ACOUSTIC INDICES OF VOCAL FOLD AGING IN YOUNG AND MIDDLE-AGE ADULT MALES.

by

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ACOUSTIC INDICES OF VOCAL FOLD AGING IN YOUNG AND

MIDDLE-AGE ADULT MALES

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INTRODUCTION

The Vocal Folds

The vocal folds are elastic connective tissues housed within and supported by the larynx, which is made up of muscles, connective tissue, ligaments and cartilages. The vocal folds are bilateral structures that are involved in various physiological functions such as respiration, airway protection, and phonation. Phonation is the production of voice by the vibrating vocal folds, which occurs when intrinsic laryngeal muscles adduct (close) the vocal folds above a subglottal stream of air pressure. Adduction of the vocal folds leads to vocal fold vibration while abduction (opening) leads to the absence of voice.

The vocal folds are able to adduct (close), abduct (open), elongate, and shorten through muscle movement. The intrinsic laryngeal muscles that allow the vocal folds to adduct (close) include the lateral cricoarytenoid muscles, interarytenoid muscles, and the thyromuscularis (part of the thyroarytenoid muscle). Activation of these muscles occurs during voice production, swallowing, coughing, and throat clearing. The intrinsic laryngeal muscle that allows the vocal folds to abduct (open) is the posterior cricoarytenoid, which is active when an individual actively inhales. The cricothyroid muscle allow the vocal folds to elongate while the thyrovocalis (also part of the thyroarytenoid muscle) muscle allow the vocal folds to shorten. When phonation occurs contraction of the adductors causes the vocal folds to come closely together under tension. Changes to vocal fold tension, which is influenced by the antagonistic activity of the cricothyroid and thyroarytenoid muscles, can change vocal fundamental frequency [7].

Vocal fold tension and the vibratory dynamics of the vocal folds are in large part dependent on their structural properties. The vocal folds are composed of five layers of tissue. The first layer is a protective layer of squamous epithelium. This protective layer helps in keeping the delicate tissues of the vocal folds moist by assisting with fluid retention. The second layer of the vocal folds is the superficial lamina propria (SLLP) which consists of a few cells, a few proteins, and a lot of gelatinous "ground substance". The epithelium and SLLP are displaced during phonation – they actively vibrate. The third layer is the intermediate lamina propria (ILLP). This layer is made up of many elastin fibers with a few collagen fibers. The fourth layer is the deep lamina propria (DLLP) made up of many collagen fibers with a few elastin fibers. This layer provides a scaffold for vocal fold structure and is linked by collagen fibers to the vocal muscle below. Together the ILLP and DLLP form the vocal ligament that provides elasticity and strength to the vocal folds[8]. The fifth layer of the vocal folds is the thyrovocalis (vocalis) muscle, which serves as the main body of the vocal folds. During phonation, the loose vocal fold cover vibrates over the stiff body, and these two functional layers are connected to each other by the vocal ligament.

<u>Anatomical Effects of Aging</u>

Voice changes related to the aging process have been attributed to irregularities in vocal fold vibration, glottal incompetence, vocal fold atrophy and laryngeal tension[10]. The thyroarytenoid muscle loses bulk and the flexible tissue of the SLLP becomes thinner, stiffer, and less pliable [9]. This process leads to perceptual changes in the voice quality of the elderly, which can lead to a clinical condition known as presbylaryngis. Some commonly reported changes associated with presbylaryngis include hoarseness, breathiness, vocal instability, and changes in the pitch of the voice. As the vocal folds age, such as after age 65, vocal fundamental frequency becomes higher in men and lowers in women [2]. Changes in voice related to age vary in severity and time of onset from individual to individual [9].

There is not enough knowledge of age-related changes in the vocal folds, but evidence shows that changes in the layers of the vocal folds alter their biomechanical properties. The epithelium in the vocal folds thickens as age increases, although there are disagreements in the literature to these age-related changes. Investigations have shown that mucosal thickness changes with aging may be gender- related. Studies have shown that epithelium thickness increases until about 70 years of age and then decreases into old age in males. In females the epithelium increases gradually with aging, especially after 70 years of age. In males the elastic tissues of the vocal folds thicken and become edematous. After age 40 in males the ILLP becomes thinner. The density of elastic fibers also decreases in this layer. Changes in the DLLP occur after age 50 in males. Changes include thickening associated with increasing density of collagenous fibers. Collagenous fibers also become irregular in their arrangement [6].

The glottis is a term used to refer to the space in between the vocal folds. When the vocal folds come together to vibrate, the glottis is considered closed. During phonation if the glottis is not closed accurately the space between the vocal folds is known as a glottal gap, chink, or open glottis. There are several glottal gap configurations that can occur secondary to functional disorders, vocal fold lesions, or presbylaryngis (dysphonia due to the processes of aging). Disruption of nerve supply, declines in hydration, erosion of joints, alterations in cartilage composition, edema, atrophy of muscles and connective tissue can cause imprecise vibration of the vocal folds and incomplete glottal closure patterns [6].

In addition to aging in laryngeal tissue and muscle, the laryngeal joints can also suffer from the effects of aging. The laryngeal joints include the cricoarytenoid and the cricothyroid joint. The cricothyroid joint allows the thyroid cartilage to pivot forward and down along the cricoid cartilage. The joint allows for the most important adjustments for change in vocal fundamental frequency. The cricoarytenoid joint permits rocking, gliding, and minimal rotation of the arytenoid cartilages. The rocking action brings the two vocal processes of the arytenoids toward each other, permitting the vocal folds to make adduct [8]. The cricothyroid joint has not been investigated in age-related changes, but significant age related changes have been reported in the cricoarytenoid joint. As aging occurs the cricoarytenoid joint loosens with erosion of articular surfaces. Investigations show that erosion with aging might be fairly inconsequential. Age-related changes in the cricoarytenoid have been denoted in males. Changes include thinning of the articular surfaces, breakdown/disorganization of the collagen fibers in the cartilage matrix, changes in the synovial membrane and surface irregularities [6].

Perceptual Effects of Aging

As humans age there are perceptually noticeable changes that occur in the voice. Presbylaryngis is a clinical condition that refers to age related structural changes of the vocal folds. This condition results in weak voice, restricted vocal range, and reduced vocal stamina. There is a loss in vocal fold tone and elasticity due to aging which affects voice quality. If the atrophy and bowing becomes severe, significant dysphonia, throat clearing, cough, and even aspiration (swallowing difficulty) may result. Patients with presbylaryngis often present with symptoms of glottal insufficiency (lack of full closure when the vocal folds adduct). These symptoms of glottal insufficiency include hoarseness, vocal fatigue, pain or discomfort with prolonged speaking, and diplophonia (a two-tone quality to the voice) [3].

A large body of research has been dedicated to the topic of age recognition from voice. Factors such as listener age, listener response bias, variability within elderly speakers and speakers' race have been mentioned as factors that can affect the listener's accuracy. Vocal characteristics considered by listeners as typical of "old" voices are: lower vocal pitch (regardless of speaker gender), increased hoarseness or harshness, increased strain, vocal tremor, increased breathiness, reduced loudness, slower speech rate, greater hesitancy, less precise articulation, and longer duration of pauses. Listeners find it easier deciding if a speaker is young versus old that they do making a direct estimate of the speakers age [6].

The physiological changes which occur in aging and presbylaryngis influence the physical properties of sound produced during phonation. One way to measure and characterize these properties is through acoustic measures. One study showed that changes occur in voice function with age by demonstrating that elderly voices have significantly higher variation in fundamental frequency, greater noise –to-harmonic ratio, and greater amplitude perturbation quotient values compared to younger voices. It was suggested that these changes were due to increased noise and instability in the acoustic signal reflected underlying changes in the vocal fold structure and vibratory dynamics [5.]

A recent study established the normal acoustic parameters in Iranian adults without voice problems. The fundamental frequency (F_o) that reflects habitual pitch and is an important parameter in both the functional and anatomical larynx assessment, and it is determined by the number of cycles per second produced by the vocal folds. In this study the F_o in vowels /a/ and /i/ was greater for females than for males. There were no significant differences in average shimmer and jitter between females and males. In the study the value of HNR was greater for females than for males. The study concluded that the F_o, jitter, shimmer, and harmonic-to-noise ratio are relatively stable and do not change with aging in each gender for adults between 20 and 50 years of age [1]. This is one of the few studies available which has investigated acoustic features of voice in speakers between these age ranges.

Acoustic Analyses

Until recently acoustic measures of vocal function were restricted to productions of sustained vowels and were only valid in normal or mildly dysphonic voices. The reason for this is that the software used to analyze the recorded signals used vibratory cycle boundary detection across time (time-based measures) to calculate measures. However, vibratory cycle boundaries become highly irregular in connected speech and in moderate-to-severely dysphonic voices, which can result in measurement validity issues. There is new software that was released in 2012 that allows for clinically efficient spectral/cepstral measures of vocal function. These measurements do not require detection of cycle boundaries. Instead, they perform a Fourier analysis of the recorded signal to break it down into its frequency and amplitude components. The software can then calculate a harmonic-to-noise equivalent measure by measuring the energy in the lower frequencies (the harmonic energy) and that in the higher frequencies (the noise energy). By then performing another Fourier analysis, the software can obtain measurements from the cepstrum, such as cepstral peak, which represents the periodicity of vocal fold vibration.

The advantage that these spectral/cepstral measures hold over time-based measures is that they can be validly applied to moderate-to–severely dysphonic voices and connected speech. This software analyses vocal function at any period of time from the spectrum and the cepstrum. The location of the cepstral peak along the x-axis shows the fundamental frequency. The height of the cepstral peak along the y-axis shows how regular (periodic) the vibration was. The higher the peak in the axis the more normal (periodic) the voice is. Although the new software holds an advantage over the time-based software, application to normal young and middle-age adult populations has not yet been fully obtained and normative data is needed.

<u>Review</u>

In summary, the vocal folds adduct (close) and abduct (open) through muscle movement in order to produce speech. The vocal folds are located in the larynx, which is made up of muscles, connective tissue, ligaments, and cartilages. As a person ages there are anatomical and physiological changes that occurs in the vocal folds. New acoustic measures that calculate frequency and periodicity from the spectrum and cepstrum allow for voice analysis in vowels and connected speech, which allows us to learn about vocal function in different speaking contexts.

Purpose

The purpose of this study was to measure the acoustic features of connected speech in male speakers that are between 20 to 29, 30 to 39, and 40 to 49 years of age using these new acoustic measurements. Specific research questions to be asked are: (1) Do spectral/cepstral measurements of phonation periodicity differ between the three age groups during different vocal tasks; (2) Do spectral/cepstral measurements of fundamental frequency differ between the three age groups during different vocal tasks; and (3) Do multidimensional measurements of voice quality differ between the three age groups during different vocal tasks.

METHODOLOGY

Participants

Participants for this study were adult males between the ages of 20-49, assigned to three different age groups (20-29, 30-39, 40-49). Ten participants from each age group were recruited for the study. In order for the subjects to participate they must have meet the following criteria:

a. Must have been males between the ages of 20-49
b. Non-smokers for the past ten years
c. No history of diagnosed voice problems or voice complaints within the past two months other than symptoms that might be age related (i.e. breathiness or subtle pitch changes)

d. No history of neurological disease

Participants were recruited from the local community by posting flyers around the Texas Christian University (TCU) campus, local churches, and snowball sampling methods (i.e., referrals from other recruited participants).

Instrumentation

Equipment for this study consisted of the KayPentax (Montvale, NJ) Computerized Speech Lab (CSL) and affiliated software program. The CSL digitized and recorded analog signals produced by speakers, which were input to the CSL from an AKG Acoustics (Northridge, CA) head-mounted microphone. All recorded signals were sampled at 44,100 Hz and saved to a desktop computer. The software program Analysis of Dysphonia in Speech & Voice (ADSV – KayPentax) was used to analyze the recorded signals and collect the dependent variable measurements.

Procedures

All participants were recorded at the Miller Speech and Hearing Clinic in the laboratory of Dr. Christopher Watts. Participants had to read and sign a consent form prior to testing. After participants agreed to participate the researcher explained the instructions to them. The head-mounted microphone was placed on them and they were recorded producing different utterances using the core CSL program.

a) They produced the vowels /i/ and /u/, with the following instructions:

"Take an easy breath in, and say the vowel /i/ (or /u/) at a comfortable pitch and loudness, as steady as you can, until I say stop. I will ask you to stop after 5 or 6 seconds."

b) They were asked to read the sentence "*We were away a year ago*" from the *Consensus Auditory Perception Evaluation of Voice* (CAPE-V) silently. Then they were asked to produce the sentence with the following instructions:

"Please read each of these sentences at a comfortable pitch and loudness, just as if you were talking to me in a conversation. Make sure you take an easy breath in before reading each sentence."

c) They were asked to read the Rainbow Passage silently. Then they were asked to produce the passage with the following instructions:

"Please read this paragraph at a comfortable pitch and loudness, just as if you were talking to me in a conversation."

These processes generated four different measurable stimuli for every participant (2 vowels, 1 sentence, and the Rainbow Passage). See Analyses section for specifics.

Analyses

The ADSV program was used to calculate three different measurements from each recorded stimulus: (1) Fundamental Frequency (F_o), (2) Cepstral Peak Prominence, and the (3) Cepstral Spectral Index of Dysphonia (CSID). This resulted in three different ADSV measurements (F_o, cepstral peak, CSID) for four different stimuli (vowels /i/ and /u/, sentence, and paragraph). Table 1 illustrates the stimuli acquired and the measurements which were derived from them.

Table 1. Dependent Variables

Stimulus			
	Measurements (dependent variables)		
Vowels	F_o (Hz)	Cepstral Peak (dB)	CSID
CAPE-V sentences	F_o (Hz)	Cepstral Peak (dB)	CSID
Rainbow Passage	F_o (Hz)	Cepstral Peak (dB)	CSID

Four separate two-way mixed analyses of variance (ANOVA's) were be applied to the dependent variables with Group (20yr olds vs. 30yr olds vs. 40yr olds) as the between subject factor and Stimulus (vowels vs. sentences vs. paragraph) as the within subject factor. Because the formula for the CSID measurement is different for vowels than it is for connected speech, these stimuli were analyzed in separate ANOVA's. The cumulative statistical analyses included a 2-way ANOVA for CPP (group x speaking condition), a 2-way ANOVA for F_o (group x speaking condition), a 2-way ANOVA for vowel CSID (group x vowel), and a 2-way ANOVA for connected speech CSID (group x connected speech). For significant main effects, post-hoc analyses were conducted via pairwise comparisons using Fisher's the Least Significant Difference (LSD) test. Inter-measurer reliability was assessed by randomly selecting 10% of the recorded files and re-measuring dependent variables. A Pearson-product moment correlation was applied to the reliability data to assess the degree of relationship between the first and second measurements.

RESULTS

Inter-measurer reliability was calculated by re-measuring 10% of the data and comparing it to the initial measures using a Pearson-product moment correlation. Results revealed a high degree of reliability for all measurements, with inter-measure CPP reliability r = 0.993, F_o reliability r = 0.983, and CSID reliability r = 0.990 .

The following describe analytical findings after CPP, F_o, and CSID measures were applied to vowels /i/ and /u/, the CAPE-V sentence, and The Rainbow Passage in 20, 30, 40 year-old speakers' voices. Table 2 displays means and standard deviations for all dependent variables across the three age groups.

Table 2. Means & standard deviations for dependent variables

Group	CPPi		CPPu		CPP Sentence		CPP Rainbow	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
20	10.0224	1.85798	10.4441	1.68204	7.7900	1.37639	5.9585	1.30138
30	10.3149	2.02540	11.3046	1.39177	7.9149	1.44619	6.0126	.75012
40	11.3088	2.39086	10.3297	2.72997	7.6801	1.11897	5.4932	1.14488
	F_oi		F_ou		F_o Sentence		F_o Rainbow	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
20	124.7229	19.93441	121.6464	18.02475	138.6223	19.02930	155.2648	20.58634
30	125.3248	16.66906	129.5709	17.55585	127.8847	17.28331	139.9395	8.91249
40	118.4667	12.82084	124.2310	24.03416	128.7747	10.13214	155.9132	19.14170
	CSIDi		CSIDu		CSID Sentence		CSID Rainbow	
	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
20	21.5010	14.84469	9.7687	10.14447	-19.6802	9.48334	-13.7485	14.07354

CPP Analysis

The Cepstral Peak (CPP) is a measure of periodicity in the vibratory cycles of the vocal folds during phonation. The larger the CPP, the less dysphonic the voice sounds. It was predicted that 20 year-olds would have the highest CPP, followed by

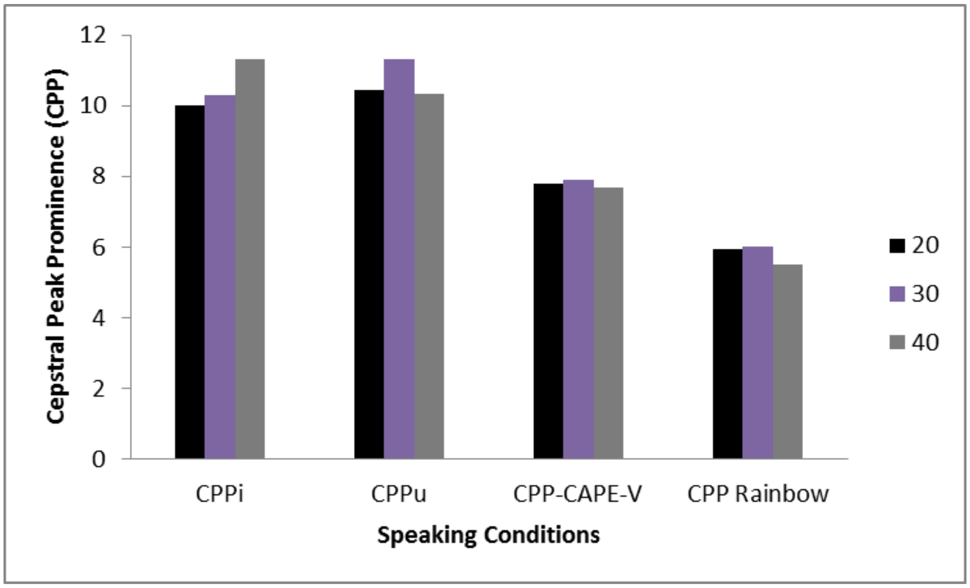
30 year-olds and 40 year-olds. Figure 1 illustrates the mean CPP measures for each age group in each speaking condition and visually shows the relationship between groups on the CPP measure.

The descriptive statistics indicated that 20 year-olds had higher CPP measures compared to 40-year olds, with the exception of the CPP measure of the vowel /i/. But 20-year olds always had lower CPP measures compared to 30 year olds. 30 year-olds had higher CPP measures than 20 and 40 year olds, with the exception of the vowel /i/ CPP measure which resulted lower when compared to 40 year-olds vowel /i/ CPP measure. 40 year-olds had the lowest CPP measures compared to 20 and 30 year olds, with the exception of the vowel /i/ CPP measure which resulted in the highest measure of all age groups. Overall the results indicate no trend in CPP between 20-49 year olds.

Results from the two-way ANOVA applied to the CPP data in each speaking condition revealed: a significant condition effect ($F[3, 81]= 89.2$, $P<0.001$), no significant interaction effect ($F [6, 81] = 1.303$, $P= 0.265$), and no significant group effect ($F [2,27]= 0.189$, $P= 0.829$)

Post-hoc pairwise comparisons of the condition data using Fisher's Least Significant Difference (LSD) test revealed that CPP measures were significantly greater for the vowels /i/ and /u/ compared to the CAPE-V Sentences ($P<0.001$) and the Rainbow Passage ($P<0.001$). In addition, the CPP measure for the CAPE-V sentence was significantly greater than the Rainbow Passage.

Figure 1. Means and standard deviations for cepstral peak prominence (CPP) for the age groups in each speaking condition (/i/, /u/, CAPE-V Sentence, Rainbow Passage).



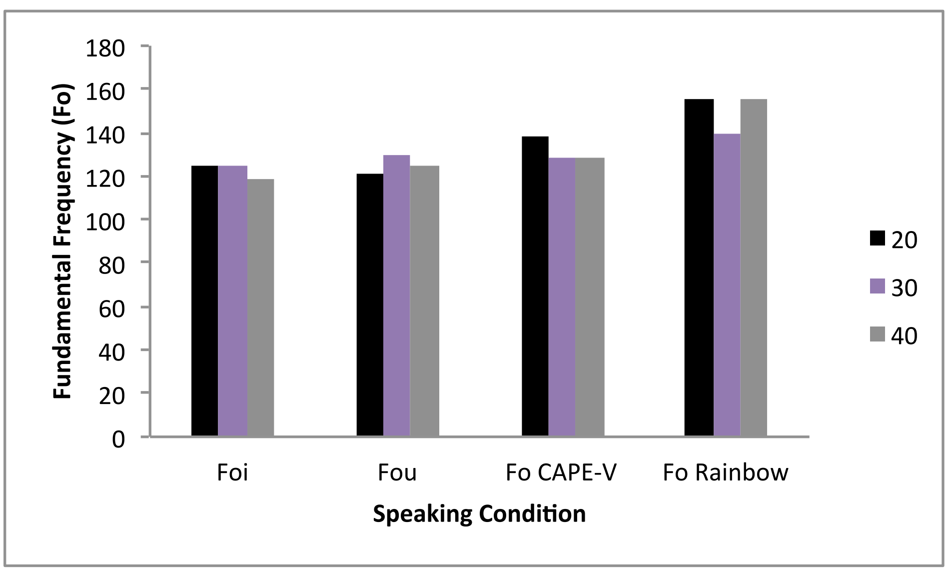
Fo Analysis

The Fundamental Frequency (F_o) is a measure of the number of vibratory cycles per second produced by the vocal folds. Since speaking F_o increases in males over 50 years old, it was expected that the F_o of the participants would be higher for the 40 year old age group. Figure 2 illustrates the mean F_o measures for each age group in each speaking condition and visually shows the relationship between groups on the F_o measure. The results of the study indicated that 20 year-olds had the highest F_o measures for CAPE-V and the lowest F_o measure for the vowel /u/ compared to 30 and 40-year olds. 30 year-olds had the highest F_o measures for the vowel /i/ and /u/, but the lowest F_o measures for CAPE-V and the Rainbow Passage compared to 20 and 40-year olds. 40- year olds had the highest F_o measures for the Rainbow passage, but the lowest F_o measure in the vowel /i/ and /u/, and CAPE-V compared to 20 and 30 year olds. Overall the result indicated no trend in F_o between 20-49 year olds.

Results from the two-way ANOVA applied to the F_o data in each speaking condition revealed a significant condition effect ($F [3,81]= 17.710, P<0.0001$), no significant interaction effect ($F [6, 81] = 1.609, P= .155$), and no significant group effect ($F [2,27]= 0.473, P=.628$).

Post-hoc pairwise comparisons of the condition data using Fisher's Least Significant Difference (LSD) test revealed that F_o measures were significantly lower for the vowel /i/ compared to the CAPE-V (P=.038) and the Rainbow Passage (P<0.001). The F_o measures were significantly lower for the vowel /u/ compared to the Rainbow Passage (P<0.001). And the F_o measures were significantly lower for the CAPE-V sentence compared to the Rainbow Passage (P< .0001)

Figure 2. Means and standard deviations for fundamental frequency (Fo) for the age groups in each speaking condition (/i/, /u/, CAPE-V Sentence, Rainbow Passage).



<u>CSID Analysis</u>

The Cepstral Spectral Index of Dysphonia (CSID) is a multiparametric measure which correlates very well to perceived dysphonic severity in patients with voice disorders. A larger CISD indicates less periodicity in vocal fold vibration and possibly greater noise in the vocal spectrum of sound. The measure of CSID includes CPP and its standard deviation, but also includes a measure of additive noise in the vocal signal (the ratio of low frequency harmonic energy to high frequency harmonic energy) and its standard deviation. It was expected that 40 year-olds would have the largest CSID results compared to the 20 and 30 year-olds. Figure 3 illustrates the mean CSID measures for each age group in each speaking condition and visually shows the relationship between groups on the CSID measure. The results of the study indicated that 20 year-olds had the highest CSID measure for the vowel /i/ but the lowest CSID measures for the vowel /i/, CAPE-V, and Rainbow compared to 30 and 40 year-olds. 30 year-olds had the lowest CSID measures for the vowel /i/ and /u/ compared to 20 and 40 year olds. But 30 year-olds had higher CSID measures for CAPE-V and Rainbow compared to 20-year olds. 40 year-olds had the highest CSID measures for the vowel /u/, CAPE-V, and Rainbow compared to 20 and 30 year olds. Overall the results indicate no trend in CSID between 20-40 year olds.

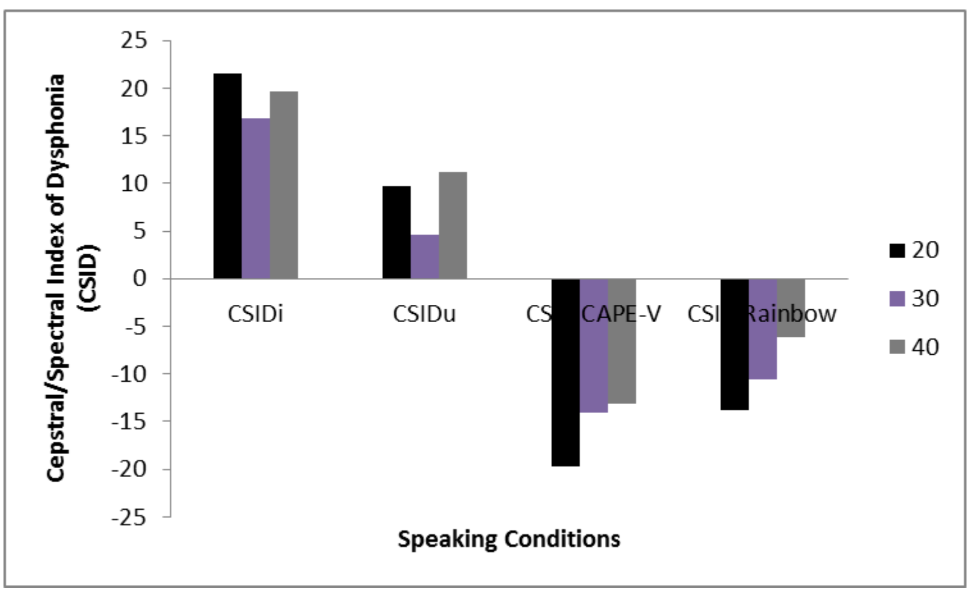
Results from the two-way ANOVA applied to the CSID /i/ and /u/ data in these speaking condition revealed a significant condition effect ($F [1,27]=16.438$, $P< .0001$), no significant interaction effect ($F [2,27]= 0.189$, $P= 0.829$), and no significant group effect ($F [2,27]= 0.650$, $P= 0.530$).

Post-hoc pairwise comparisons of the condition data using Fisher's Least Significant Difference (LSD) test revealed that CSID measures were significantly greater for the vowel /i/ compared to vowel /u/.

Results from the two-way ANOVA applied to the CSID, CAPE V- and The Rainbow Passage, data in these speaking condition revealed a significant condition effect (F [1, 27]=5.677, P= .024, no significant interaction effect (F [2,27]= 0.201, P= 0.819), and no significant group effect (F [2,27]= 1.322, P= 0.283)

Post-hoc pairwise comparisons of the condition data using Fisher's Least Significant Difference (LSD) test revealed that CSID measures were significantly lower for CAPE-V sentences compared to the Rainbow Passage.

Figure 3. Means and standard deviations for Cepstral/Spectral Index of Dysphonia (CSID) for the age groups in each speaking condition (/i/, /u/, CAPE-V Sentence, Rainbow Passage).



DISCUSSION

Summary of Findings

The purpose of this study was to measure the acoustic features: CPP, F_o, and CSID, in vowels (/i/ and /u/) and connected speech (The CAPE-V Sentence and The Rainbow Passage) in male speakers ages 20 to 49 utilizing spectral and cepstral measures. Specifically, this study asked 3 research questions: (1) Do spectral/cepstral measurements of phonation periodicity differ between the three age groups during different vocal tasks; (2) Do spectral/cepstral measurements of fundamental frequency differ between the three age groups during different vocal tasks; and (3) Do multidimensional measurements of voice quality differ between the three age groups during different vocal tasks.

With respect to age groups, measures of CPP, F_o, and CSID measures resulted in no identifiable pattern and none of the data collected resulted in statistically significant findings. These results were somewhat surprising, as multiple studies have proven acoustic changes in the aging male voice using time-based measures. Additionally, other studies have validated the use of spectral and cepstral measures in analyzing connected speech and dysphonic voice. There are several hypothesized reasons as to why these results did not meet expectations, relating to sample representation, sample size, and attributes of the participants included in the study.

One factor that may have impacted the lack of group effects is that the sample may have been too representative across the age ranges. Within each group, participants were in the upper end of the age range and the lower end of the age range. This meant that some participants were in their later 20's and early 30's, yet in two different age groups. The sample representation for each group may not have been different enough to find an actual effect.

Another possible explanation for the lack of a group effect on the dependent variables is that thirty participants may not have been a large enough sample to yield statistically significant results. Power is the ability to determine a statistical difference, if in fact a difference does exist. Calculations of statistical power revealed that the greatest power for group comparisons was 0.12, which is very low. A much larger sample size may have allowed for enough power to find a difference, if indeed males between these ages do produce acoustic vocal differences.

Another factor that may have impacted results was the variability of the participants. While there were specific criteria that each participant had to meet to be included in the study, there were limits as far as what could be controlled. Because of a high variability between voices within each age group, the thirty subjects who volunteered may not have been representative of the adult male population as a whole. Several of the participants in this study were professors recruited from a university campus. Two participants were singers who received vocal training. These men may have used or trained their voices more than the average adult male in their age range. Results may have been a reflection of these differences. A study by Wingate et al indicated that professional voice users make up 25 to 35 percent of the working population in the United States. They are also more likely to seek and receive treatment for their voices. However, participants in this study had no history of current or past voice complaint. Additionally, while the majority of participants spoke English as their first language, three participant's first language was Spanish. Even though both men spoke fluent English, their voices may not accurately reflect the average adult male's voice.

A final explanation for the lack of group effect in this study is that vocal fold vibration, and the sound that it produces, simply is not different in males between the ages of 20 through 49.

The results of this study did find effects for condition on each of the dependent variables. This was predicted for a number of reasons. For measures of CPP, participants were asked to sustain vowels "as steady as they can", which was not an instruction for connected speech. As such, CPP measures in sustained vowels were greater than connected speech. The two connected speech samples were also phonetically different from each other. The CAPE-V sentence contained all voiced phonemes, while the Rainbow passage sentence contained a mix of voiced and unvoiced phonemes. These articulatory changes would naturally effect the acoustic spectrum, resulting in measureable differences in acoustic periodicity.

Differences in F_o measures could also be attributed to the nature of the stimuli. For sustained vowels, which were significantly lower in F_o than connected speech stimuli, participants produced tokens at one controlled frequency. However, during connected speech participant utilize intonation, which can result in dramatic pitch rises and falls. The overall trend of raising F_o for pitch inflections likely caused the F_o measures of connected speech stimuli to be significantly greater than those of sustained vowels.

Conclusions

This study did not find significant differences in measurements of CPP, F_o, and CSID in the three age groups (20, 30, 40), nor in the interaction between the age groups (20, 30, 40) and the speaking conditions (/i/, /u/, CAPE-V Sentence, Rainbow Passage). There was a significant difference in measurements of CPP, F_o, and CSID in the four different speaking conditions (/i/, /u/, CAPE-V Sentence, Rainbow Passage). Previous research has found that the male voice changes physically and perceptually with aging. In this study we used cepstral/spectral analyses to obtain the acoustic measurements in male speakers between 20 and 49 years of age. The results of this study did not find age-related changes in acoustic measures in males who were between these age ranges. Future research will be needed to further clarify whether no differences actually exist, or if some other factor explains the lack of group significance in this study. The investigation did find significant condition effects on acoustic measures, which were likely due to the instructions given to each participant and the phonetic structure of the recorded stimuli.

REFERENCES

[1] Dehqan, A., Ansari, H., & Bakhtiar, M. (2008). Objective Voice Analysis of Iranian Speakers with Normal Voices. *Journal of Voice*, *24*(2), 161-167.

[2] "Fact Sheet: The Voice and Aging." *American Academy of Otolaryngology*. N.p., n.d. Web. 3 Feb. 2013. <http://www.entnet.org/HealthInformation/Voice-and-Aging.cfm>.

[3] "Persbylarynx" Center for Voice and Swallowing, UCDAVIS Health System. Web. 24 Feb.3013. <http://www.ucdvoice.org/presby.html>.

[4] Cralidis, Ann, & Hooper, Celia R. (2009). Normal Changes in the Speech of Older adults: You've still got what it takes; it just takes a little longer. Perspectives on Gerontology, Vol.14 no.2, 47-56. doi: 10.1044/gero14.2.47.

[5] Gorham-Rowan, Mary M, Laures-Gore, Jacqueline. (2005). Acoustic-Perceptual Correlates Of Voice Quality in Elderly Men and Women. *Journal of Communication Disorders.*

[6] Linville, Sue Ellen. Vocal Aging . (2001). Canada. Thomas Learning.

[7] Pena-Brooks, Adriana, & Hegde, M.N. (2007). Assessment and Treatment of Articulation and Phonological Disorders in Children. Austin, Texas. Pro-Ed An International Publisher.

[8] Seikel, John A., Douglas W. King, and David G. Drumright. *Anatomy & Physiology for Speech, Language, and Hearing*. Australia: Thomson Delmar Learning, 2005. Print.

[9] Sulica, Lucian, Dr. "Aging Voice." *Voice Medicine*. N.p., 2009. Web. from http://www.voicemedicine.com/aging.htm.

[10] Dedivitis, R., Abrahao, M., Simoes, M., Mora, O., & Cervantes, O. (2001). *Cricoarytenoid joint: histological changes during aging* (Master's thesis).

ABSTRACT

Objective: To measure the acoustic features of vowels and connected speech in male speakers between the ages of 20-49 using new cepstral/spectral measures (Fo, CPP, and CSID).

Method: The software program Analysis of Dysphonia in Speech & Voice (ADSV-KayPentax) was used to analyze vowels and connected speech across three age groups: 20 to 29, 30 to 39, and 40 to 49. This resulted in three different ADSV measurements (Fo, cepstral peak, CSID) for the four different stimuli (vowels /i/ and /u/, CAPE-V Sentences, and The Rainbow Passage).

Results: This study did not find significant differences in measurements of CPP, Fo, and CSID in the three age groups (20, 30, 40), nor in the interaction between the age group (20, 30, 40) and the speaking conditions (/i/, /u/, CAPE-V Sentence, Rainbow Passage). But there was a significant difference in measurements of CPP, Fo, and CSID in the four different speaking conditions (/i/, /u/, CAPE-V Sentence, Rainbow Passage).

Conclusion: Results may be due to the use of cepstral/spectral measures, sample representation within each age group, sample size, or professional voice use in the current sample. Alternatively, there may not be a true difference between 20, 30, and 40 year-old speakers and the results of this study may accurately reflect reality. Future research is needed.