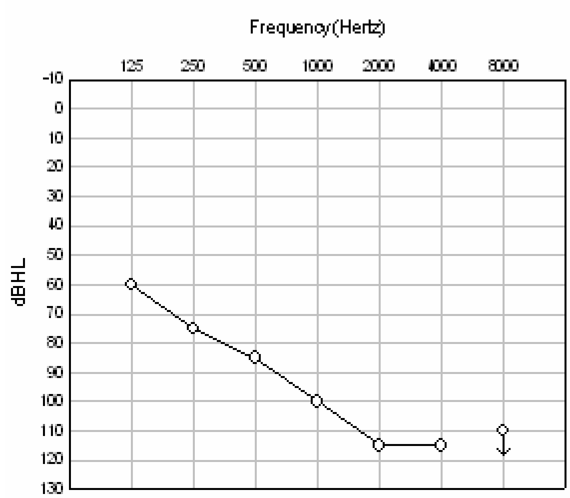
Participant 2 - Right Ear



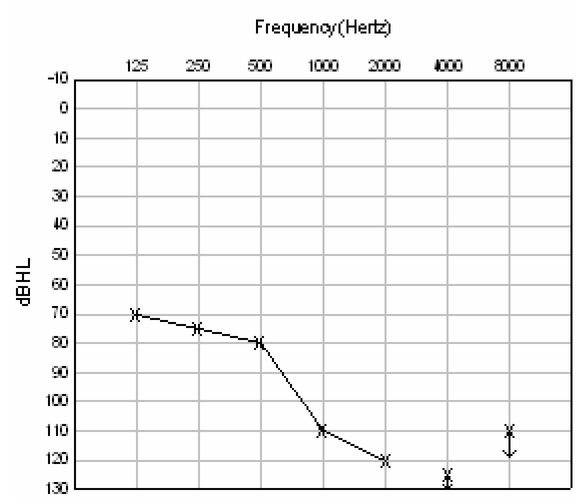
Participant 2 - Left Ear

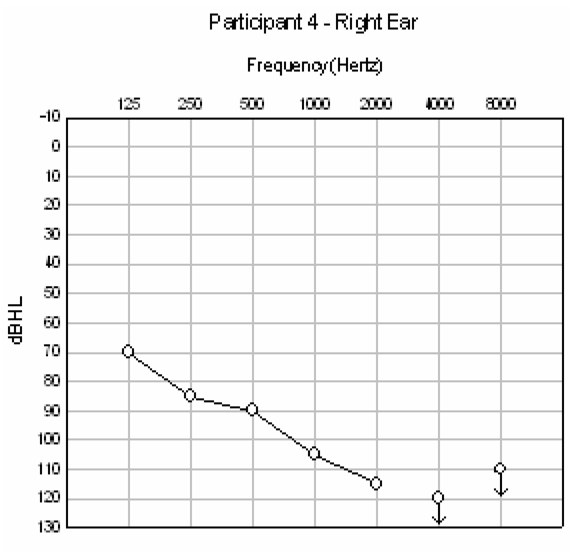


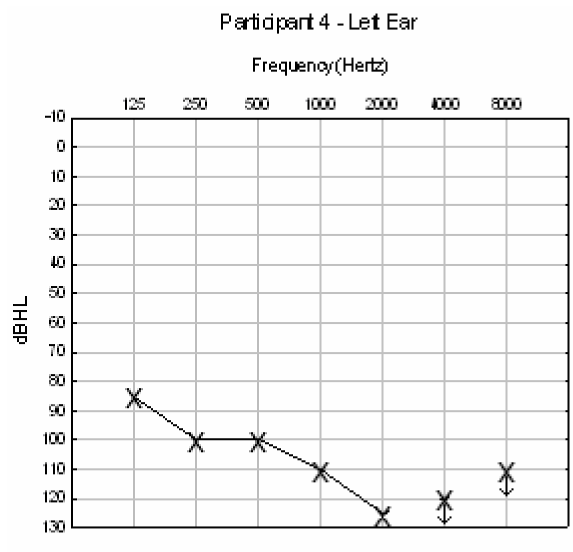
Participant 3 - Right Ear

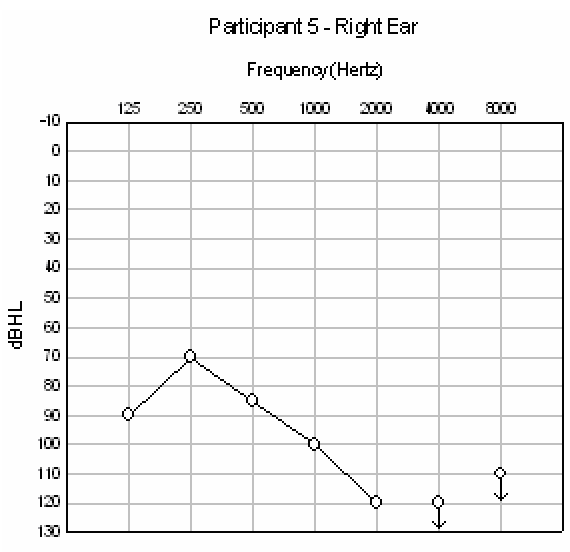


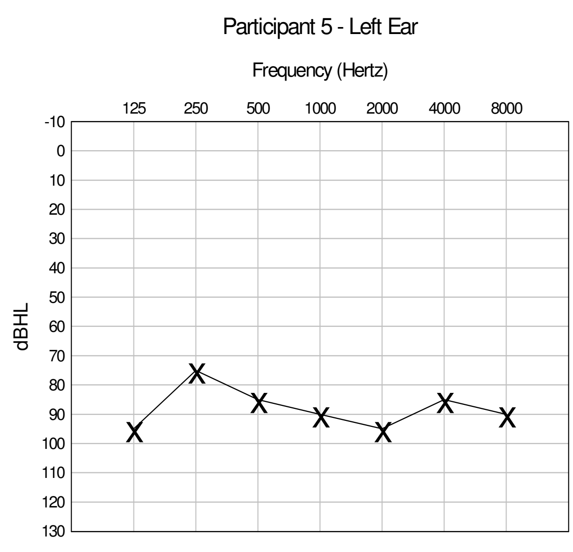
Participant 3 - Left Ear

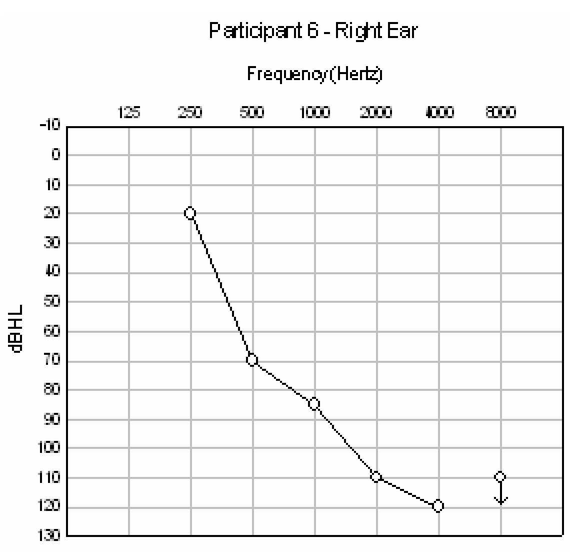


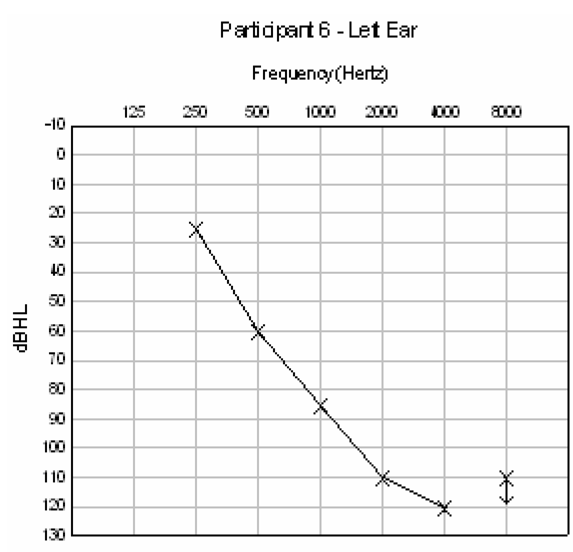

Participant 4 - Right Ear
Frequency(Hertz)
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130
dBHL


Participant 4 - Left Ear
Frequency(Hertz)
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130
dBHL

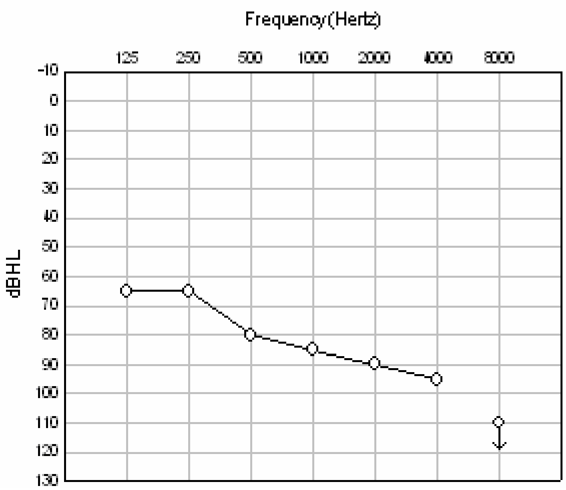

Participant 5 - Right Ear
Frequency(Hertz)
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130
dBHL


Participant 5 - Left Ear
Frequency (Hertz)
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130
dBHL

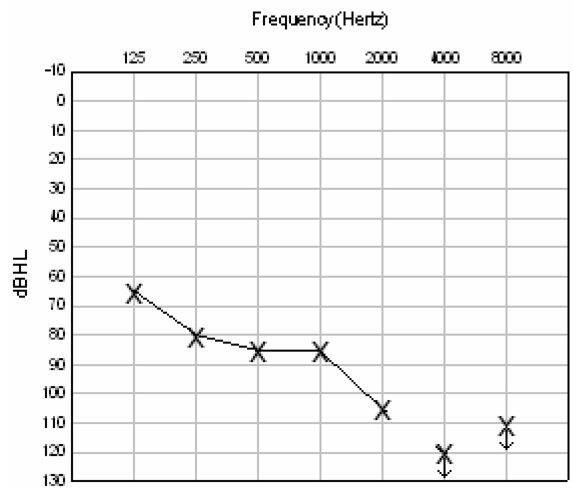

Participant 6 - Right Ear
Frequency(Hertz)
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130
dBHL


Participant 6 - Left Ear
Frequency(Hertz)
125 250 500 1000 2000 4000 8000
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130
dBHL

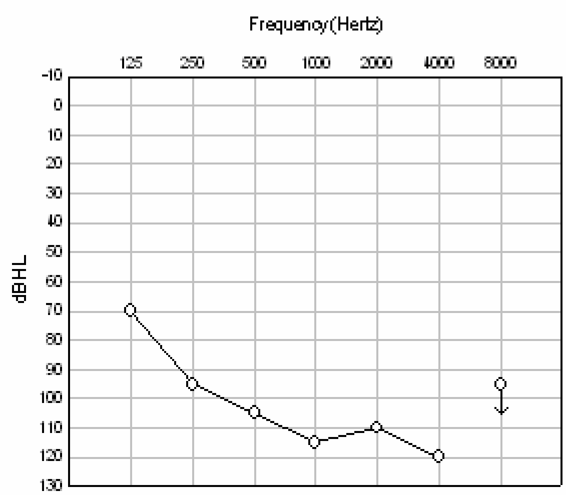
Participant 7 - Right Ear



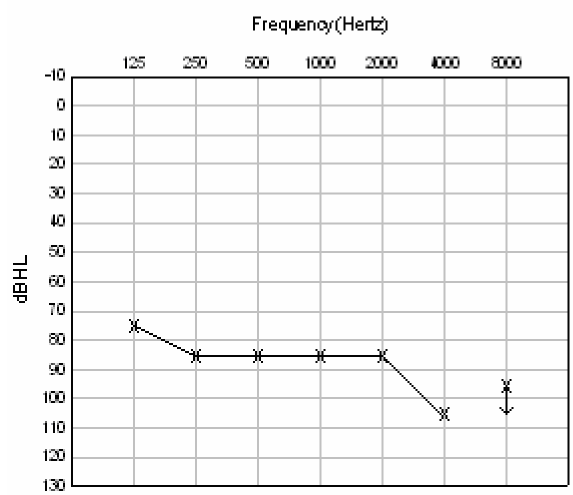
Participant 7 - Left Ear



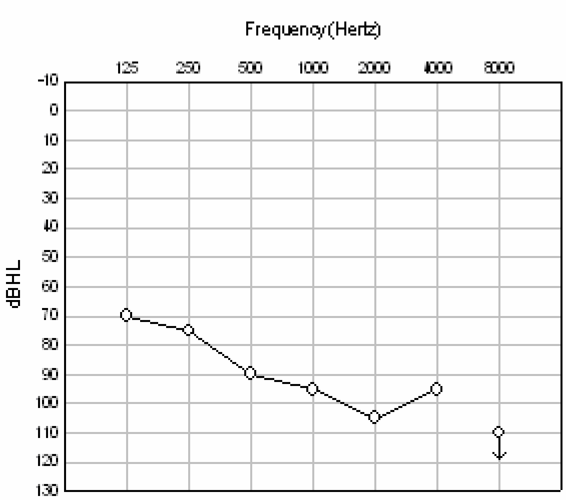
Participant 8 - Right Ear



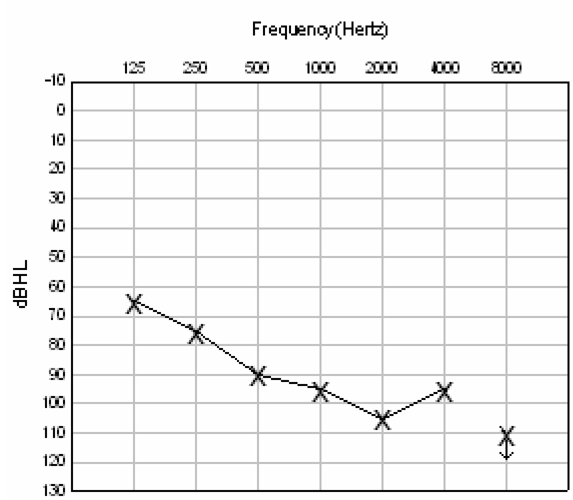
Participant 8 - Left Ear

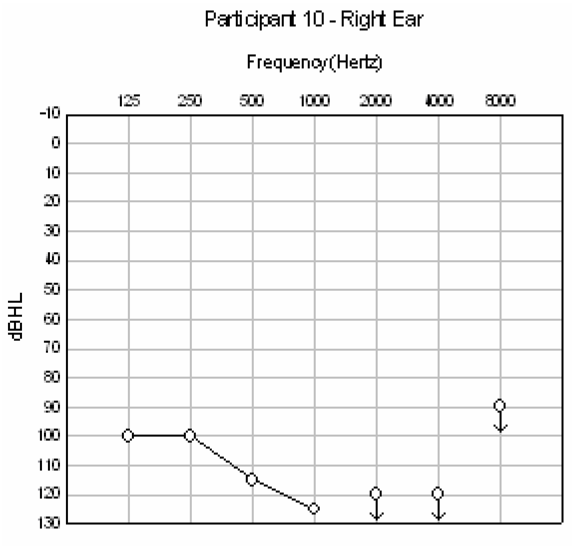


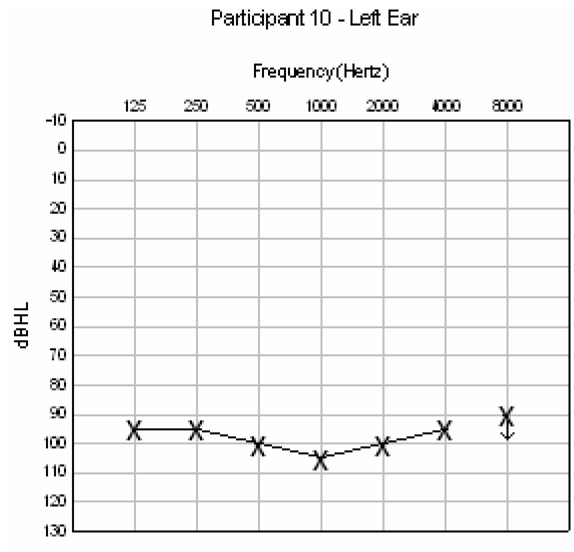
Participant 9 - Right Ear

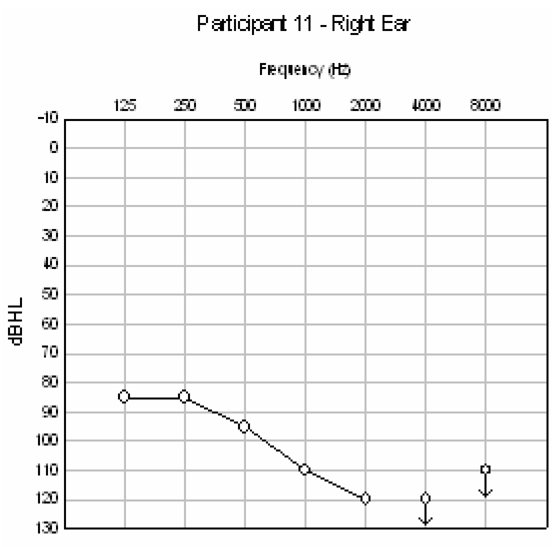


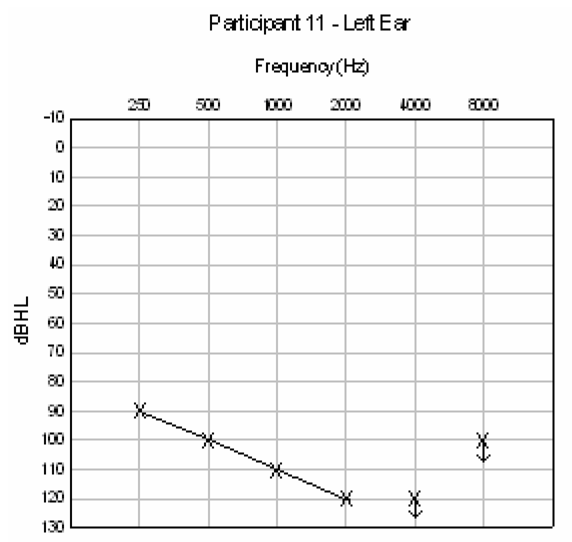
Participant 9 - Left Ear




Participant 10 - Right Ear
Frequency(Hertz)
125
250
500
1000
2000
4000
8000
dBHL
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130


Participant 10 - Left Ear
Frequency(Hertz)
125
250
500
1000
2000
4000
8000
dBHL
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130


Participant 11 - Right Ear
Frequency (Hz)
125
250
500
1000
2000
4000
8000
dBHL
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130


Participant 11 - Left Ear
Frequency(Hz)
250
500
1000
2000
4000
8000
dBHL
-10
0
10
20
30
40
50
60
70
80
90
100
110
120
130

Appendix III

Text of *The Fox and the Crow* (Avery, 2000)

One day a fox saw a crow
fly off with some cheese in its beak
The crow sat on a wall to eat the cheese.
“I would like that cheese” said Fox.
So Fox walked up to the stone wall.

“Hello Crow” said Fox
“How beautiful you look today.
How black your feathers are.
How bright your eyes are.
You are the queen of all birds.
I am sure that you sing well too.
Will you sing a little song for me?”

The Crow liked being called
the queen of all birds.
She lifted her head and began to sing.
“Caw, caw, caw!”
But the moment she opened her beak
the cheese fell from her mouth
and was snapped up by Fox.

“That will do” said Fox.
“Now in exchange for the cheese
I will give you some advice.
Never trust flatterers.”