THE RELATIONSHIP BETWEEN HYPERNASALITY AND VOWEL FORMANTS FOR ENGLISH AND SPANISH SPEAKING SUBJECTS

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CHAPTER I

INTRODUCTION

The judgement of hypernasality in speech is one based on the listener's perception of the sound that is heard. It has been reported that listeners base their judgements of nasality upon their prior experience with the sounds of the specific language involved, and listen for distortions in the vowel spectra they have learned (Andrews and Rutherford, 1972; House, 1960). Speech pathologists frequently have to judge a person's speech in a foreign context with which they are not totally familiar, for instance, the Mexican-American child with a Spanish dialect. Therefore, it is important to know if a perceptual bias exists concerning the speech of individuals with dialects.

It is important because from these perceptual judgements, many decisions, either surgical or therapeutic or both, are made. Several studies (House, 1960; Peterson, 1961; Schwartz, 1968; Dickson, 1962; House and Stevens, 1956; and Adnrews and Rutherford, 1972) have demonstrated that a high correlation exists between spectrographic analysis and perceptual judgements of nasalized speech; however, these studies were concerned with monolingual English speaking subjects. It is not known if the same correlation exists for speakers with a foreign dialect. The purpose of the present study was to determine if a correlation exists between spectrographic analysis and perceptual judgements of nasalized speech produced by speakers with a Mexican-American dialect.

Since certain terms are used in the literature associated with nasalized speech and spectrographic analysis, it should prove useful to the reader for those terms to be defined. First, resonance is defined by Hoops (1969, p. 145) as "the seeming amplification of sound resulting from a reflection and concentration of sound waves in a manner that makes possible more output of the vibrating body". Zemlin (1968, p. 547) defined resonance as "the absorption by a structure of energy at a specific frequency band, and the emission of energy by the same structure at the same frequency band". The presence of too much nasal resonance would be considered hypernasality, while the presence of too little nasal resonance would be hyponasality. Resonance is dependent on the movement of air through all the resonating chambers in the vocal tract, all of which are joined together. Coupling, which occurs when two or more resonators are hooked together and respond as one body (Hoops, 1969), becomes a very important aspect of resonance in the human voice. For example, a loosely coupled system is one in which the force that any part of the system exerts on the other parts of the system is small. A tightly coupled system is one in which the force that one part of the system exerts on the other parts is great. Nasalization is said to occur when this coupling is increased sufficiently to produce a perceptually significant change in the speech signal. The interaction between the pharyngeal-oral tract and the nasal cavity is related to the extent of coupling between them (Curtis, 1968). If the velopharyngeal port is sufficiently open, some of the sound energy will be transmitted by way of this opening through the nasal cavity and to the outside air. There may be two transmission channels for this sound energy which work as one generating unit. The division of sound energy between the two channels will be related to the opposition to the flow of energy through each. This opposition to energy transmission is correctly termed impedance (Curtis, 1968).

One instrument which has been used to physically measure speech quality is the sound spectrograph. Two terms associated with this instrument shall be defined. The first term is formant, which Zemlin (1968, p. 541) defined as, "regions of prominent energy distribution in a speech sound". Hoops (1969, p. 142) defined formant as, "frequency area having relatively high intensity compared to other frequencies in a sound". Intensity is defined by Hoops as, "magnitude of force, energy, power, or pressure" (p. 143).

Review of the Literature

A review of the literature was conducted. Although no studies were found pertaining to voice or resonance characteristics related to Mexican-American dialect in speech, several research articles reviewed were related to the spectral analysis and the perception of voice quality of monolingual English speakers.

House (1960) investigated formant band widths and their relation to vowel preference of English speakers. The purpose of his study was to determine an alternative, or indirect, method of determining typical values of formant band width. House used an electrical synthesizer which generated five vowel sounds. The stimuli were given the characteristics of the vowels /i/, /ɛ/, /æ/, /ɔ/, and /u/. In the synthesizer, two of its five circuits were fixed to represent the fourth and fifth vowel formants. The circuits representing the lowest three formants were variable.

Each of the five vowels was synthesized in seven different versions. For the listening task, the vowels were presented in pairs. In each pair, the band widths of the formants were the only variables. The center frequencies of the formants, temporal and excitation factors were identical. The various pairs were stored electrically on magnetic tape, and presented to eight normal hearing adults. The listeners were asked to decide which sound in each pair sounded better.

House found that as the formants of a vowel were widened, there was a decrease in the "naturalness", or acceptability, of the vowel. The vowel samples that had relatively narrow formants were preferred. As the formants were widened, a general reduction in the preferences for the vowels was observed.

The listener preferences for formant band widths correlated positively with phonetic or physiological descriptions of vowel production. House concluded that these preferences are established in human listeners as a result of the source characteristics of human speech and the lengthy experience of the listener in processing such speech signals.

Peterson (1961) conducted a study concerned with various acoustical parameters involved in vowel production and perception. Subjects in an anechoic chamber listened to recorded reference vowels and attempted to produce vowels which were equivalent in phonetic quality to the reference vowels. The subjects were men, women, and children who were native speakers of English. They were trained to produce non-English vowels. Both the speaker and the experimenter judged the speaker's recorded attempts to match the reference vowels. Only vowel matches which appeared to have normal phonation were analyzed by a sound spectrograph.

He found that it was possible to alter the fundamental voice frequency without appreciably changing the formant frequencies. In back vowels, the higher formants were weak in amplitude and intelligibility was reduced very little when formants above the second were eliminated.

He discovered that formant amplitudes, fundamental voice frequency, and phonetic environment all appeared to have an influence on the perception of vowel qualities.

If a formant was reduced in amplitude so that it became lost in the background, or if it was increased in amplitude so that it obscured a nearby formant, then marked effects upon vowel perception occurred.

Peterson (1961) found several characteristics which were common to nasalized vowels. These include: (1) a first formant which may be broadened and shifted in frequency (2) the presence of secondary resonances between the primary formants, and (3) an increase or decrease in the energy level of the third formant. Its frequencies may shift up or down, depending on the particular vowel formation.

Schwartz in 1968 conducted a study concerned with the acoustics of normal and nasal vowel production. He cited four features of importance in the spectra of nasalized vowels. The first was a reduction in the intensity of the first formant. He thought this was the result of the damping characteristics of the nasal cavity wall surfaces. The second feature was the presence of anti-resonance within the vowel spectrum, which caused a sharp drop in the intensity of a portion of the spectrum. He described this as an acoustic phenomenon which occurred when a tube, such as the oral-pharyngeal cavity, was coupled to a side branching tube, the nasal cavity. Another feature was the presence of reinforced harmonics at frequencies where energy was not normally expected, or secondary resonances as described by Peterson. The last characteristic of nasalized vowels Schwartz found was a shift in the relative frequency positions of the formants. Schwartz stated that when a vowel was perceived as nasal, its spectrum would show at least one of the four features just described.

According to his study, the basic difference between a normal vowel and a hypernasal vowel was in the intensities of the harmonics. Schwartz (1968) suggested that a hypernasal vowel spectrum which was consistently weaker than its normal counterpart was less distorted perceptually than a hypernasal vowel spectrum which was alternately weaker and stronger.

In a study by Dickson (1962), acoustic characteristics of nasal speech corresponded exactly to those features of nasality cited by Peterson (1961) and Schwartz (1968). Dickson found that the degree of perceived nasality depended upon the number of spectrum characteristics related to increased damping and the addition of resonances and anti-resonances.

An analog study of nasalization of vowels was conducted by House and Stevens in 1956. The authors assumed that nasality in speech sounds was produced generally by coupling the nasopharynx to the vocal tract. They designed an electrical analog of the nasal structure, combined this analog with an electrical analog of the vocal tract and observed the activity of the systems. When the configuration of the two analogs was set up and the vocal tract was excited appropriately, the acoustic end product was characterized by a first formant frequency at about 300 cps, a second formant at about 2300 cps, and a third formant at about 3000 cps. When the output was given appropriate secondary characteristics (rise and decay, duration, and inflection) listeners identified the sound as being very similar to the vowel /i/. Articulatory configurations of other vowels were approximated when the parameters of the model were manipulated appropriately.

When voiced sounds were made, the vocal tract was excited with a quasi-periodic source with a relatively high acoustical impedance. The waveform had a sawtooth shape and the amplitude of the harmonics of the spectrum decreased with increasing frequency at 6 to 12 dB per octave.

The authors observed that if the impedance of the nasal tract was greater than the impedance of the vocal tract, the effect of the nasal tract on the combined acoustic output of both systems would be small. If the reverse were true, that is, if the impedance of the vocal tract was greater that the impedance of the nasal tract, the combined acoustic output would be influenced appreciably by nasal coupling. The principal effect would occur in the frequency ranges where the differences in the impedances was greatest, particularly in the first vowel formant.

According to the study, there was an inverse relation between the magnitude of the impedance for the vowel and the height of the vowel.

For example, the vowels /i/ and /u/ would have the highest impedance, while /æ/ and /ɑ/ would have the lowest impedance, and /ɛ/ and /ɔ/ would fall somewhere in between.

In "normal" speech, the velum was raised during the vowel production. Furthermore, it was raised higher during the production of the /i/ and /u/ than during the production of the /æ/ and /ɑ/.

The nose radiated much less sound energy than the mouth when nasalized vowels were produced. The principal influence of nasal coupling served to modify the vocal tract. The general effect of increasing nasal coupling was to broaden and flatten peaks in the vowel spectra and the most pronounced changes occurred in the first formant.

House and Stevens also reported that increased nasal coupling resulted in a reduction of the amplitude of the third vowel formant. Another characteristic they reported which agreed with previously reviewed articles was the presence of additional peaks above the first formant. The presence of extra resonances in nasal speech was also reported.

When House and Stevens compared their perceptual judgements of nasality to the physical data, they found a high correlation between the two. The perceptual judgements of nasality were made by 24 undergraduate students of speech at Emerson College and 10 graduate students or professional linguists. As the average area of coupling increased, the more nasal responses to /i/ and /u/ started sooner than to the /ɛ/ and the /ɔ/. The nasal responses to /ɑ/ were the last to be manifested.

Therefore, they concluded that coupling produced more nasality in /i/ than /ɑ/. Curtis (1968) agreed with this observation when he reported that high vowels were judged to be nasal with very little nasal coupling, whereas low vowels required much greater nasal coupling to be judged as nasal.

Andrews and Rutherford conducted a study to distinguish between orally and nasally emitted sound and to determine the extent to which nasally emitted sound may contribute to a listener's perception of nasality. Nasally and orally emitted components of vowel spectra were recorded separately, but simultaneously, as a normal speaker wearing a variable aperture prosthesis produced four different speech samples. The samples consisted of the vowels /i/, /u/, /ɑ/, and /ɛ/ preceded by a glottal aspirate. Each syllable was produced six times at each velopharyngeal aperture condition. Five different aperture sizes were used, ranging in size from 0 mm^2 to 240 mm^2. A condenser microphone at the subject's nose recorded the nasally emitted sound. Another microphone placed at the subject's lips picked up the orally emitted sound.

A panel of three judges was selected to rate, on a five point scale, the degree of nasality of both the combined oral and nasal signals and the oral component alone. The listening tape consisted of 120 different speech samples which were randomly arranged.

The authors found that for the vowel /u/ the combined signal was consistently more nasal then the oral signal. In eleven of the fifteen productions, the degree of nasality of the combined signal exceeded that of the oral signal alone. For all samples, the effect of adding the nasally emitted component to the orally emitted component increased markedly at the 240 mm^2 condition. The increases in hypernasality associated with the increases in aperture sizes were especially apparent for the two high vowels.

The vowel spectra of both the combined oral and nasal signal and the oral component alone were analyzed for each production in order to identify spectrum changes that were associated with changes in degree of perceived nasality. Comparisons were made of the first, second, and third formant frequencies and intensities of formants two and three relative to the first formant.

For the spectra of the oral component alone for the vowel /u/, the relative intensity of the third harmonic decreased as severity of nasality increased. An increase in hypernasality was perceived when a reduction of the first formant frequency and a rise in the second formant frequency occurred. For the vowel /i/, the intensity of the third harmonic decreased in intensity with increases in nasality. As nasality increased, a decrease in the first formant frequency occurred.

Few systematic changes were seen in the oral spectra of the vowels /ɑ/ and /ɛ/ with increases in degree of nasality. At the same time, the degree of hypernasality for these two vowels did not vary greatly with increases of the velopharyngeal aperture size. The spectrum of the combined signal was essentially the same as that of the oral signal. The feature that was associated with relatively large increases in degree of nasality of the combined spectrum was the combination of increased intensity and reduced frequency of the third formant. The two high vowels, /i/ and /u/, were found to be more nasal than the two low vowels, /ɑ/ and /ɛ/. The findings of Andrews and Rutherford indicated that with greater nasal tract coupling, the nasally emitted component could be expected to contribute proportionately to judgements of hypernasality.

From their study, Andrews and Rutherford concluded that the presence of new resonances did not systematically affect the degree of nasality when the resonances did not alter the characteristics of the vowel formants. They also concluded the identification of hypernasality on vowels was perceived when some feature of the vowel spectrum was distorted. The final conclusion of the authors was that:

> Listeners apparently base their judgements of nasality upon their prior experience with the sounds of the specific language involved, and listen for distortions in the vowel spectra they have learned. The implications of this hypothesis for the identification of hypernasality in a language or dialect with which the listener is not extremely familiar needs to be explored (p. 155).

From the literature reviewed on spectral analysis, one or more of the following characteristics are present in nasalized speech:

1. A reduction in amplitude or intensity of the first formant, which may appear broadened or flattened, was observed.

2. A change in the energy level, often seen as a reduction in amplitude, of the third formant was reported.

3. The presence of anti-resonances within the vowel spectra was seen.

4. Extra or secondary resonances where energy was not normally expected were cited.

5. A shift in relative frequency positions of the formants was observed.

Statement of Problem

Previous research concerned with spectral analysis related to perceptual judgements has dealt with monolingual English speaking subjects. All studies have found a high correlation between the two dimensions measured. However, no studies have dealt with the population of hypernasal speakers with a foreign dialect.

The purpose of this study was to examine the speech of both monolingual speakers and speakers with a foreign dialect, which, in this case, were Mexican-American individuals, to determine if the same correlation existed between spectral analysis and perceptual judgements of hypernasality for both groups.

CHAPTER II

METHODS AND PROCEDURES

The purpose of this study was to determine if the same correlation existed between spectral analysis and perceptual judgements of hypernasality for both English speakers and speakers with a Mexican-American dialect. In this chapter, the methods and procedures used in conducting this study will be presented.

Subjects

Twenty subjects in four different subgroups were included in this study. Subgroup I consisted of five monolingual English speaking Anglo children with sufficient velopharyngeal closure. Four males and one female, ages four to eleven years were in this subgroup. Subgroup II consisted of five monolingual English speaking Anglo children with insufficient velopharyngeal closure. Four males and one female, ages five to twelve years, were in this subgroup. Subgroup III consisted of five bilingual Spanish-English speaking Mexican-American children with sufficient velopharyngeal closure. Three males and two females, ages five to twelve years, were in this subgroup. Subgroup IV consisted of five bilingual Spanish-English speaking Mexican-American children with insufficient velopharyngeal closure. In this subgroup, there were three males and two females, ages six to twelve years. The subjects included in this study were enrolled in private nursery centers, public schools, and the Texas Tech University Speech and Hearing Clinic in Lubbock, Texas. The ten subjects with insufficient velopharyngeal closure were diagnosed as such by the Cleft Palate Team in Lubbock, Texas.

Procedures

Recording of Subjects' Speech

The recording of each subject's speech was done individually in a 14 feet by 14 feet sound treated room using a Shure microphone (Model SM 53), an Electro-Voice microphone (Model 635 A), and an Ampex monophonic AG-500 tape recorder. Each subject was seated 12 inches from the microphones during the recording session. The recordings were made at a tape speed of fifteen inches per second on Ampex Type #641 low noise reel to reel recording tape.

Speech samples elicited from all the subjects consisted of the vowels /i/, /ɑ/, /u/, and /ɛ/ in a syllable consisting of the aspirated /h/ followed by the vowel and in an English sentence. In addition, the subjects in subgroups III and IV repeated a sentence in Spanish for each of the four vowels. The speech samples are presented in Appendix A.

Spectral Analysis

The speech samples were analyzed by a speech spectrograph, a machine that made possible the visual examination of the three acoustic properties of speech sounds. These properties included: 1) frequency, which refers to the rate of vibration of the vocal folds during the production of a sound. Speech sounds are considered to be primarily high frequency, low frequency, or a combination of both; 2) time, which refers to the number of milliseconds necessary for the speech sound to be produced; and 3) amplitude, which refers to the energy with which the vocal folds vibrate during the production of a speech sound (Singh and Singh, 1976).

The sound spectrograph was able to display the acoustic properties of the speech samples on a graph known as a sound spectrogram or sonogram. The frequency region on the sonogram that was significantly amplified for a period of time was a formant frequency. The lowest formant of the sonogram was the first formant and was denoted by F_1. The next higher bandwidth with a noticeable stretch of darkness was the second formant (F_2). The third higher bandwidth was the third formant (F_3), and so on. For this study, the first three formants were the only ones analyzed.

Each speech sample was analyzed on a Sona-Graph 85-800 CPS Spectrum Analyzer (Model 6061A). A 600 ohm headphone output of the Ampex monophonic tape recorder (Model AG-500) was patched into the 600 ohm input of the Sona-Graph. The AGC dial of the Sona-Graph was set at three, with the mark level at six. The machine reproduced the speech samples visually as wide band, linear frequency recordings. The visual output of each speech sample was recorded on a Type B/65 Sonagram. Each sonagram was calibrated with a 500 Hz calibration tone.

Perceptual Judgements

Construction of experimental tape. The 200 speech samples containing the vowels /i/, /ɑ/, /u/, and /ɛ/ were taken from the master tape and recorded in a random order on an 1800 feet Ampex low noise tape at seven and one half inches per second. This recording was made using two Sony recorders (Model TC 106A) and one Sony recorder (Model TC 104A).

Seven practice examples were prepared. These examples included three speech samples that were not included on the tape for judging and four examples were included on the tape for final judging. The examples included subjects with both sufficient and insufficient velopharyngeal closure. Examples in both Spanish and English were used.

Two standards were prepared. The first standard was a normal voice. The second standard was judged by the investigator to be marked by extreme hypernasality and audible escape of air. The subject for this segment normally wore a speech obturator. For the recording of the speech sample, the subject spoke with his obturator removed.

The experimental tape was arranged to present the standard of normal speech first, then the standard of extreme hypernasality. This was followed by the seven practice items. Following the practice items, the two standards were again inserted. The randomly arranged speech samples from the master recording followed. At intervals of twenty-five speech samples, the two standards were inserted.

Judging procedures for scaling nasal resonance. The experimental tape was played on a Roberts tape recorder (Model 770 X) for seven judges. The listeners performed the judging task as a group. Instruction sheets and response sheets (Appendix B) were provided each judge. The judges had all taken a course in voice disorders and had experience in rating nasal resonance. One judge was a graduate student in speech pathology and the six remaining judges had at least a Master's degree in speech pathology.

A seven point equal appearing interval scaling technique was used. The judges were instructed that they would be listening to a series of short segments of speech from recordings of individuals who varied in adequacy of nasal resonance. Some of the speech samples would be in English and the remaining speech samples would be in Spanish. The judges did not consult with each other before or during the judging task.

The judges who rated the speech samples were prepared for their task by the presentation of two voice standards, one a normal voice and one judged by the experimenter to be an extremely hypernasal voice. Seven example segments for practice scaling were then presented. The two standards were identified and played before the first of the 200 samples and after each 25 samples.

Judge reliability was computed using a sampling of speech samples consisting of the sentences for each vowel from the monolingual Anglo group. The formula used was $r = 1 - \frac{V_e}{V_{ind}}$ (Kerlinger, 1973, p. 448). The reliability of the judges was established to be .80.

Statistical Analysis

A Spearman's Rank-Order Correlation (Bruning and Kintz, 1968, p. 156) was computed to determine the relationship between the perceptual judgement ratings and the amplitude of the first and third formants. The formula used for computing this correlation was:

$$\text{rho} = 1 - \frac{6\Sigma D^2}{N(N^2 - 1)}$$

To test the significance of rho, a t-test was computed. The formula used for computing this t-test was:

$$t = rho\sqrt{\frac{N - 2}{1 - rho^2}}$$

A Pearson Product-Moment Correlation (Bruning and Kintz, 1968, p. 153) was computed to establish the relationships between the perceptual judgement ratings and the mean frequency of each of the formants. It was also used to determine the relationship between the mean frequency of the first and third formants. The formula used for computing this correlation was:

$$r = \frac{N\Sigma XY - (\Sigma X)(\Sigma Y)}{\sqrt{[N\Sigma X^2 - (\Sigma X)^2][N\Sigma Y^2 - (\Sigma Y)^2]}}$$

To compare the perceptual judgement ratings with the frequencies of both formants, a multiple correlation to compare the three variables was computed (Bruning and Kintz, 1968, p. 172). The formula used in this computation was:

$$R_{zxy} = \sqrt{\frac{r_{zx}^2 + r_{zy}^2 - 2r_{zx}r_{zy}r_{xy}}{1 - r_{xy}^2}}$$

CHAPTER III

RESULTS AND DISCUSSION

Results

Relationships Between Perceptual Judgements and Formant Amplitudes

The amplitudes of formant one, formant three, and formants one and three were ranked in order from the greatest amplitude to least amplitude for each vowel within each subgroup. The mean ratings of the perceptual judgements of hypernasality were also ranked in order from good voice to extreme hypernasality for each vowel within each subgroup. Spearman's Rank-Order Correlation (Bruning and Kintz, 1968, p. 156) was used to determine if the rank order of the amplitudes was related to the rank of the perceptual judgements. A t-test was then computed to determine if these results were significant. To be considered significant at the .05 level, a t value of greater than 2.31 was required. The correlation results are presented in Table 1.

Table 1: Correlation of perceptual judgements and formant amplitudes.

	Anglos		M-A English		M-A Spanish	
	rho	t-value	rho	t-value	rho	t-value
/i/						
P and F_1	.62	2.23	-.16	-.46	.26	1.30
P and F_3	.62	2.23	-.24	-.70	.36	2.82*
P and F_1F_3	.72	2.94*	.07	.20	-.02	-.06
/ɑ/						
P and F_1	.28	.83	-.05	-.14	.07	.20
P and F_3	.64	2.36*	-.09	-.26	-.03	-.09
P and F_1F_3	.67	2.55*	.30	.89	.03	.09
/u/						
P and F_1	.42	1.31	.08	.23	.08	.23
P and F_3	.62	2.23	.17	.49	.24	.70
P and F_1F_3	.55	1.86	.25	.73	.21	.61
/ɛ/						
P and F_1	.89	5.49*	.12	.34	.26	.76
P and F_3	.93	7.03*	.18	.49	.31	.92
P and F_1F_3	.85	4.55*	.24	.73	.37	1.13

* denotes significance at the .05 level

P and F_1 = relationship between perceptual judgements and amplitude for formant one

P and F_3 = relationship between perceptual judgements and amplitude for formant three

P and F_1F_3 = relationship between perceptual judgements and amplitude for formants one and three

The mean ratings of the perceptual judgements are presented in Appendix C.

<u>Monolingual English speakers</u>. The results of the Spearman Rank-Order Correlation (rho) for the monolingual English speakers will be

presented first. For the vowel /i/, a correlation of $\rho = .62$ ($t = 2.23$, $p > .05$) was computed between amplitudes of formant one and perceptual judgements. A correlation of $\rho = .62$ ($t = 2.23$, $p > .05$) was computed between the amplitude of formant three and perceptual judgements. Between perceptual judgements and formants one and three, a correlation of rho - .72 ($t = 2.94$, $p < .05$) was computed. These results indicated that a perceived increase in nasality was related to a decrease in the amplitudes of formants one and three.

For the vowel /ɑ/, a correlation of $\rho = .28$ ($t = .83$, $p > .05$) was computed between perceptual judgements and the amplitudes of formant one. Between perceptual judgements and the amplitude of formant three, a correlation of $\rho = .64$ ($t = 2.36$, $p < .05$) was computed. A perceived increase in perceptual judgements of nasality was related to a decrease in the amplitude of formant 3. A correlation of $\rho = .67$ ($t = 2.55$, $p < .05$) was computed between perceptual judgements and the amplitude of formants one and three. Therefore, a perceived increase in nasality was related to a decrease in the amplitude of both formants.

For the vowel /u/, a correlation of $\rho = .42$ ($t = 1.31$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one. A correlation of $\rho = .62$ ($t = 2.23$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitude of formants one and three, a correlation of $\rho = .55$ ($t = 1.86$, $p > .05$) was computed. There was not a significant relationship between perceived increases in nasality and decreases in formant amplitudes.

For the vowel /ɛ/, a correlation of rho = .89 ($t = 5.49$, $p < .05$) was computed between perceptual judgements and the amplitude of formant one. A perceived increase in nasality was related to a decrease in the amplitude of formant one. A correlation of rho = .93 ($t = 7.03$, $p < .05$) was computed between perceptual judgements and the amplitude of formant three. A perceived increase in nasality was related to a decrease in the amplitude of the third formant. A correlation of rho = .85 ($t = 4.55$, $p < .05$) was computed between perceptual judgements and the amplitude of formants one and three. A perceived increase in nasality was found to be related to a decrease in the amplitudes of formants one and three.

Bilingual subjects speaking English. This section includes the results of the Spearman's Rank-Order Correlations for the Mexican-American children speaking English. For the vowel /i/, a correlation of rho = -.16 ($t = -.46$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = -.24 ($t = -.70$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitude of formants one and three, a correlation of rho= .07 ($t = .20$, $p > .05$) was computed. There was not a significant relationship between perceived increases in nasality and the amplitude of the formants.

For the vowel /ɑ/, a correlation of rho = -.05 ($t = -.14$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = -.09 ($t = -.26$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitudes of formants one and three, a correlation of rho = .30 (t = .89, p>.05) was computed. This was not a significant relationship.

For the vowel /u/, a correlation value of rho = .08 (t = .23, p>.05) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = .17 (t = .49, p>.05) was computed between perceptual judgements and the amplitude of formant three. Between the perceptual judgements and the amplitude of both formants, a correlation of rho = .25 (t = .73, p>.05) was determined. Again, there was not a significant relationship between these variables.

For the vowel /ɛ/. a correlation of rho = .12 (t = .34, p>.05) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = . 18 (t = .49, p>.05) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitude of formants one and three, a correlation of rho = .24 (t = .73, p>.05) was determined. There was not a significant relationship between increases in perceived nasality and decreases in the amplitude of the formants.

Bilingual subjects speaking Spanish. This section includes the results of the Spearman Rank-Order Correlations for the Mexican-American children speaking Spanish. For the vowel /i/, a correlation of rho = .26 (t = 1.30, p>.05) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = .36 (t = 2.82, p<.05) was computed between perceptual judgements and the amplitude of formant three. An increase in perceived nasality was related to a decrease in the amplitude of formant three. A correlation of rho = -.02 (t = -.06, p>.05) was computed between perceptual judgements and the amplitudes of formants one and three. Therefore, there was not a significant relationship between a perceived increase in nasality and a decrease in the amplitudes of the formants.

For the vowel /ɑ/, a correlation of rho = .07 (t = .20, p>.05) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = -.03 (t = -.09, p>.05) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitudes of formants one and three, a correlation value of rho = .03 (t = .08, p>.05) was computed. This indicates that there was not a significant relationship between perceived increase in nasality and a decrease in the amplitudes of the formants.

For the vowel /u/, a correlation of rho = .08 (t = .23, p.>05) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = .24 (t = .70, p>.05) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitudes of formants one and three, a correlation of rho = .21 (t = .61, p>.05) was determined. There was not a significant relationship between increases in perceived nasality and the amplitudes of formants one and three.

For the vowel /ɛ/, a correlation of rho = .26 (t = .76, p>.05) was computed between perceptual judgements and the amplitude of formant one. A correlation of rho = .31 (t = .92, p>.05) was computed between perceptual judgements and the amplitude of formant three. Between perceptual judgements and the amplitudes of formants one and three, a correlation of rho = .37 (t = 1.13, $p > .05$) was determined. Therefore, there was not a significant relationship between an increase in perceived nasality and a decrease in the amplitude of the formants.

Relationships Between Perceptual Judgements and Formant Frequencies

A Pearson Product-Moment Correlation (Bruning and Kintz, 1968, p. 152) was used to determine the relationships between the perceptual judgements and the mean frequency of the first formant, and between perceptual judgements and the mean frequency of the third formant for each of the vowels within each subgroup. The Pearson Product-Moment Correlation was also used to determine the relationship between the mean frequencies of formants one and three. A multiple correlation (Bruning and Kintz, 1968, p. 171) was used to determine the relationship between perceptual judgements and the mean frequencies of formants one and three for each vowel within each subgroup. The results of these correlations are presented in Table 2. The coefficient of determination, r^2, was alos computed. This gives the amount of common variance, or , when multiplied by 100, the per cent of common variance.

Table 2: Correlation of perceptual judgements and formant frequencies.

	Anglos		M-A English		M-A Spanish	
	r	r^2	r	r^2	r	r^2
/i/						
P and F_1	-.17	.03	-.79	.62	-.65	.42
P and F_3	.05	.003	-.47	.22	-.36	.13
F_1 and F_3	.53	.28	.74	.55	.56	.31
P and F_1F_3	.24	.06	.80	.64	.65	.42
/ɑ/						
P and F_1	.14	.02	-.64	.41	-.63	.40
P and F_3	-.51	.26	-.38	.14	-.04	.002
F_1 and F_3	.46	.21	.47	.22	.32	.10
P and F_1F_3	.65	.42	.64	.41	.66	.42
/u/						
P and F_1	.16	.03	.63	.40	.31	.10
P and F_3	-.10	.01	-.24	.06	-.28	.08
F_1 and F_3	.61	.37	.70	.49	.82	.67
P and F_1F_3	.31	.10	.70	.49	.98	.96
/ɛ/						
P and F_1	.18	.03	-.77	.59	-.53	.28
P and F_3	-.84	.71	-.17	.03	.01	.0001
F_1 and F_3	.06	.003	.41	.17	.06	.003
P and F_1F_3	.90	.81	.78	.61	.53	.28

P and F_1 = relationship between perceptual judgements and mean formant frequency for formant one

P and F_3 = relationship between perceptual judgements and mean formant frequency for formant three

F_1 and F_3 = relationship between mean frequencies for formants one and three

P and F_1F_3 = relationship between perceptual judgements and mean formant frequencies for formants one and three

Monolingual English speakers. The results of the correlations for the monolingual English speakers will be presented first. For the vowel /i/, a correlation of $r = -.17$ ($r^2 = .03$) was computed between perceptual judgements and the mean frequency of formant one. This indicated that three per cent of the perceived increase in nasality was related to a decrease in the frequency of formant one. A correlation of $r = .05$ ($r^2 = .003$) was computed between perceptual judgements and the mean frequency of formant three. Less than one per cent of the perceived increase in nasality was related to a change in the mean frequency of that formant. Between the mean frequency of formants one and three, a correlation of $r = .53$ ($r^2 = .28$) was computed. Twenty-eight per cent of the change in one formant was related to a change in the other formant. A correlation of $r = .24$ ($r^2 = .06$) was computed between perceptual judgements and the mean frequencies of formants one and three. Six per cent of the perceived increases in nasality were related to decreases in the mean frequencies of both formants.

For the vowel /ɑ/, a correlation of $r = .14$ ($r^2 = .02$) was computed between preceptual judgements and the mean frequency of formant one. An extremely small amount of the perceived changes in nasality were common to changes in frequencies of the first formant. A correlation of $r = -.51$ ($r^2 = .26$) was computed between perceptual judgements and the mean frequency of the third formant. Twenty-six per cent of the perceived increase in nasality was related to a decrease in the frequency of the third formant. Between the mean frequencies of formants one and three, a correlation of $r = .46$ ($r^2 = .21$) was computed.

This indicated that forty-two percent of the perceived increase in nasality was related to a decrease in the frequencies of the formants.

For the vowel /u/, a correlation of $r = .16$ ($r^2 = .03$) was computed between perceptual judgements and the mean frequency of the first formant. Almost none of the perceived change in nasality was related to a change in the frequency of formant one. A correlation of $r = -.10$ ($r^2 = .01$) was computed between perceptual judgements and the mean frequency of formant three. Therefore, no more than one per cent of the perceived increase in nasality was related to a decrease in the third formant frequency. Between the mean frequencies of formants one and three, a correlation of $r = .61$ ($r^2 = .37$) was computed. Thirty-seven per cent of the change in the frequency of one formant was related to the change in frequency of the other formant. A correlation of $r = .31$ ($r^2 =.10$) was computed between perceptual judgements and the mean frequencies of formants one and three. Ten per cent of the perceived increase in nasality was related to a decrease in the mean frequency of the formants.

For the vowel /ɛ/, a correlation of $r = .18$ ($r^2 = .03$) was computed between perceptual judgements and the mean frequency of the first formant. Three per cent of the change in perceived nasality can be attributed to a change in the frequency of formant one. A correlation of $r = -.84$ ($r^2 = .71$) was computed between perceptual judgements and the mean frequency of formant three. Seventy-one per cent of the perceived increase in nasality was related to a decrease in the frequency of the third formant. A correlation of $r = .06$ ($r^2 = .003$) was computed between the frequencies of formants one and three. Practically none of the change in one formant was related to a change in the other formant. A correlation of $r = .90$ ($r^2 = .81$) was computed between perceptual judgements and the mean frequencies of formants one and three. Eighty-one per cent of the perceived increase in nasality was related to a decrease in frequency of both formants.

Bilingual subjects speaking English. This section will include the results of the correlation for the Mexican-American children speaking English. For the vowel /i/, a correlation of $r = -.79$ ($r^2 = .62$) was computed between perceptual judgements and the mean frequency of formant one. Sixty-two per cent of the perceived increase in nasality was related to a decrease in the frequency of formant one. A correlation of $r = -.47$ ($r^2 = .22$) was computed between perceptual judgements and the mean frequency of formant three. Twenty-two per cent of the perceived increase in nasality was related to a decrease in the frequency of formant three. A correlation of $r = .74$ ($r^2 = .55$) was computed between the mean frequencies of formants one and three. Fifty-five per cent of the change in one formant was related to the change in the frequency of the other formant. A correlation of $r = .80$ ($r^2 = .64$) was computed between perceptual judgements and the mean frequencies of formants one and three. Sixty-four per cent of the perceived increase in nasality was related to a decrease in the frequency of formants one and three.

For the vowel /ɑ/, a correlation of $r = -.64$ ($r^2 = .41$) was computed between perceptual judgements and the mean frequency of formant one. Forty-one per cent of the perceived increase in nasality was related to a decrease in the frequency of the first formant. A correlation of $r = -.38$ ($r^2 = .14$) was computed between perceptual judgements and the mean frequency of formant three. This indicated that fourteen per cent of the perceived increase in nasality was related to a decrease in the frequency of the third formant. A correlation of $r = .47$ ($r^2 = .22$) was computed between the mean frequencies of the two formants. Twenty-two per cent of the change in the frequency of one formant was related to the change in frequency of the other formant. A correlation of $r = .64$ ($r^2 = .41$) was computed between perceptual judgements and the mean frequencies of formants one and three. Forty-one per cent of the perceived increase in nasality was related to a decrease in the frequencies of formants one and three.

For the vowel /u/, a correlation of $r = -.63$ ($r^2 = .40$) was computed between perceptual judgements and the mean frequency of formant one. Forty per cent of the perceived increase in nasality was related to a decrease in the frequency of formant one. A correlation of $r = -.24$ ($r^2 = .06$) was computed between perceptual judgements and the mean frequency of formant three. Six per cent of the perceived increase in nasality was related to a decrease in the frequency of formant three. A correlation of $r = .70$ ($r^2 = .49$) was computed between the mean frequencies of both formants. Forty-nine per cent of the change in the frequency of one formant was related to a change in frequency of the other formant. A correlation of $r = .70$ ($r^2 = .49$) was computed between perceptual judgements and the mean frequencies of formants one and three. Therefore, forty-nine per cent of the perceived increase in nasality was related to a decrease in the frequencies of formants one and three.

For the vowel /ɛ/, a correlation of $r = -.77$ ($r^2 = .59$) was computed between perceptual judgements and the mean frequency of formant one. Fifty-nine per cent of the perceived increase in nasality was related to a decrease in the frequency of the first formant. A correlation of $r = -.17$ ($r^2 = .03$) was computed between perceptual judgements and the mean frequency of formant three. Three per cent of the perceived increase in nasality was related to a decrease in the frequency of formant three. A correlation of $r = .41$ ($r^2 = .17$) was computed between the mean frequencies of both formants. Seventeen per cent of the change in the frequency of one formant was related to the change in frequency of the other formant. A correlation of $r = .78$ ($r^2 = .61$) was computed between perceptual judgements and the mean frequencies of formants one and three. Sixty-one per cent of the perceived increase in nasality was related to a decrease in the frequencies of formants one and three.

Bilingual subjects speaking Spanish. This section will include the results for the Mexican-American children speaking Spanish. For the vowel /i/, a correlation of $r = -.65$ ($r^2 = .42$) was computed between perceptual judgements and the mean frequency of formant one. This indicated that forty-two per cent of the perceived increase in nasality was related to a decrease in the frequency of the first formant. A correlation of $r = -.36$ ($r^2 = .13$) was computed between perceptual judgements and the mean frequency of the third formant. Thirteen per cent of the perceived increase in nasality was related to a decrease in the frequency of the third formant. A correlation of $r = .56$ ($r^2 = .31$) was computed between the mean frequencies of both formants. Thirty-one per cent of the change in frequency of one formant was related to a change in the frequency of the other formant. A correlation of $r = .65$ ($r^2 = .42$) was computed between perceptual judgements and the mean frequencies of both formants. Forty-two per cent of the perceived increase in nasality was related to a decrease in the frequency of formants one and three.

For the vowel /ɑ/, a correlation of $r = -.63$ ($r^2 = 40$) was computed between perceptual judgements and the mean frequency of formant one. Forty per cent of the perceived increase in nasality was related to a decrease in the frequency of the first formant. A correlation of $r = -.04$ ($r^2 = .002$) was computed between perceptual judgements and the mean frequency of the third formant. None of the perceived increase in nasality can be assumed to be related to a decrease in the frequency of the third formant. A correlation of $r = .32$ ($r^2 = .10$) was computed between the mean frequencies of formants one and three. Ten per cent of the change in the frequency of one formant was related to a change in the frequency of the other formant. A correlation of $r = .66$ ($r^2 = .42$) was computed between perceptual judgements and the mean frequencies of formants one and three. Forty-two per cent of the perceived increase in nasality was related to a decrease in the frequencies of formants one and three.

For the vowel /u/, a correlation of r = .31 (r^2 = .10) was computed between perceptual judgements and the mean frequency of formant one. Ten per cent of the perceived change in nasality was related to a change in the frequency of the first formant. A correlation of r = -.28 (r^2 = .08) was computed between perceptual judgements and the mean frequency of formant three. Eight per cent of the perceived increase in nasality was related to a decrease in the frequency of the third formant. A correlation of r = .82 (r^2 = .67) was computed between the mean frequencies of formants one and three. This indicated that sixty-seven per cent of the change in the frequency of one formant was related to a change in frequency of the other formant. A correlation of r = .98 (r^2 = .96) was computed between perceptual judgements and the mean frequencies of formants one and three. Ninety-six per cent of the perceived increases in nasality were related to a decrease in the frequencies of formants one and three.

For the vowel /ɛ/, a correlation of r = -.53 (r^2 = .28) was computed between perceptual judgements and the mean frequency of formant one. Twenty-eight per cent of the perceived increase in nasality was related to a decrease in the frequency of formant one. A correlation of r = .01 (r^2 = .0001) was computed between perceptual judgements and the mean frequency of formant three was computed. None of the changes in perceived nasality were related to changes in the frequency of formant three. A correlation of r = .06 (r^2 = .003) was computed between the mean frequencies of both formants. Again, none of the change in the frequency of one formant was related to a change in the frequency of the other formant. A correlation of $r = .53$ ($r^2 = .28$) was computed between perceptual judgements and the mean frequencies of both formants. Twenty-eight per cent of the perceived increase in nasality was related to the decrease in frequency of formants one and three.

Discussion

The high correlations between perceptual judgements and spectrographic formant amplitudes for the monolingual Anglo group are consistent with the findings of House (1960), Peterson (1961), Schwartz (1968), and House and Stevens (1956). When the Anglo subjects repeated the vowels /i/, /ɑ/, and /ɛ/ in speech samples, as perceptual judgements of nasality increase, a decrease occurred in the amplitude of formants one and three of the spectrographic analysis.

The low correlations between perceptual judgements and the amplitudes of the first and third formants on all vowels for the Mexican-American group when speaking either English or Spanish seem to support Andrews and Rutherford's (1972, p. 155) conclusion that:

> Listeners apparently base their judgements of nasality upon their prior experience with the sounds of the specific language involved, and listen for distortions in the vowel spectra they have learned.

The increases in the perceptual ratings of nasality for the Mexican-American subjects when speaking either English or Spanish were not associated with decreases in the amplitudes of the two formants studied, possibly because of the dialect involved.

The correlations between perceptual judgements and spectrographic formant mean frequencies for the bilingual Mexican-American group are consistent with the findings of Andrews and Rutherford (1972), House and Stevens (1956), Peterson (1961), and Schwartz (1968). When the Mexican-American subjects repeated the four vowels in speech samples in English and repeated the /i/, /ɑ/, and /u/ in speech samples in Spanish, as perceptual judgements of nasality increased, a decrease occurred in the mean frequency of formants one and three of the spectrographic analysis. When the Mexican-American group repeated the /ɛ/ in speech samples in Spanish, there were low correlations between the perceptual judgements and the mean frequency of formant one, formant three, and formants one and three. The Spanish language does not have a true /ɛ/, rather the vowel used in the Spanish sentence for the /ɛ/ vowel was a cross between the /æ/ and the /e/. Therefore, the judges had relatively little experience with the Spanish vowel and apparently had difficulty identifying the distortions in the vowel spectra they had not learned.

The high correlations between perceptual judgements and the mean frequency of formant three and formants one and three for the monolingual English speaker's productions of /ɛ/ are in agreement with previous research (Andrews and Rutherford, 1972; House and Stevens, 1956; Peterson, 1961; and Schwartz, 1968). As more nasality was perceived on /ɛ/ productions, the mean frequency decreased on formant three or on formants one and three. The low correlations between the perceptual judgements and the spectrographic analysis of the mean frequencies for the monolingual English subjects' productions of /i/, /ɑ/, and /u/ were unexpected findings. The West Texas dialect may influence perception of nasality for the Anglo group when the perceptual judgements are compared with the mean frequencies of the formants.

The results of this study indicate that the same correlation does not exist between spectral analysis and perceptual judgements of nasality for monolingual English speakers and for bilingual speakers with a Mexican-American dialect. For the monolingual English speaking Anglo group, an increase in perceived nasality was associated with a decrease in the amplitude of formants one and three. However, increases in perceived nasality were not related to shifts in the mean frequency of the formants. For the Mexican-American group, the opposite relationships appear to exist. A high correlation exists between perceptual judgements and mean frequency of the formants; however, a low correlation is present between perceptual judgements and formant amplitudes.

CHAPTER IV

SUMMARY AND CONCLUSIONS

Purpose of Study

Correlations between perceptual judgements and spectrographic analysis have been done concerning English speakers; however, no such investigation has been done on speakers with a dialect. The purpose of this study was to determine if the same correlation existed between spectral analysis and perceptual judgements of hypernasality for both English speakers and speakers with a Mexican-American dialect.

Procedures

The 20 subjects were divided into four groups. Group I included five monolingual Anglo children with sufficient velopharyngeal closure. Group II included five monolingual Anglo children with insufficient velopharyngeal closure. Group III consisted of five bilingual Mexican-American children with sufficient velopharyngeal closure. Group IV consisted of five bilingual Mexican-American children with insufficient velopharyngeal closure. All children with insufficient velopharyngeal closure were diagnosed as such by the Cleft Palate Team in Lubbock, Texas.

Each subject repeated the speech samples containing the vowels /i/, /ɑ/, /u/, and /ɛ/. All subjects repeated these vowels in a syllable preceded by /h/ and also in a sentence. The Mexican-American children repeated additional sentences in Spanish for each vowel.

Each speech sample was randomly arranged on a tape to be judged by seven listeners. All listeners had experience in judging nasal resonance. One judge was a graduate student in speech pathology and the six remaining judges had at least a Master's degree in speech pathology. The listeners rated each speech sample on a one to seven point scale with one being good voice and seven being extreme nasal resonance. The judge reliability was determined to be .80.

Each speech sample was analyzed on a speech sonograph. The amplitude, or frequency, of formants one, two, and three were measured. Correlations were computed between the mean for the first and third formants and the perceptual judgements of nasality.

Results

The following results were obtained from the frequency analysis of the speech samples for the monolingual English speaking subjects:

1. For the vowel /i/

   a. A correlation value of -.17 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of .05 was computed between perceptual judgements and the frequency of formant three.

   c. A correlation value of .53 was computed between the frequency of formants one and three.

   d. A correlation value of .24 was computed between perceptual judgements and the frequency of formants one and three.

2. For the vowel /ɑ/

   a. A correlation value of .14 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of -.51 was computed between perceptual judgements and the frequency of formant three.

   c. A correlation value of .46 was computed between the frequency of formants one and three.

   d. A correlation value of .65 was computed between perceptual judgements and the frequency of formants one and three.

3. For the vowel /u/

   a. A correlation value of .16 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of -.10 was computed between perceptual judgements and the frequency of formant three.

c. A correlation value of .61 was computed between the frequency of formants one and three.

d. A correlation value of .31 was computed between perceptual judgements and the frequency of formants one and three.

4. For the vowel /ɛ/

a. A correlation value of .18 was computed between perceptual judgements and the frequency of formant one.

b. A correlation value of -.84 was computed between perceptual judgements and the frequency of formant three.

c. A correlation value of -.06 was computed between the frequency of formant one and three.

d. A correlation value of .90 was computed between perceptual judgements and the frequency of formants one and three.

The following results were obtained from the frequency analysis of the speech samples for the bilingual subjects speaking English:

1. For the vowel /i/

a. A correlation value of -.79 was computed between perceptual judgements and the frequency of formant one.

b. A correlation value of -.47 was computed between perceptual judgements and the frequency of formant three.

c. A correlation value of .74 was computed between the frequency of formants one and three.

d. A correlation value of .80 was computed between perceptual judgements and the frequency of formants one and three.

2. For the vowel /ɑ/

a. A correlation value of -.64 was computed between perceptual judgements and the frequency of formant one.

b. A correlation value of -.38 was computed between perceptual judgements and the frequency of formant one.

c. A correlation value of .47 was computed between the frequency of formants one and three.

d. A correlation value of .64 was computed between perceptual judgements and the frequency of formants one and three.

3. For the vowel /u/

a. A correlation value of -.63 was computed between perceptual judgements and the frequency of formant one.

b. A correlation value of -.24 was computed between perceptual judgements and the frequency of formant three.

c. A correlation value of .70 was computed between the frequency of formants one and three.

d. A correlation value of .70 was computed between perceptual judgements and the frequency of formants one and three.

4. For the vowel /ɛ/

a. A correlation value of -.77 was computed between perceptual judgements and the frequency of formant one.

b. A correlation value of -.17 was computed between perceptual judgements and the frequency of formant three.

c. A correlation value of .41 was computed between the frequency of formants one and three.

d. A correlation value of .79 was computed between perceptual judgements and the frequency of formants one and three.

The following results were obtained from the frequency analysis of the speech samples for the bilingual subjects speaking Spanish:

1. For the vowel /i/

   a. A correlation value of -.65 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of -.36 was computed between perceptual judgements and the frequency of formant three.

   c. A correlation value of .56 was computed between the frequency of formants one and three.

   d. A correlation value of .65 was computed between perceptual judgements and the frequency of formants one and three.

2. For the vowel /ɑ/

   a. A correlation value of -.63 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of -.04 was computed between perceptual judgements and the frequency of formant three.

   c. A correlation value of .32 was computed between the frequency of formants one and three.

   d. A correlation value of .66 was computed between perceptual judgements and the frequency of formants one and three.

3. For the vowel /u/

   a. A correlation value of .31 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of -.28 was computed between perceptual judgements and the frequency of formant three.

   c. A correlation value of .82 was computed between the frequency of formants one and three.

   d. A correlation value of .98 was computed between perceptual judgements and the frequency of formants one and three.

4. For the vowel /ɛ/

   a. A correlation value of -.53 was computed between perceptual judgements and the frequency of formant one.

   b. A correlation value of .01 was computed between perceptual judgements and the frequency of formant three.

   c. A correlation value of .06 was computed between the frequency of formants one and three.

   d. A correlation value of .53 was computed between perceptual judgements and the frequency of formants one and three.

The following results were obtained from the amplitude analysis of the speech samples for the monolingual English speaking subjects:

1. For the vowel /i/

   a. A correlation of rho = .62 ($t = 2.23$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

   b. A correlation of rho = .62 ($t = 2.23$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three.

   c. A correlation of rho = .72 ($t = 2.94$, $p < .05$) was computed between perceptual judgements and the amplitude of formants one and three.

2. For the vowel /ɑ/

   a. A correlation of rho = .28 ($t = .83$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

   b. A correlation of rho = .64 ($t = 2.36$, $p < .05$) was computed between perceptual judgements and the amplitude of formant three.

   c. A correlation of rho = .67 ($t = 2.55$, $p < .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

3. For the vowel /u/

   a. A correlation of rho = .42 ($t = 1.31$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

   b. A correlation of rho = .62 ($t = 2.23$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three.

   c. A correlation of rho = .55 ($t = 1.86$, $p > .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

4. For the vowel /ε/

   a. A correlation of rho = .89 ($t = 5.49$, $p < .05$) was computed between perceptual judgements and the amplitude of formant one.

   b. A correlation of rho = .93 ($t = 7.03$, $p < .05$) was computed between perceptual judgements and the amplitude of formant three.

   c. A correlation of rho = .85 ($t = 4.55$, $p < .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

The following results were obtained from the amplitude analysis of the speech samples for the bilingual subjects speaking English:

1. For the vowel /i/

   a. A correlation of rho = -.16 ($t = -.46$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

   b. A correlation of rho = -.24 ($t = -70$, $p > .05$) was computed between perceptual judgement and the amplitude of formant three.

   c. A correlation of rho = .07 ($t = .20$, $p > .05$) was computed between perceptual judgements and the amplitudes of formant one and three.

2. For the vowel /ɑ/

   a. A correlation of rho = -.05 ($t = -.14$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = -.09 (t =-.26, p>.05) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = .30 (t = .89, p>.05) was computed between perceptual judgements and the amplitudes of formants one and three.

3. For the vowel /u/

a. A correlation of rho = .08 (t = .23, p>.05) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = .17 (t = .49, p>.05) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = .25 (t = .73, p>.05) was computed between perceptual judgements and the amplitudes of formants one and three.

4. For the vowel /ɛ/

a. A correlation of rho = -.12 (t = .34, p>.05) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = .18 (t = .49, p>.05) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = .24 (t = .73, p>.05) was computed between perceptual judgements and the amplitudes of formants one and three.

The following results were obtained from the amplitude analysis of the speech samples for the bilingual Mexican-American subjects speaking Spanish:

1. For the vowel /i/

a. A correlation of rho = .26 (t = 1.30, p>.05) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = .36 ($t = 2.82$, $p < .05$) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = -.02 ($t = -.06$, $p > .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

2. For the vowel /ɑ/

a. A correlation of rho = .07 ($t = .20$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = -.03 ($t = -.09$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = .03 ($t = .09$, $p > .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

3. For the vowel /u/

a. A correlation of rho = .08 ($t = .23$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = .24 ($t = .70$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = .21 ($t = .61$, $p > .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

4. For the vowel /ɛ/

a. A correlation of rho = .26 ($t = .76$, $p > .05$) was computed between perceptual judgements and the amplitude of formant one.

b. A correlation of rho = .31 ($t = .93$, $p > .05$) was computed between perceptual judgements and the amplitude of formant three.

c. A correlation of rho = .37 ($t = 1.13$, $p > .05$) was computed between perceptual judgements and the amplitudes of formants one and three.

Conclusions

From the analysis of the data the following conclusions were made:

1) When the bilingual Mexican-American subjects produce the /i/, /ɑ/, /u/, and /ɛ/ vowels in English speech samples one or both of the following characteristics are present in nasalized speech. A reduction in mean frequency of the first formant occurred as the perception of nasality increased. A reduction in frequency of the third formant occurred as the perception of nasality increased.
2) When the bilingual Mexican-American subjects produce the /i/, /ɑ/, and /u/ vowels in Spanish speech samples one or both of the following characteristics are present in nasalized speech. A reduction in mean frequency of the first formant occurred as the perception of nasality increased. A reduction in frequency of the third formant occurred as the perception of nasality increased.
3) A reduction of the mean frequency of formant one, formant three, or formants one and three was not related to perceived increases in nasality for a Spanish vowel which is not in the language of the judges.
4) A reduction in the amplitude of formant one, formant three, or formants one and three was not related to perceived increases in nasality for the bilingual Mexican-American subjects speaking English or Spanish.

5) When monolingual Anglo subjects with a West Texas dialect produce the /i/, /ɑ/, and /ɛ/ vowels in speech samples, one or more of the following characteristics are present in nasalized speech. A reduction in amplitude or intensity of the first formant occurred as the perception of nasality increased. A reduction in the amplitude or intensity of the third formant occurred as the perception of nasality increased. In addition, on the production of the /ɛ/ in speech samples, one or more of the following characteristics are present in nasalized speech. A reduction in the mean frequency of formant three occurred as the perception of nasality increased. A reduction in the mean frequency of formants one and three occurred as the perception of nasality increased.

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APPENDICES

A. Speech Samples

B. Instructions and Response Sheets for Scaling Nasal Resonance

C. Mean Ratings of Perceptual Judgements

APPENDIX A: SPEECH SAMPLES

The subjects repeated the following items in the following order:

1. /hi/
2. /hɑ/
3. /hu/
4. /hɛ/
5. I see Lee sleeping.
6. The cars are parked.
7. Who had soup at the zoo?
8. Ted fed his pet.

The Mexican-American subjects also repeated the following sentences:

1. Tu tia y tio estan aqui.
2. El se va a la casa.
3. A el le gusta la cachucha azul.
4. El puede ver el perro.

APPENDIX B: INSTRUCTIONS FOR SCALING NASAL RESONANCE

You are asked to listen to a series of short segments of speech from recordings of persons who vary in adequacy of nasal resonance. The speech samples will be presented to you one at a time. You are to estimate the relative adequacy of nasal resonance in relation to a good voice standard and a poor voice standard which will be played for you soon. You do this by assigning the number of points you believe represents the relative excellence for each sample.

Now you will hear what we call the standards. Standard 1, good voice, would be assigned a scale value of one; standard 2, poor voice, would be assigned a scale value of seven. The point assignments you will be asked to make on the succeeding examples and samples should represent the relative excellence of each sample. For example, if a sample seems to be midway between the two standards of nasal resonance, it would be assigned a scale value of four. A sample that is very hypernasal but less so that the poor voice would be assigned a scale value of five or six. Thus each sample is to be rated on a seven point scale.

Now you will hear the standard stimuli followed by seven practice examples. Scale these examples in keeping with the above instructions. Mark the point assignments in the spaces provided on the response sheet. Remember that this is to be a comparison of the relative excellence of the nasal resonance of the sample based upon the two standards. If you are somewhat doubtful about what number to assign, make a guess. Four seconds are provided for recording your judgements. Are there any questions?

We are now ready to judge the experimental samples. You will again hear the standards to which the scale values of one and seven, respectively, would be assigned. This will be followed by 25 samples and a repetition of the standards. The standards are presented after every 25 samples. There are a total of 200 samples. Male and female subjects are included, and they may vary in vocal intensity. There will be samples in both Spanish and English. You are to judge the excellence of nasal resonance, not on any other aspect.

Before we begin, do you have any questions? Remember that a scale value of one represents a good voice and a scale value of seven represents a poor voice. This scale is shown on your response sheet.

APPENDIX B: RESPONSE SHEET FOR SCALING NASAL RESONANCE

Name___________________

Date___________________

RATING SCALE

1	2	3	4	5	6	7
Good Voice						Extreme Nasal Resonance

STANDARDS

Examples

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______

STANDARDS

Samples

1. ______
2. ______
3. ______
4. ______
5. ______
6. ______
7. ______
8. ______
9. ______
10. ______
11. ______
12. ______
13. ______
14. ______
15. ______
16. ______
17. ______
18. ______
19. ______
20. ______
21. ______
22. ______
23. ______
24. ______
25. ______

STANDARDS

26. ______
27. ______
28. ______
29. ______
30. ______
31. ______
32. ______

RATING SCALE

1	2	3	4	5	6	7
Good Voice						Extreme Nasal Resonance

33. ______
34. ______
35. ______
36. ______
37. ______
38. ______
39. ______
40. ______
41. ______
42. ______
43. ______
44. ______
45. ______
46. ______
47. ______
48. ______
49. ______
50. ______

STANDARDS

51. ______
52. ______
53. ______
54. ______
55. ______
56. ______
57. ______
58. ______
59. ______
60. ______
61. ______
62. ______
63. ______
64. ______
65. ______
66. ______
67. ______
68. ______
69. ______
70. ______
71. ______
72. ______
73. ______
74. ______
75. ______

STANDARDS

76. ______
77. ______
78. ______
79. ______
80. ______
81. ______
82. ______
83. ______
84. ______
85. ______
86. ______
87. ______
88. ______
89. ______
90. ______
91. ______
92. ______
93. ______
94. ______
95. ______
96. ______

RATING SCALE

1	2	3	4	5	6	7
Good Voice						Extreme Nasal Resonance

97. ______
98. ______
99. ______
100. ______

STANDARDS

101. ______
102. ______
103. ______
104. ______
105. ______
106. ______
107. ______
108. ______
109. ______
110. ______
111. ______
112. ______
113. ______
114. ______
115. ______
116. ______
117. ______
118. ______
119. ______
120. ______
121. ______
122. ______
123. ______
124. ______
125. ______

STANDARDS

126. ______
127. ______
128. ______
129. ______
130. ______
131. ______
132. ______
133. ______
134. ______
135. ______
136. ______
137. ______
138. ______
139. ______
140. ______
141. ______
142. ______
143. ______
144. ______
145. ______
146. ______
147. ______
148. ______
149. ______
150. ______

STANDARDS

151. ______
152. ______
153. ______
154. ______
155. ______
156. ______
157. ______
158. ______
159. ______

RATING SCALE

1	2	3	4	5	6	7
Good Voice						Extreme Nasal Resonance

160. ______
161. ______
162. ______
163. ______
164. ______
165. ______
166. ______
167. ______
168. ______
169. ______
170. ______
171. ______
172. ______
173. ______
174. ______
175. ______

STANDARDS

176. ______
177. ______
178. ______
179. ______
180. ______
181. ______
182. ______
183. ______
184. ______
185. ______
186. ______
187. ______
188. ______
189. ______
190. ______
191. ______
192. ______
193. ______
194. ______
195. ______
196. ______
197. ______
198. ______
199. ______
200. ______

APPENDIX C: MEAN RATINGS OF PERCEPTUAL JUDGEMENTS

Mexican-American English

Subjects with sufficient closure	/i/	/ɑ/	/u/	/ɛ/
Subject U	1.42	1.92	1.51	3.07
Subject Q	1.49	1.78	1.85	2.14
Subject R	1.85	2.35	1.71	2.06
Subject S	1.99	1.35	2.56	3.99
Subject T	3.07	2.78	4.42	4.14

Subjects with insufficient closure	/i/	/ɑ/	/u/	/ɛ/
Subject N	1.57	2.21	3.21	3.57
Subject I	2.49	2.00	2.56	2.42
Subject O	3.42	4.13	3.78	4.57
Subject K	4.21	2.42	3.78	2.49
Subject M	6.00	5.14	5.21	5.78

Mexican-American Spanish

Subjects with sufficient closure	/i/	/ɑ/	/u/	/ɛ/
Subject Q	1.14	1.14	1.14	2.14
Subject R	1.14	1.14	1.42	1.71
Subject U	1.14	1.42	1.28	2.28
Subject S	1.71	1.00	1.14	1.28
Subject T	2.28	3.85	5.00	2.85

Subjects with insufficient closure	/i/	/ɑ/	/u/	/ɛ/
Subject N	1.42	1.57	2.00	2.42
Subject K	2.00	4.00	3.42	2.42
Subject I	2.85	2.14	2.14	2.00
Subject O	4.57	4.52	3.85	6.00
Subject M	6.85	6.42	7.00	6.14

APPENDIX C: MEAN RATINGS OF PERCEPTUAL JUDGEMENTS

Anglos

Subjects with sufficient closure	/i/	/ɑ/	/u/	/ɛ/
Subject P	1.35	1.07	1.71	1.49
Subject F	2.35	2.28	2.28	2.71
Subject C	2.78	1.14	3.00	1.56
Subject D	2.92	2.21	2.49	2.64
Subject E	3.13	2.92	1.92	2.49

Subjects with insufficient closure	/i/	/ɑ/	/u/	/ɛ/
Subject J	1.35	2.64	2.64	4.00
Subject G	1.92	1.49	1.71	2.78
Subject A	2.35	2.92	3.28	3.13
Subject L	3.71	3.49	2.71	3.35
Subject B	4.14	3.56	4.85	5.35