

ACOUSTIC MEASURES OF THE VOICES OF OLDER SINGERS AND
NON-SINGERS

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by

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ACOUSTIC MEASURES OF THE VOICES OF OLDER SINGERS AND
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ABSTRACT

The present study sought to investigate whether there were differences in the acoustic measures of fundamental frequency (Fo), jitter, intensity and shimmer of older amateur singers and non-singers and whether there were significant correlations between these acoustic measurements and listener judgments of speaker age. Acoustic measurements were obtained on 60 speaker participants from a sustained vowel production. Study participants included 30 male and female singers and 30 male and female non-singers who were between the ages of 65 and 80. In addition, 10 speech language pathology graduate students were recruited as listener participants to estimate the age of speaker participants from recorded vowel sounds.

The results of this study partially supported previous findings regarding acoustic measures and listener age judgments of elderly speakers. Speaker participants were perceived as significantly younger than their real ages and male and female singers were perceived to be significantly younger than male and female non-singers. Significant differences were found between male and female singers and non-singers with regard to jitter and intensity, with singers displaying significantly less jitter and significantly greater intensity than non-singers. Perceived age was found to be related to jitter in male singers and non-singers and female singers. Perceived age was found to be related to

intensity in female non-singers. No statistically significant differences were found between singers and non-singers with regard to F_0 or shimmer. No significant correlations were found between perceived age and intensity in male singers, male non-singers or female singers. Possible explanations for the differences between the present study results and results of earlier studies are discussed. Possible directions for future research studies are presented.

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CHAPTER I

Introduction

According to census data estimates, the aging population is the fastest growing demographic segment in the country (Shapiro, 1997). As the population of older persons increases, information regarding the normal progression of aging increases in its relevance to health care practitioners and to society. An understanding of the changes in structure and function of the vocal tract that occur in the normal process of aging will allow healthcare providers to differentiate between changes that normally occur in the voice with aging and voice problems that may be experienced by older individuals.

A significant body of research exists concerning the changes that occur in the human body with normal aging and the effects of these changes on the functioning of the individual. Voice quality is one aspect of functioning that is known to change with age. Anatomical changes within the vocal mechanism, and the resultant changes in physiology, lead to changes in many parameters of voice as one ages. The rate and extent of the changes that occur are variable between individuals and have also been shown to vary between men and women (Linville, 2004; Sataloff, 1998). Over the last 20 years, there has been increased interest in the physical and histological changes that normally occur in the vocal mechanism with aging. With sophisticated technology, we have been able to learn about changes that occur at the cellular level even before there is a perceptual change in the voice quality of the aging individual (Casiano, Ruiz & Goldstein, 1994; Diamond, Skaggs & Manaligod, 2002; Filho, Nascimento, Tsuji &

Sennes, 2003; Rodeno, Sanchez-Fernandez & Riva-Pomar, 1993; Thibeault, Glade & Wenhua, 2006).

Although the knowledge base regarding the aging voice has increased, studies focused on the aging singer's voice are relatively scarce. Research regarding the aging singer's voice indicates that in the presence of good physical health, singing may diminish changes that make a person's voice sound "old" (Boone, 1997; Brown, Hunt & Williams, 1988; Brown, Morris, Hicks & Howell, 1993; McCrea & Morris, 2005; Rothman, Brown, Sapienza & Morris, 2001; Sataloff, Caputo-Rosen, Hawkshaw & Spiegel, 1997; Wedin & Ögren, 1982;). The duration of singing experience among aging singers included in the aforementioned studies ranged from 2 years of continuous singing experience to 10 years of continuous singing experience. A question that may be answered by future research regarding the aging singing voice is how much singing experience would have the effect of decreasing listener perception of a senescent voice. Research regarding the voices of aging non-singers suggests that physical exercise is related to delays in the onset of listener perception of the "sound of senescence" (Chodzko-Zajko & Ringel, 1987; Xue & Mueller, 1997). Therefore, any study of the effect of singing on the aging voice must control for the variable of physical exercise in order to make valid statements about the possible effects of singing.

The field of speech language pathology has historically addressed functional and organic voice pathologies. It is only in the past 20 years that the field of vocology has emerged as a sub-specialty addressing voice production and voice problems in professional voice users such as singers. It is anticipated that the present study will add

to the knowledge base regarding the relationship between participation in choral singing and the effects of vocal aging in healthy and comparatively sedate individuals.

Definitions of Key Terms

Active Choir – A choral group that holds 9-12 months of at least once weekly meetings for rehearsal or performance

Experienced SLP – One who has at least 10 years of professional experience

Non-singer – A person who had never been involved in choral singing and who had not received any formal voice training, including training from school choir or church choir, since high school.

Older – Between the ages of 65 and 80

Physically sedate – “No” responses to items 1 and 4 of the Physical Activity Staging scale (Appendix B).

Singers – People who were involved in an active choir at the time of the study and had participated in an active choir for a period of at least 10 continuous years at the time of the study.

Relevance of Research to the Field

Demographic data show that the proportion of older people in the United States population will continue to grow at a rapid pace. In the year 2004, an estimated 35 million people (12% of the population), were age 65 or older. By 2030, it is estimated that 70 million people (20% of the population) will be 65 or older (www.agingstats.gov, 2004). Although there will be steady growth of the older population from 1990 to 2010,

the population aged 65 and over will increase nearly 80 percent when the Baby Boom generation retires (from 2010 to 2030). By 2030, the older adults will account for one-fifth of the total U.S. population (www.agingstats.gov, 2004).

With regard to health issues, data indicate that 22% of office visits made to otolaryngologists in the year 2000 were made by patients aged 65 or older. Of this number, approximately 12% of patients reported voice problems and it is estimated that this number will double in the next 30 years (Calhoun & Eibling, 2006).

The older population is extremely diverse in its social, economic, and health status. Most people age 65 to 74 are healthy, active and independent (Shapiro, 1997). With the anticipated increase in the older population, it can reasonably be anticipated that there will be a growing number of older individuals who wish to maintain effective vocal functioning in social and professional pursuits for as long as possible. Good vocal communication skills can serve as an important avenue to socialization for the aging person. As Mueller (1991) stated: "The voice is a mirror of personality and senescence may cloud the image" (p.5). Working to understand the factors that affect vocal function in the normal aging population can assist in improving quality of life for the aging population. Awareness by speech-language pathologists of the normal characteristics of the aging voice and the ability to differentiate voice changes that are caused by disease, abuse or misuse should assist clinicians in improving assessment and management of the older voice. It is hoped that this study challenged the notion of the inevitability of gradual, progressive vocal decline with aging.

Delimitations/Limitations

This study included volunteer participants between the ages of 65 and 80 who lived in the Northeast Ohio area. The results of the study may be generalized to individuals in the geographic area who demonstrate characteristics similar to the experimental participants. This study was limited to healthy older individuals in the Northeast Ohio area. The results of the study may not be applied to all older individuals in the geographic area or to older individuals from other areas of the state or regions of the country, or in less healthy physical and vocal conditions. This study included only volunteer participants, and therefore the results of the study may not generalize to older individuals who would not volunteer for a study.

Contribution to Knowledge Base

There are numerous studies (Awan, 2006; Baker, Olson Ramig, Sapir, Luschei & Smith, 2001; Benjamin, 1981; Biever & Bless, 1989; Boone, 1997; Boulet & Oddens, 1996; Brückl & Sendlmeier, 2003; Ferrand, 2002; Gorham-Rowan & Laures-Gore, 2006; Harries, 2006; Higgins & Saxman, 1991; Hollien & Tollhurst, 1978; Linville & Fisher, 1985; Morris & Brown, 1987; Mueller, 1997; Ramig & Ringel, 1983; Ryan, 1972) and an entire textbook (Linville, 2001) devoted to vocal aging as well as a great deal of literature devoted to the singing voice (Baker, 1999; Barnes, Davis, Oates & Chapman, 2004; Bloothoof & Plomp, 1986; Brown et al., 1993; Brown, Morris, Hollien & Howell, 1991; Kovacic, Boersma & Domitrovic, 2003; Sataloff, 2000; Sundberg, 2003). Research has focused on acoustic and perceptual voice measurements of aging non-singers (Brückl &

Sendlmeier, 2003; Cleveland, Sundberg & Stone, 2001; Debruyne & Decoster, 1999; Ferrand, 2002; Gorham-Rowan & Laures-Gore, 2006; Hollien, Dew & Phillips, 1971; Linville & Fisher, 1985; Morris & Brown, 1987; Ptacek & Sander, 1966a; Ramig & Ringel, 1983; Ryan, 1972; Shipp & Hollien, 1969; Wilcox & Horii, 1980; Xue, 1995). Studies have also examined acoustic and perceptual differences in the voices of younger and older singers and younger and older non-singers (Brown et al., 1991; Brown et al., 1993; Leonard, Ringel, Horii & Daniloff, 1988; Rothman et al., 2001; Sulter, Schutte & Miller, 1995; Sundberg, Thornvik & Soderstrom, 1998).

According to the present researcher's knowledge, this was the first study to examine the question of the relationship between singing and vocal aging comparing acoustic measures and listener age judgments of older singers to those of older non-singers. The current study obtained data on the relationship of singing to the aging voice taking into account the level of physical activity and smoking. The study method was designed to emphasize the difference in singing experience by controlling for the physical activity level and smoking of all speaker participants. The current study compared data from older adults with no comparisons made to younger adults. This is another feature of the study which differentiated it from extant research. It is hoped that this study has made a contribution to the knowledge base regarding the relationship of singing and vocal aging.

CHAPTER II

Review of the Literature

Introduction

The vocal tract undergoes marked anatomic and physiologic changes during adulthood and into old age (Linville, 2001). Voice changes with advancing age have been associated with degenerative changes in the respiratory, laryngeal and articulatory mechanisms (Colton & Casper, 2006; Honjo & Isshiki, 1980; Kahane, 1981; Kahane, 1987; Linville, 2004; Sperry & Klich, 1992). Although a large body of research exists with regard to the effect of normal aging on the speaking voice, there is a smaller body of research with regard to the effects of aging on the singing voice. Much of the research that is available regarding the singing voice is distributed within the speech language pathology and vocal pedagogy literature and a large part of this research focuses on the aging female singer (Barnes et al., 2004; Biever & Bless, 1989; Brown et al, 1993; Brown et al., 1991; Hazlett & Ball, 1996; Sapir & Larson, 1993). This chapter will present a review of the research regarding anatomic and physiologic changes that occur with aging with regard to their effects on the speaking and singing voice of older males and females. This information served as the basis for discussion of the present research study results.

Anatomic and physiologic changes in the vocal mechanism with age

Respiratory system function and aging

Research indicates that respiratory function during speech changes with

increasing age for both men and women. In a study comparing speech breathing in older and younger women, Sperry & Klich (1992) found that older women breathed more deeply and used more air during oral reading than did younger women and that inhalatory volume in older women was affected by sentence length and continuous reading.

Significant physiological changes associated with aging include a decrease in the static elastic recoil of the lung, a decrease in compliance of the chest wall, and a decrease in the strength of respiratory muscles (Janssens, Pache & Nicod, 1999; Polkey, Harris & Hughes, 1997; Sataloff & Linville, 2006). Studies of age-associated changes in the chest wall have indicated that chest wall compliance decreased progressively with age and that the stiffening of the chest wall was presumably related to calcification and other structural changes of the rib cage (Dhar, Shastri & Lenora, 1976; Kahane, 1981; Thurlbeck, 1991). Janssens et al. (1999) stated that modifications occurring in the chest wall with aging not only decreased chest wall compliance but changed the curvature of the diaphragm, producing a decrease in the ability of the diaphragm to generate respiratory force. Polkey et al. (1997) indicated that there was a significant decrease in strength of the diaphragm of older participants when compared to younger participants. Lung volumes have also been found to change with increasing age. Studies have indicated that residual volume increased by approximately 50% between ages 20 and 70, and vital capacity decreased to approximately 75% of best values during the same age period (Janssens et al., 1999; Tolep, Higgins, Muza, Criner & Kelsen, 1995). These

studies are in agreement with Sperry & Klich's (1992) study of young and older women which indicated older participants breathed at higher lung volumes than younger participants. Osteoporosis, which causes more stiffness, can occur in the thorax (Kahane, 1981; Morris & Brown, 1987). These changes resulted in decreased breath support for speech and singing as individuals age.

According to Kahane (1981) and Ptacek & Sander (1966b), there was a significant difference between the vital capacity of younger and older adults, which may be attributed, in part, to fixation of the thorax. Age related decline in respiratory function was found in both men and women, but the pattern and extent of the changes in respiratory function varied by gender. Both men and women showed larger lung volume excursions and higher percentage on vital capacity measurements with advanced age, although these changes were reported to be associated with different mechanisms.

Laryngeal valving

In men, it has been suggested that glottal gaps accompanying aging accounted for the differences found in laryngeal valving when compared to younger men. In women, it has been speculated that age related changes in valving at the level of the velopharynx, tongue or lips might account for observed differences between older and younger women (Colton & Casper, 2006; Hoit & Hixon, 1987; Linville, 2001).

Laryngeal airway resistance has been measured to assess the efficiency of laryngeal valve function in young and older individuals during speaking tasks. In a study of men who ranged in age from 25 to 75, Melcon Hoit & Hixon (1989) found that 75 year old men

produced a lower mean airway resistance during a speaking task than younger men. The authors speculated that this finding indicated less efficient laryngeal valving in older men than in younger and that this could be attributed to decreased vocal fold approximation in the oldest group of participants.

Holmes, Leeper & Nicholson (1994) conducted a study that measured laryngeal airway resistance at four intensity levels (25th, 50th and 75th percentile of sound pressure level range and comfortable voice level). Participants included males and females age 55 and older, divided into three age groups. The study concluded that laryngeal airway resistance values for the oldest group of females was higher at each SPL level than those of the younger females and the oldest group of males differed from the youngest group of males in laryngeal airway resistance values only at the 75th percentile of sound pressure level. Overall, the results of this study indicated that laryngeal airway resistance values were higher for females than males at all age levels and that dB sound pressure levels can have an affect on laryngeal airway resistance values. In comparing the results of these studies it is clear that it is difficult to make sweeping generalizations when studying the vocal function of the older population and that separate norms need to be used for males and females on many measures of vocal tract function.

Laryngeal cartilage and joint changes and aging

There are two types of cartilage that comprise the cartilaginous framework of the larynx. The thyroid, cricoid, and portions of the arytenoid cartilages are made of hyaline

cartilage. The epiglottis, corniculate and cuneiform cartilages are made of elastic cartilage. The primary difference between the two types of laryngeal cartilage is that hyaline cartilages tend to ossify with age and elastic cartilages do not (Jurik, 1984; Mupparapu & Vuppalapati, 2005; Zemlin, 1998). Ossification is the hardening of soft tissues, such as cartilage, into bone.

Ossification of the laryngeal cartilages may cause increased stiffness to the laryngeal structure. This stiffness may decrease a person's ability to adduct the vocal folds sufficiently when speaking, resulting in a weak, breathy voice (Sataloff, 1998; Woodson, 2003). Kahane (1987) suggested that there was progressive calcification in the hyaline cartilages of the larynx and atrophy of the laryngeal joints, thus creating "stiffening" and instability of the larynx, which can have the effect of decreasing vocal range and variety. There is research indicating that ossification of laryngeal cartilages took place to a greater extent in older males than older females, but a similar pattern of thinning of laryngeal articular joint surfaces occurred in older men and women (Colton & Casper, 2006). According to Kahane (1987), the hyaline cartilages of the larynx began ossification as early as the second decade of life in males and females. Jurik (1984) and Yeager, Lawson & Archer (1982) found that the degree and frequency of ossification of the thyroid and cricoid cartilages were lower in females than in males, especially in the anterior portions of the cartilages. Ossification of the thyroid cartilage began at the inferior cornua and extended along the posterior lamina to the superior cornua (Casiano et al., 1994). Ossification began in the posterior lamina and continued in a fan-like

progression with the cricoid arch displaying ossification last. The central portion of the arytenoid cartilages ossified first and ossification spread peripherally. However, the apices and vocal processes of the arytenoid cartilages have not shown ossification when studied by Kahane (1983).

Laryngeal joints have been found to sustain wear and tear with age. The joints within the larynx may age as easily as those in the rest of the body (Sinard & Hall, 1998). As individuals age, the joints of the larynx may undergo thinning, collagen fiber breakdown and irregularity of articular surfaces. All of these changes can affect approximation of the vocal folds, causing diminished vocal quality and reduced vocal intensity due to air leakage through loosely approximated vocal folds (Kahn & Kahane, 1986; Paulsen & Tillmann, 1998). The cricoarytenoid joint has been the most extensively studied with regard to the effects of aging. The majority of investigations regarding the effect of aging on the cricoarytenoid joint have indicated that changes with age involved mostly inflammatory changes, such as arthritis, which often caused loss of flexibility and limitation of arytenoid movement. (Dedivitis & Abrahao, 2001; Kahn & Kahane, 1986; Paulsen & Tillman, 1998; Titze, 1994). Several studies of the aging cricoarytenoid joint indicated that there was an increase in fibrous tissue on the articular joint surfaces, producing a thickening of the articular surface as well as the presence of adipose tissue. These changes decreased the smoothness of cricoarytenoid joint movement (Dedivitis et al., 2001; Kahn & Kahane, 1986; Paulsen & Tillman, 1998). Casiano et al. (1994) examined seven normal human larynges and found no appreciable

changes in the synovium or joint space in the aged cricoarytenoid joints and no differences between the degree of collagen and elastin fibers between younger and older cricoarytenoid joints. The investigators found progressive cricoid and arytenoid ossification and periarticular muscular atrophy and fibrosis with age. The authors suggested that changes found in the aged cricoarytenoid joints may not be significant enough to produce the changes in the voice associated with senescence.

Vocal fold and laryngeal nerve changes and aging.

It is well known that any change in the length, tension, or mass of the vocal folds will result in a change in the fundamental frequency or intensity of the voice (Baken, 2000; Boone, McFarlane & Von Berg 2005; Ferrand, 2001; Zemlin, 1998). Vocal fold bowing, atrophy and edema were the three most common findings in research regarding aging vocal folds (Andrews, 2006; Boone et al., 2005; Colton & Casper, 2006; Linville, 2001; Sataloff, 2000). A study conducted by Honjo & Isshiki (1980) indicated that aged males showed signs of marked vocal fold atrophy or edema, while aged females showed only edema of the vocal folds. Mueller, Sweeney & Baribeau (1985) performed postmortem examinations of 25 excised male larynges (aged 60-88 years) and found that in addition to sulcus vocalis, increased calcification of laryngeal cartilages and fatty degeneration of adjacent tissues, 76 percent of the participants demonstrated “arrowhead” glottal configurations. The authors suggested that the glottal shape observed in the aged larynges was the result of vocal fold bowing and atrophy. A recent study (Pontes, Brasolotto & Behlau, 2005) of laryngoscopic images from 88 men and 122 women

reported that vocal fold bowing, sulcus vocalis, vocal fold edema, polypoid degeneration and prominence of vocal processes were frequently seen in older individuals. The study reported that the incidence of voice complaint was highest among men who presented with vocal fold bowing and women who presented with polypoid degeneration.

With regard to age-related changes in the vocal fold epithelium, there is disagreement in the literature. A number of studies reported thickening of the vocal fold and laryngeal epithelium, while others found no changes with aging (Chan & Titze, 1999; Hirano, Kuritani & Sakaguchi, 1989; Ishii, Zhai, Akita & Hirose, 1996; Kahane, 1987). Hirano et al. (1989) suggested that vocal fold epithelium increased in thickness in males up to age 70 and decreased with continued aging. In women, the vocal fold epithelium progressively increased in thickness with age. In older men, the mucosa stiffened and increased in viscosity when compared with women and younger men (Chan & Titze, 1999; Ishii et al., 1996).

Neuronal atrophy has been found in studies of the aging larynx. Mortelliti, Malmgren & Gacek (1990), found a significant age-related loss of myelinated nerve fibers in the human larynx in post mortem studies. The loss of neurons appeared mainly in nerve fibers with small axonal diameter. The authors speculated that the loss of neuronal fibers may be correlated to the observed age-related change in sensorimotor function seen in older individuals. In a study of rat larynges Rosenberg, Malmgren & Woo (1989) found that while the number of myelinated and unmyelinated fibers did not dramatically change with aging, there was significant axonal degeneration in older

animals. The authors suggested that the age-related changes seen in older rats could lead to decreased conduction velocity or complete fiber dysfunction in the rat larynx and stated that a number of the changes seen in aged rat larynges resembled changes seen in aging human peripheral nerves.

Effects of physical health and aging on the voice

As described in previous sections, normal aging affects the structures of the human larynx and the respiratory system. Studies have indicated that changes in vocal function may be affected by the level of physical health and physical conditioning of the aging individual. In a study of 31 elderly adults, Xue (1995) found that listeners judged the voices of physically active older adults to be significantly younger than the voices of physically sedate adults in same age group when listening to sustained vowel sounds. Ramig & Ringel (1983) studied 48 men from three age groupings (ages 25-35, 45-55 and 65-75), and two levels of physical condition (good and poor) to assess the effect of level of physical condition on acoustic voice measures such as fundamental frequency, jitter, shimmer and phonation range. Participants of all age groups who were in poor physical condition were found to have significantly more jitter and shimmer and significantly decreased phonation range than participants of all age groups who were in good physical condition. Further inspection of the means indicated that the differences for jitter, shimmer and phonation range were greatest in the elderly group. These studies underscore the importance of considering physical health and activity level in any study of the aging voice.

Effects of singing on acoustic measures of the voice

Since the time of Manuel Garcia in the early 1800s, vocal training has been promoted as a way to enhance the desirable qualities of the singing voice (Sataloff, 1998). Numerous studies have described acoustic and perceptual differences between the voices of trained singers and non-singers (Brown et al., 1993; Hollien et al., 1971; Leonard et al., 1988; Sapir & Larson, 1993; Watson & Hickson, 1985). Within the speech-language pathology and vocal pedagogy literature, the three aspects of voice production that have been studied in attempts to differentiate singers and non-singers are breathing, phonation and articulation patterns (Sundberg, 2003). Most of the literature regarding the singing voice was based on studies of the classically trained voice, but recent studies have considered country and folk singing styles in their studies (Cleveland et al., 2001; Kovačić et al., 2003).

Studies of the differences in breathing between singers and non-singers have found that singers are better able than non-singers to make adjustments in subglottal air pressure during pitch changes and were able to accurately increase subglottal pressure with increasing pitch in order to avoid pitch errors (Sundberg, 1987; Sundberg, Elliot, Gramming & Nord, 1993; Titze, 1989). Sundberg et al. (1993) also indicated that the singer was able to produce adjustments in subglottal air pressure based not only on pitch, but on intensity and musical stress or accent. Data from studies of pitch control indicated that in order to sing in tune, the singer must adjust subglottal pressure and cricothyroid activity not only for pitch and loudness, but also for lung volume (Shipp & McGlone,

1971; Sundberg, Thornvik & Soderstrom, 1998). Studies comparing transglottal wave forms of singers and non-singers have reported that non-singers tended to use pressed mode of phonation when increasing loudness, whereas singers tended to maintain flow mode and changed mode of phonation less often when producing changes in loudness (Gauffin & Sundberg, 1989; Titze, 1994).

Relationship between changes of anatomic and physiologic parameters and acoustic parameters of the voice

The anatomic and physiologic changes in the respiratory and laryngeal mechanisms would be expected to influence the (quasi)periodic acoustic signal produced by vocal fold vibration. Indeed, a wide variety of investigations have shown that changes in acoustic measures associated with the rate of vocal fold vibration and the intensity of the voice change with age. In addition, previous research has demonstrated that these age-related changes in the acoustics of the voice are influenced by a person's gender and physical health, particularly in the elderly. Some evidence also indicates that the vocal experience of people in their vocational or avocational pursuits also influenced age-related changes in the acoustics of the voice. The effects of these various factors, particularly in relation to age-related changes in the voice, on several common acoustic measures of the voice are reviewed in the following sections.

Acoustic and perceptual changes in voice parameters with age

The aging process has significant impact on many areas of daily life and is currently being researched extensively in order to gain insight into which facets of aging can be modified and which must be accommodated. Numerous studies have described

perceptual changes in the speaking voice that can occur with age. Research conducted by Shipp & Hollien (1969) indicated that listeners were reasonably accurate (correlation coefficients between .74 and .93) in identification of the age of speakers from young, middle and older adult age groups when listening to speech samples. Accurate age estimations were made from sustained vowel sounds alone (Ryan & Capadano, 1978), and from whispered vowel productions (Linville & Fisher, 1985). Studies indicate that listeners described older voices using adjectives such as “hoarse”, “breathy”, “shaky”, “raspy” and “weak” (Andrews, 2006; Linville, 2001; Mueller, 1997; Ryan & Capadano, 1978; Sataloff, 1998). In the geriatric population, vocal unsteadiness, loss of pitch and intensity range and voice fatigue may be associated with typical physiologic aging changes such as vocal fold atrophy (Sataloff, 1998; Woodson, 2003). In routine speech, such vocal changes allowed a person to be identified as “older” even over the telephone (Calhoun & Eibling, 2006; Linville, 2001).

Among singers, voice changes with age are typically associated with breathiness, loss of pitch range, change in the characteristics of vibrato, development of tremolo (described as “wobble”), loss of breath control, vocal fatigue and pitch inaccuracies (Woodson, 2003). However, studies have shown that many of these acoustic phenomena are not caused by irreversible aging changes. Rather, they may be consequences of poor laryngeal respiratory and abdominal muscle condition undermining the power source of the voice (Sataloff, 1998; Sinard & Hall, 1998; Titze, 1994). When older singers reported voice complaints, the medical history usually revealed minimal aerobic exercise,

and shortness of breath climbing stairs (Brown et al., 1993; Sataloff, 2005). Studies have indicated that in the presence of good health, singers tended to demonstrate stability of fundamental frequency throughout life (Brown et al., 1991; Sundberg et al., 1998). It has been repeatedly found that features of the voice such as fundamental frequency, intensity range, and vocal quality can be maintained into the seventh decade in otherwise healthy individuals (Benjamin, 1981; Gorham-Rowan & Laures-Gore, 2006; Hollien & Shipp, 1972; Mysak & Hanley, 1958; Ryan, 1972; Wilcox & Horii, 1980).

Speaking Fundamental Frequency

Speaking fundamental frequency is a feature of the voice that changes with age. In males, speaking fundamental frequency decreases over time from young adulthood into middle age and then increases into old age. In females, speaking fundamental frequency decreases slightly at puberty, but remains fairly stable until menopause when a more dramatic decrease occurs (Boulet & Oddens, 1996; Debruyne & Decoster, 1999; Linville, 1996). It was hypothesized that the decrease in fundamental frequency in post-menopausal women was due to hormonal changes that caused vocal fold edema (Abitbol, Abitbol & Abitbol, 1999; Baker, 1999; Biever & Bless, 1989; Linville & Korabic, 1987; Woodson, 2003). There is great individual variability with regard to the age at which these changes take place. Studies indicated that physiologic age may be more predictive of vocal performance than chronological age (Ringel & Chodzko-Zajko, 1987; Shindo & Hanson, 1990; Spirduso, 1980; Xue & Mueller, 1997).

Vocal Intensity

In a study including 80 men ranging in age from 40-79 years, Ryan (1972) measured vocal intensity from a reading passage and in conversation. The study results indicated that men over age 70 demonstrated greater vocal intensity in conversation than younger men in either speech sample. Morris and Brown (1994) measured vocal intensity in 50 women ranging in age from 20-90 years during a reading and conversational speech task. The investigators found no difference in vocal intensity between younger and older women in either speaking condition. Contradictory data come from a study examining vocal volume in four young subjects (2 women, ages 26 and 27 years; and 2 men, ages 24 and 28 years) and five older subjects (1 woman, age 68 years; and 4 men age range 69-79 years) during repeated syllable production at “soft”, “comfortable” and “loud” intensity levels (Baker et al., 2001). Results of the study indicated that absolute intensity levels were lower for the older subjects than the younger subjects. The differences in number of subjects, instructions given to the subjects and speech tasks examined may be the source of discrepancy in the results.

Stability of fundamental frequency and intensity

Jitter and Shimmer are measures of the stability of fundamental frequency and intensity respectively. Jitter has been defined as cycle-to-cycle variations in frequency of vocal fold vibration (Ferrand, 2001; Titze, 1994). Studies investigating pitch perturbation (jitter) indicated that jitter increases with increasing age (Benjamin, 1981; Benjamin, 1997; Biever & Bless, 1989; Casiano et al., 1994; Ferrand, 1995; Hagen & Lyons, 1996;

Mueller, 1997; Ramig, Gray, Baker, Corbin-Lewis, Buder, Luschei et al., 2001; Xue, 1995). Other researchers noted that older persons who were in good physical condition experienced fewer of the effects of normal aging with regard to jitter values than those who were in poorer physical condition (Chodzko-Zajko, 1987; Ferrand, 2002; Gelfer, 1995; Orlikoff, 1990; Ramig & Ringel, 1983; Wilcox & Horii, 1980; Xue, 1995).

Shimmer has been defined as cycle-to-cycle variations in the amplitude of vocal fold vibration, and is a measure of intensity perturbation (Ferrand, 2001). Ramig & Ringel (1983) studied 48 men in three age groups (young, middle age and older) and at two levels of physical condition (good and poor). Study results indicated that jitter and shimmer values were more closely related to physical condition than chronological age. Brückl & Sendlmeier (2003) studied 56 women, who were in good health according to self report, ranging in age from 20 to 87 years and found that measures of amplitude perturbation (shimmer) were highly and positively correlated with chronological age and perceived age.

Statement of the Problem

Numerous studies have examined changes in fundamental frequency, jitter, intensity, and shimmer in the normal aging process (Benjamin, 1981; Biever & Bless, 1989; Boulet & Oddens, 1996; Debruyne & Decoster, 1999; Ferrand, 1995; Linville, 1996; Morris & Brown, 1994; Ramig & Ringel, 1983; Ryan, 1972; Xue, 1995). Studies have investigated differences in acoustic measurements and listener age judgments of younger and older non-singers (Baker et al., 2001; Biever & Bless, 1989; Brown et al.,

1993; Debruyne & Decoster, 1999; Hartman & Dannhauer, 1976; Higgins & Saxman, 1991; Morris & Brown, 1987). Studies of younger speakers indicate that listeners can distinguish between singers and non-singers based on singing and speaking voice samples. Most studies of the aging voice have compared the voices of younger individuals to the voices of older individuals. The effects of singing on the aging voice taking physical activity and health status into account are not known. The present study was conducted to provide data and spur further investigation of this topic.

The purpose of this study was to investigate whether there are differences in the acoustic measures of fundamental frequency, jitter, intensity and shimmer measures of older amateur singers and non-singers and whether there are significant correlations between listener judgments of speaker participant age and these acoustic measures.

Research Questions

The proposed study was an effort to answer the following research questions:

1. Are the voices of older amateur male singers and non-singers statistically significantly different with regard to selected acoustic measures?
2. Are the voices of older amateur female singers and non-singers statistically significantly different with regard to selected acoustic measures?
3. Are there significant correlations between selected acoustic measures and listener age judgments?
4. Are listener age judgments of the voices of older singers statistically significantly different from those of the voices of older non-singers?

CHAPTER III

Method

Participants

Speaker participants. The speaker participants for this study included 30 women and 30 men. The participants were further divided into subgroups of 15 female singers, 15 female non-singers, 15 male singers and 15 male non-singers. Definitions of key terms used in this study can be found in the Definitions of Terms section of Chapter 1. All speaker participants were between the ages of 65 and 80 years, were in good health according to self-report (Lyyra, Heikkinen, Lyyra, & Jylha, 2005), did not report allergies or reflux, were native speakers of English, and did not demonstrate symptoms of a voice disorder as determined by the principal investigator and a fellow experienced speech language pathologist. Speaker participants did not take any medications known to alter voice production, particularly medications for allergy, thyroid function or hormonal medications at the time of the study. Speaker participants were physically sedate as measured by “No” responses on items 1 and 4 of a scale of physical activity (Nigg, Hellsten, Norman, Braun, Breger, Burbank, Coday, Elliot, Garber, Greaney, Keteyian, Lees, Matthews, Moe, Resnick, Rieve, Rossi, Toobert, Wang, Welk, & Williams, 2005), had not smoked in the past ten years (Sorenson & Horii, 1982) and passed a pure tone hearing screening at 30 dB in the frequencies 1 kHz, 2 kHz and 4 kHz in at least one ear, administered by the principal investigator. Each speaker participant completed the questionnaire found in Appendix A and the checklist found in Appendix B to determine if they qualified for inclusion in the study. Questionnaire items for the inclusion criteria

were chosen based on review of previous research which indicated that age (Brown et al., 1993; Brown et al., 1991; Morris & Brown, 1994), self-report of overall health (Lee, 2000; Lyyra et al., 2005; Reuben, Siu & Kimpau, 1992), fitness level (Chodzko-Zajko & Ringel, 1987; Ferrand, 2002; Orlikoff, 1990; Ramig & Ringel, 1983; Wilcox & Horii, 1980 Xue, 1995) native language (Lisker & Abramson, 1964, 1967), smoking (Højslet, Moesgaard-Neilson & Karlsmore, 1990; Murphy & Doyle, 1987; Sorenson & Horii, 1982; Stoicheff, 1981) and gender (Hirano, Kurita & Nakashima, 1983; Ryalls, Zipprer & Baldauff, 1997; Smith, 1978; Sulter et al., 1995; Swartz, 1992; Whiteside & Irving, 1998) may influence acoustic voice measurements and listener judgments of speaker age. The speaker participants participated in this study on a voluntary basis.

Classification of the speakers into the singer groups or the non-singer groups was based on the level of participation in singing as reported by the speakers. Singers indicated that they were currently involved in a choir and had participated in a choir for a period of at least 10 continuous years at the time of the study. Classification of speakers into the non-singer groups was based on speaker report of lack of participation in choral singing since high school. Non-singers had not participated in any formal vocal training, including any singing instruction from participation in church or community choir since high school.

Listener Participants. The listener participants for this study included 10 students enrolled in graduate level courses in speech pathology and audiology. The listener participants had not taken a course in voice disorders at the time of the study. Listeners demonstrated normal hearing sensitivity as measured by a pure tone hearing screening

administered by the principal investigator. Listener participants participated in the study on a voluntary basis.

Speech Task

Speakers were asked to produce the vowel /a/ three consecutive times for at least five seconds (Biever & Bless, 1989; Brown et al., 1991; Brown, Morris & Michel, 1990; Fozo & Watson, 1998; Gelfer, 1995; Shipp & Hollien, 1969; Xue, 1995) in order to obtain the selected acoustic measures as well as for presentation to the listeners. Five second duration was measured for the speaker participants by the principal investigator who counted the seconds by holding up one finger per second. The instructions given to the speakers can be found in Appendix F. A two-second segment from the mid-portion of the second of three vowel sound productions was assessed for voice disorders, used for acoustic analysis and presented to the listener participants for chronological age judgments.

Instrumentation and Procedures

Voice recordings were made in a closed room in a quiet environment (<50dB ambient noise as measured by sound level meter). Voice recordings were captured in a Dell® Inspiron 600m laptop computer equipped with a Sound Blaster® Audigy2 ZS external sound card connected to a stand mounted Audio Technica® Pro 61 hypercardioid microphone. Voice recordings were digitized via the sound card at a sampling frequency of 44.1 KHz (Deliyski, Shaw & Evans, 2005). The voice recordings were stored as .wav files on a USB flash drive. Speaker participants were standing while

producing the vowel sounds. A stand mounted microphone was placed at the level of the mandible on each speaker and was placed 4cm from the speaker's mouth (Ferrand, 2001; Kent & Ball, 2000; Kent & Read, 1992; Titze & Winholtz, 1993). The microphone was positioned 45 degrees off center to avoid aerodynamic noise from the speaker's mouth (Titze & Winholtz, 1993). The checklist used by the principal investigator to insure consistent recording environment and set-up appears in Appendix H.

Acoustic Measurements

The measures used in this study were as follows:

1. Fundamental frequency as a measure of pitch.
2. Jitter as a measure of pitch stability.
3. Intensity as a measure of sound pressure level.
4. Shimmer as a measure of intensity stability.

Acoustic Analysis

A two second segment from the mid point of the second of three vowel sounds produced by each speaker participant was subjected to acoustic analysis extracting fundamental frequency (Fo), jitter, shimmer and intensity, using PRAAT © (version 4.5.14) analysis software (Weenink & Boersma, 2003; Karnell, Scherer & Fischer 1991). PRAAT © is a software program for speech analysis and synthesis. It can extract acoustic data from sound signals and can generate synthesized signals for use in research (Weenink & Boersma, 2003). Mean values for the selected acoustic measures served as data points for statistical analysis.

Perceptual Ratings

Listener participants were presented with voice sample segments 2 seconds in duration from the center portion of the second vowel sound production from each speaker. The voice samples were presented to listeners in individual sessions, over headphones in a quiet environment ($< 50\text{dB}$ ambient noise as measured by sound level meter). The listener participants were asked to write direct age judgments on a single sheet of paper after hearing each vowel sound. One sheet was used for each vowel sound heard. Instructions given to listener participants are presented in Appendix G.

Chapter IV

Results

Reliability Measures

Listener Age Judgments. The listener interrater reliability was evaluated with the intraclass correlation coefficient (ICC). The ICC obtained for this group of listeners was .74. Values less than .80 are not considered acceptable for reliability (Kirkwood & Sterne, 2003). The listeners who participated in this study did not demonstrate good reliability when making speaker age judgments. This finding is consistent with previous studies utilizing listener age judgments (Hollien & Shipp, 1987; Linville & Fisher, 1985; Neiman & Applegate, 1990; Ptacek & Sander, 1966a). This finding lends support to the practice of obtaining data from 10 listeners as was the case in this study.

Interrater Reliability for Voice Quality. Speakers needed to demonstrate normal voice quality in order to qualify for inclusion in the present study. Normal voice quality was assessed by the principal investigator (an experienced voice therapist), and a fellow experienced speech-language pathologist (SLP) with experience in voice therapy. Normal voice quality was determined by a score of “0” on the overall voice quality measure “G” on the internationally known and accepted GRBAS scale (Hirano, 1981). Each SLP listened to the 2 second segments of the vowel /a/ used in the acoustic and perceptual analyses. Kappa statistic was calculated to determine the degree of agreement. Agreement between the raters was very good (kappa = .97).

Selection of level of significance

Because (1) there was no intention of comparing males to females and (2) perceived and real age could not be combined in an ANOVA, it was decided to conduct

t tests to evaluate target comparisons of means. Since several t tests were conducted, a Bonferroni correction was considered, which would have placed the level of significance at .003. This was deemed to be too stringent a criterion considering the low level of risk of harm to individuals resulting from a type 1 error. An a priori significance level of .01 was set for the statistical analyses in order to make a conservative adjustment for multiple t tests.

Perceptual Measure

The perceptual measure consisted of listener age judgments. Perceived age judgments for each speaker were obtained from 10 listeners. Consistent with the method used for the acoustic data, perceived age judgments were based on a two second segment of the second of three productions of the vowel /a/. Results from males and females were considered separately. Mean real and perceived ages for all four speaker groups are contained in Table 1 and displayed in Figure 1 (males) and Figure 2 (females).

Table 1
Mean (and standard deviation) real and perceived ages for male and female singers and non-singers.

	Male		Female	
	Singers	Non-singers	Singers	Non-singers
Real Age	70.3 (3.8)	70.5 (3.6)	69.1 (3.5)	69.2 (3.5)
Perceived Age	45.6 (5.3)	53.7 (8.3)	44.7 (6.8)	56.9 (3.5)

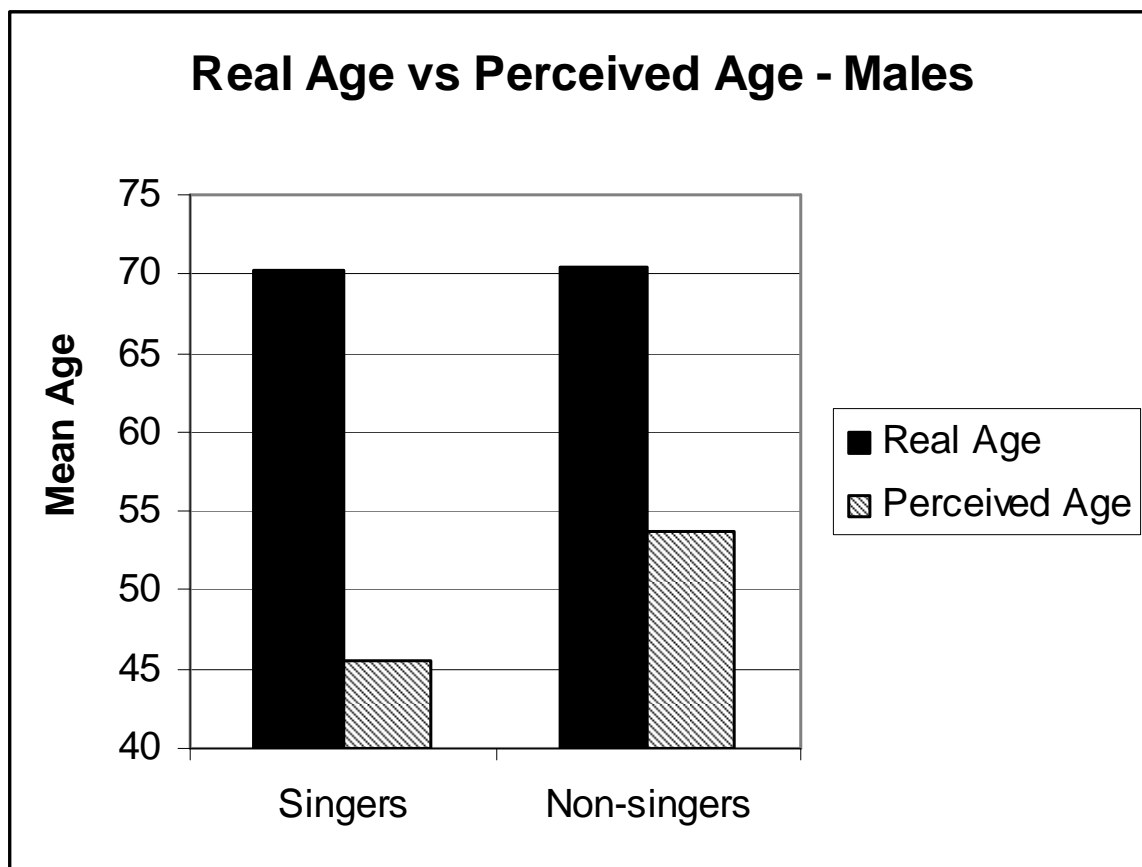


Figure 1. Mean real and perceived ages for male singers and non-singers.

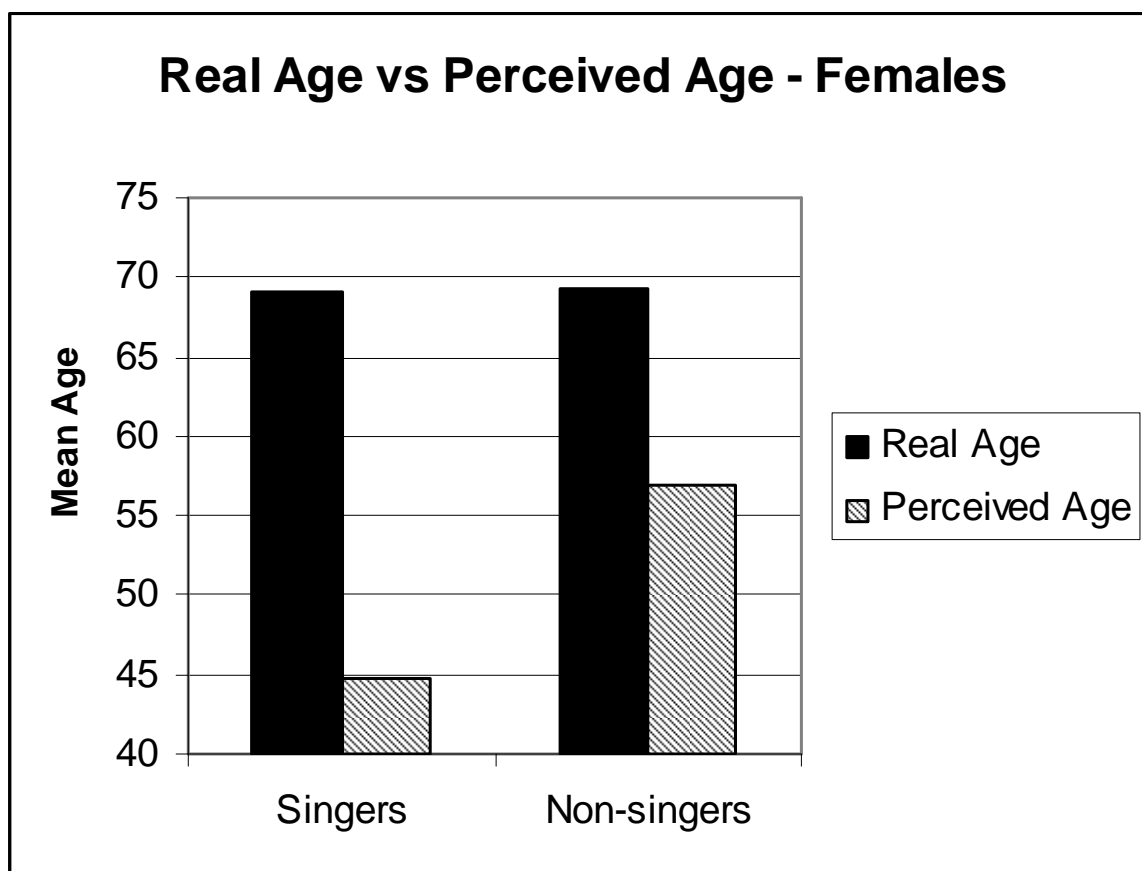


Figure 2. Mean real and perceived ages for female singers and non-singers.

Results of a paired samples t test indicated that the real and perceived ages of male singers were statistically significantly different, $t(14) = 14.25$, $p < .01$. Male singers were perceived to be significantly younger than their real ages. Results of a paired samples t test indicated that the real and perceived ages of male non-singers were statistically significantly different, $t(14) = 7.70$, $p < .01$. Male non-singers were perceived to be significantly younger than their real ages.

Results of a paired samples t test indicated that the real and perceived ages of female singers were statistically significantly different, $t(14) = 13.72$, $p < .01$. Female singers were perceived to be significantly younger than their real ages. Results of a paired samples t test indicated that the real and perceived ages of female non-singers were statistically significantly different, $t(14) = 6.04$, $p < .01$. Female non-singers were perceived to be significantly younger than their real ages.

Results of a t test for independent samples indicated that while the mean real ages of male singers and non-singers were not statistically significantly different, $t(28) = .10$, $p = .92$, perceived ages were statistically significantly different between male singers and non-singers, $t(28) = 3.16$, $p < .01$. Cohen's d measure of effect size indicates a large effect size, $6.32/5.30 = 1.19$. Male singers were perceived to be significantly younger than male non-singers.

Similar results were obtained when comparing real age to perceived age of female singers and non-singers. Results of a t test for independent samples indicated that while the real ages of female singers and non-singers were not statistically significantly

different, $t(28) = .05$, $p = .96$, perceived ages were statistically significantly different between female singers and non-singers, $t(28) = 4.92$, $p < .01$. Cohen's d measure of effect size indicates a large effect size, $9.84/5.29 = 1.86$. Female singers were perceived to be significantly younger than female non-singers.

Acoustic Analyses

Means and standard deviations for the acoustic measures can be found in Table 2. Individual data for the four speaker groups on mean fundamental frequency (Fo), jitter, shimmer and intensity are presented in Appendices J and K. All data were analyzed by gender grouping in order to avoid a neutralization of the difference in Fo between males and females. All acoustic data are based on the analysis of the two second segment of the second of three productions of the vowel /a/.

Jitter and Intensity. Significant differences were noted between the singers and non-singers, both male and female, for *jitter* and *intensity*. A t test for independent samples for jitter in male singers and non-singers was statistically significant, $t(28) = 2.71$, $p = .01$. Cohen's d measure of effect size indicates a large effect size, $5.41/5.29 = 1.0$. A t test for independent samples for jitter in female singers and non-singers was statistically significant, $t(17.8) = 3.74$, $p < .01$. Cohen's d measure of effect size indicates a large effect size, $7.47/4.21 = 1.8$. Male and female singers were found to have significantly less jitter than male and female non-singers.

A t test for independent samples for *intensity* in male singers and non-singers was statistically significant, $t(28) = 6.85$, $p < .01$. Cohen's d measure of effect size

indicates a large effect size, $13.70/5.29 = 2.59$. A t test for independent samples for intensity in female singers and non-singers was statistically significant, $t(28) = 3.73$, $p = <.01$. Cohen's d measure of effect size indicates a large effect size, $7.45/5.29 = 1.41$. Male and female singers were found to have significantly greater intensity than male and female non-singers.

Table 2

Mean (and standard deviation) acoustic measures for male and female singers and non-singers.

	Male		Female	
	Singers	Non-singers	Singers	Non-singers
Fo (Hz.)	128.03 (10.31)	135.99 (20.28)	237.89 (40.94)	216.12 (51.37)
Jitter (%)	.34* (.15)	.53 (.22)	.26* (.06)	.43 (.17)
Intensity (dB)	64 .52* (3.17)	57.01 (2.81)	62.62* (2.58)	58.44 (3.48)
Shimmer (dB)	.22 (.10)	.38 (.27)	.31 (.22)	.26 (.12)

* Indicates that the means for singers and non-singers for that gender were significantly different.

Fo and Shimmer. There were no statistically significant differences between singers and non-singers with regard to *Fo* and *shimmer*. Results of t tests for independent samples for male singers and non-singers indicated no statistically significant difference for *Fo*, $t(28) = 1.35$, $p = .19$, or *shimmer*, $t(28) = 2.18$, $p = .04$. T tests for independent samples for female singers and non-singers also indicated no statistically significant difference for *Fo*, $t(28) = 1.28$, $p = .21$, or *shimmer*, $t(28) = .71$, $p = .49$.

Correlations

Since several correlations were conducted, a Bonferroni correction was considered, which would have placed the level of significance at .006. This was deemed to be too stringent a criterion considering the low level of risk of harm to individuals resulting from a type 1 error. An a priori significance level of .05 was set for all correlations.

Correlation analyses were carried out on listener perceptions of age and acoustic measures that were found to be significantly different between singers and non-singers (i.e., intensity and jitter). The correlation between perceived age and intensity in male singers was not significant, $r = .31$, $p = .26$. Perceived age is not associated with intensity in male singers. The correlation between perceived age and intensity in male non-singers was not significant, $r = .27$, $p = .34$. Perceived age is not associated with intensity in male non-singers.

In contrast, there was a statistically significant correlation between perceived age and jitter in male singers, $r = .59$, $p < .05$. The coefficient of determination, $r^2 = .35$, indicates that 35% of the variation in perceived age can be predicted by jitter in male singers. Perceived age is moderately positively correlated with jitter in male singers. A Pearson correlation was carried out on perceived age and jitter in male non-singers. There was a statistically significant correlation between perceived age and jitter in male non-singers, $r = .79$, $p < .05$. The coefficient of determination, $r^2 = .62$, indicates that 62% of the variation in perceived age can be predicted by jitter in male non-singers. Perceived age is moderately positively correlated with jitter in male

non-singers.

The correlation between perceived age and intensity in female singers was not statistically significant, $r = .12$, $p = .67$. Perceived age is not associated with intensity in female singers. However, there was a statistically significant correlation between perceived age and intensity in female non-singers, $r = .715$, $p < .05$. The coefficient of determination, $r^2 = .51$, indicates that 51% of the variation in perceived age can be predicted by intensity in female non-singers. Perceived age is moderately negatively correlated with intensity in female non-singers.

The correlation between perceived age and jitter in female singers was statistically significant, $r = .57$ ($p < .05$). The coefficient of determination, $r^2 = .33$, indicates that 33% of the variation in perceived age can be predicted by jitter in female singers. Perceived age is moderately positively associated with jitter in female singers. The correlation between perceived age and jitter in female non-singers was not statistically significant, $r = .11$ ($p = .685$). Perceived age was not associated with jitter in female non-singers.

Summary of Results

All speakers were perceived as significantly younger than their real ages and male and female singers were perceived to be significantly younger than male and female non-singers. There were no significant differences found between singers and non-singers with regard to Fo or shimmer. Significant differences were found between male and female singers and non-singers with regard to jitter and intensity. Male and female singers were found to have significantly less jitter than male and female

non-singers. Male and female singers were found to have significantly greater intensity than male and female non-singers.

No significant correlations were found between perceived age and intensity in male singers or non-singers. In contrast, perceived age was found to be moderately positively correlated with jitter in male singers and non-singers. No significant correlations were found between perceived age and intensity in female singers. However, perceived age was found to be moderately negatively correlated with intensity in female non-singers. A significant correlation was found between perceived age and jitter in female singers. Perceived age was found to be moderately positively correlated with jitter in female singers. Perceived age was not found to be associated with jitter in female non-singers.

Chapter V

Discussion

The process of normal aging brings anatomical and physiological changes that impact voice production in older speakers. Although a significant amount of research exists describing the effects of aging on the speaking voice, there are fewer studies describing the effects of aging on the singing voice. Within the research on the singing voice, the majority of studies focus on the female singing voice and have identified changes in F_0 and intensity with normal aging. The findings of this study suggest that participation in singing may have a significant effect on selected acoustic parameters and listener perception of speaker age.

The purpose of this study was to investigate whether there were differences between older amateur singers and older non-singers in listener age judgments and the acoustic parameters of F_0 , jitter, intensity and shimmer and whether there were significant correlations between age judgments and acoustic measures. A total of 60 elderly participants, grouped according to gender and participation in singing (male, female, singer, non-singer) were the speakers in this study. The speakers were recorded while sustaining the vowel /a/ for at least five seconds in three separate trials. Acoustic analysis was conducted on a two second segment of the second of three trials. The two second segments subjected to acoustic analysis were presented to 10 graduate student listeners who were asked to make direct age judgments of the speakers.

It was found that two of the selected acoustic parameters (jitter and intensity) were significantly different between singers and non-singers. Male and female singers

were found to have significantly less jitter than male and female non-singers. In addition, male and female singers were found to have significantly greater intensity than male and female non-singers. No statistically significant differences were found between singers and non-singers with regard to Fo and shimmer.

Regarding listener age judgments, speakers in all four groups were perceived as significantly younger than their real ages. Furthermore, male and female singers were perceived to be significantly younger than male and female non-singers. Perceived age was found to be significantly positively correlated with jitter in male singers, male non-singers and female singers, but not in female non-singers. Perceived age was found to be significantly negatively correlated with intensity in female non-singers. There were no statistically significant correlations between perceived age and intensity in male singers, male non-singers and female singers.

Listener age judgments

Numerous studies have investigated the issue of age recognition from voice alone. Listeners' ability to estimate speaker age varies in accuracy dependent on the type of speech sample presented as well as the precision of the age judgment required (Linville, 2001). Ptacek & Sander (1966a) found that listeners were able to make age judgments with good accuracy from isolated sustained vowels. Studies support the hypothesis that listeners tend to underestimate the age of older speakers (Hollien & Tolhurst, 1978; Neiman & Applegate, 1990; Ryan & Capadano, 1978; Sundberg et al., 1998; Xue & Mueller, 1997; Xue, 1995). The listener age judgment data obtained in this study are in agreement with previous research in which listeners judged older speakers to be younger

than their chronological ages. The speakers in this study were judged by listeners to be younger than their chronological ages regardless of level of participation in singing.

Huntley, Hollien and Shipp (1987) indicated that listener age may be a factor affecting age judgments and found that middle aged adults were more accurate than young adults and elderly listeners. The authors speculated that both young adults and elderly listeners may have been less familiar with the range of chronological ages represented by the speakers. Hollien and Tolhurst (1978) suggested that listeners hesitate to assign older ages to speakers during the course of a listening experiment. Linville and Fisher (1985) suggested that listeners may be responding to the increased variability among the elderly speakers when making age judgments. A theory set forth by Hollien and Tolhurst (1978) and Neiman and Applegate (1990) suggested that age judgments were more accurate when the age range of the listeners was closer to the age range of the speakers. This may at least partially explain the results of this study, since the listeners were college-age young adults making age judgments of elderly speakers.

Listener age judgments have not been used extensively when studying the aging singer's voice (Boone, 1997; Brown et al., 1993). A finding which was unique to this study was that listeners judged older singers to be significantly younger than older non-singers when level of participation in exercise was controlled. Information about which acoustic features listeners may be attending to when differentiating older singers from older non-singers is presented in the following sections.

Acoustic Analyses

It is well known that acoustic aspects of voice change with the normal aging process. It has been speculated that the acoustic changes that occur with aging result from normal anatomical and physiological changes which affect the vocal mechanism. Since measures of F_0 , intensity, jitter and shimmer have been studied extensively in the aging population, these acoustic parameters were selected in this study because substantial data are available for comparison.

Fundamental frequency (F_0). Numerous studies have suggested that there appears to be a trend for pitch to increase slightly in males, and decrease to a more moderate degree in females as a result of the normal aging process (Awan & Mueller, 1992; Higgins & Saxman, 1991; Hollien & Shipp, 1972; McGlone & Hollien, 1963; Mueller, 1985; Russell, Penny, & Pemberton, 1995; Verdonck-deLeeuw & Mahieu, 2004). Subsequently, researchers have investigated the relationship between F_0 and listener age judgments of the aging voice. The trend with regard to F_0 and perceived age appears to be that men tend to be perceived as older as F_0 increases, and women tend to be perceived as older as F_0 decreases (Horii & Ryan, 1981; Linville & Fisher, 1985; Linville & Korabic, 1986; Ryan & Burk, 1974; Shipp, Qui, Huntley & Hollien, 1992). F_0 has been identified as a robust listener cue to perceived age (Hartman & Dannhauer, 1976; Jacques & Rastatter, 1990; Linville & Fisher, 1985; Linville & Korabic, 1986). With regard to singers, studies have suggested that singers tend to maintain stability of F_0 over time and are perceived as younger by listeners than non-singers (Brown et al., 1993; Brown et al., 1991; Sundberg, 1990; Wedin & Ogrin, 1982). The results of the present

study do not support these findings. This study indicated that there was no statistically significant difference in Fo between singers and non-singers. The value of considering Fo as a factor in listener age judgments has been examined in recent studies and it has been suggested that Fo may not be as robust as previously thought as a listener cue to speaker age (Awan, 2006). Harnsberger, Shrivastav, Brown, Rothman & Hollien (2008) utilized voice resynthesis to examine the relevance of speaking rate and Fo to perceived age and suggested that Fo may not be a perceptually relevant cue to perceived age. An earlier study by Rothman et al. (2001) indicated that speaking fundamental frequency played no role in differentiating singers from non-singers. The results of this study support these more recent findings. While in the present study, listeners were asked to make age judgments from a sustained vowel production, other studies examining Fo and perceived age utilized connected speech (Brown et al., 1993; Linville & Fisher, 1985; Ryan & Burk, 1974). It is possible that the stimulus type presented to listeners has an effect on the factors that are used to form age judgments. Further research is needed regarding the relationship between Fo and listener age judgment.

Intensity. Intensity of older voices has received far less study than Fo, but some preliminary data are available regarding intensity and the aging voice and intensity and the singing voice. Among the studies which have examined intensity, several have focused on differences between younger and older participants regardless of singing experience. Ptacek & Sander (1966b) found that elderly males and females exhibited significantly less vocal intensity than younger males and females, while Ryan (1972) found that elderly males exhibited significantly greater vocal intensity than younger

males. Morris and Brown (1994) and Ramig (1983) found no differences in vocal intensity between younger and elderly females. Findings from these studies demonstrate that there is great variability among older participants, supporting the general understanding that the elderly are a heterogeneous group (Boone, 1997; Linville, 2001; Mueller, 1997; Sataloff & Linville, 2006).

The results of the present study indicated that there was a significant difference between the intensity levels of elderly singers and non-singers when producing a sustained vowel, with singers having greater intensity than non-singers. Researchers have made general statements regarding the effect of aging on vocal intensity. It has been stated that aging leads to an overall decrement of vocal intensity (Harries, 2006; Sataloff et al., 1997; Segre, 1971; Titze, 1993). Morris and Brown (1987), in a study measuring maximum, comfortable and minimum intensity levels of a sustained vowel, found that elderly females demonstrated diminished control of overall modulation of intensity at the maximum and minimum intensity levels, but demonstrated essentially no difference in intensity levels at a comfortable level when compared to younger females. In a similar study, Baker et al. (2001) found that older participants demonstrated significantly less vocal intensity across maximum, comfortable and minimum intensity tasks, and laryngeal EMG results indicated that older and younger participants modulated intensity levels in similar ways. Ptacek and Sander (1966b) found that the elderly participants, both male and female, demonstrated significantly less vocal volume than younger participants when producing a sustained vowel. These studies agree that vocal intensity is less in older people than in younger people, at least for certain levels of

intensity during a sustained vowel task. Conversely, Ryan (1972) indicated that men over the age of 70 demonstrated greater intensity levels than younger men during a conversational speech sample, but not during a reading task. Morris and Brown (1994) found that there was essentially no difference between young and older females with regard to intensity in a reading or conversational speech task. Further study is required to determine the effect of the type of speech task on vocal intensity levels in the aging population.

Brown et al. (1993) obtained intensity levels of young and middle-aged female singers and non-singers and found that among the singers, sopranos demonstrated greater intensity levels than altos and non-singers in the younger age group. In the middle-aged group, singers demonstrated significantly greater intensity levels than the non-singers. Unfortunately, because the study participants were located in different cities, recording limitations prevented the investigators from obtaining vocal intensity data on the elderly singers and non-singers. Titze and Sundberg (1992) conducted a study investigating vocal intensity in male singers and non-singers. The study participants were in a younger age group than the participants in the present study, but the results indicated that professional male singers produced greater intensity in speaking and singing tasks than male non-singers. Results of this study support previous research results regarding intensity levels of older singers and non-singers. However, a statement regarding the support that the present study can provide for the results of the previously mentioned studies can only be tentative due to differences in the populations studied.

Jitter and Shimmer. The present study results indicate that jitter was statistically significantly different between singers and non-singers, with singers exhibiting less jitter than non-singers. No statistically significant differences were found between singers and non-singers with regard to shimmer. Jitter and shimmer are often studied in voice research because they are related to the perceptual qualities of harshness and roughness. Harshness and roughness have been identified as characteristics that listeners considered typical of “old” voices (Hartman, 1979; Hartman & Dannhauer, 1976; Linville, 1987, 2001; Ryan & Burk, 1974). Acoustic analyses of sustained vowel production revealed that jitter and shimmer are higher in the elderly than in younger participants (Linville & Fisher, 1985; Ramig & Ringel, 1983; Wilcox & Horii, 1980). Nam, Nam and Lee (1997) suggested that elderly females showed the same levels of jitter and shimmer as younger females, but older males showed greater jitter and shimmer than younger males.

The relationship between jitter, shimmer and individual health and fitness variables suggest that elderly individuals who are in good physical condition exhibit less jitter and shimmer than individuals who are in poor physical condition (Ramig & Ringel, 1983; Ringel & Chodzko-Zajko, 1987), and that older speakers in good physical condition presented acoustic characteristics similar to those observed in younger speakers (Ramig & Ringel, 1983). Xue (1995) found that only jitter was significantly different when examining older participants in good vs. poor physical condition. Jitter also served as a cue to listeners when making age judgments of elderly speakers, but shimmer did not (Xue & Mueller, 1997).

The results of this study indicate that singers exhibited significantly less jitter than non-singers, but there was essentially no difference between singers and non-singers with regard to shimmer. This fact partially supports the previous studies comparing jitter and shimmer in singers and non-singers. With regard to elderly singers and non-singers, research suggests that the aging singer experiences fewer vocal changes than the aging non-singer (Boone, 1997; Sataloff, 2000, 2005; Sundberg et al., 1998). Differences in jitter between singers and non-singers have been found for younger and older speakers for reading tasks and sustained vowel productions (Brown et al., 1990; Ferrand, 1995; Hazlett & Ball, 1996). Ferrand (1995) indicated that vocal training had no effect on shimmer over four sessions, but did have a statistically significant effect on jitter in younger women. Further study is needed with regard to the value of jitter and shimmer in assessing aging voices.

Correlations

Results of this study indicate that jitter and intensity were found to be statistically significantly different between singers and non-singers. Correlation analyses were carried out on jitter and intensity to assess the relationship between these variables and perceived age. Results of the analysis indicated that there was a significant moderate positive correlation between perceived age and jitter in male singers, male non-singers and female singers, but not in female non-singers. The correlation between perceived age and intensity in the above mentioned groups was not statistically significant. However, perceived age was found to be significantly moderately negatively correlated with

intensity in female non-singers, while perceived age was not found to be related to jitter in this group.

The results of this study support earlier research indicating that individuals who are perceived as being younger have significantly less voice jitter than individuals who are perceived as being older (Debruyne & Decoster, 1999; Ramig, 1986; Ringel & Chodzko-Zajko, 1987; Xue, 1995; Xue & Mueller, 1997). With regard to intensity, the results of previous studies have indicated that there are differences between intensity measures of elderly men and women. Ryan (1972) found that elderly men had higher speech intensity levels in conversation and reading tasks than younger men. Morris and Brown (1994) examined speech intensity in young and elderly females and found no age related differences. Ryan and Capadano (1978) reported that listeners responded to perceived age judgments by indicating that decreased intensity was associated with older speakers for both males and females. However, other research suggests that vocal intensity is not a particularly good predictor of age due to the amount of variability among speakers (Baker et al., 2001; Linville, 2001; Morris & Brown, 1987, 1994; Sapienza & Dutka, 1996). Since perceived age was associated with intensity only in the female non-singers, this would suggest that intensity may not be a robust predictor of perceived age on the part of listeners.

Significance of present research

Studies of voice changes in the elderly are extremely relevant due to the expansion of the aging population and the impact of dysphonia on the social, emotional and vocational function of older adults (Boone, 1997; Calhoun & Eibling, 2006; Davies

& Jahn, 2005; Golub, Chen, Otto, Hapner, & Johns, 2006; Hagen & Lyons, 1996; Mueller, 1985, 1991; Ramig, 1986). Communication disorders such as dysphonia have been associated with anxiety and depression (Shindo & Hanson, 1990; Woo, Casper, & Colton, 1992) in a population which is at risk for these disorders (Gallo & Lebowitz, 1999; Sadock & Sadock, 2005). Studies of vocal aging and voice related quality of life suggest that the voice changes brought about by the normal aging process can precipitate decreases in social interactions and reports of impaired quality of life related to dysphonia (Golub et al., 2006; Marieke, Hakkesteegt, & Brocaar, 2006; Verdonck-deLeeuw & Mahieu, 2004). Golub et al. (2006) studied dysphonia among residents of an independent living facility and found that the prevalence of dysphonia was 20%, and that 50% of the participants with dysphonia reported significant quality of life issues related to their dysphonia.

The results of this study suggest that there is a relationship between participation in singing and perceived age as measured by listener age judgment. The results of this study also indicate that the differences in the acoustic measures of intensity and jitter may have practical significance for examining the differences between elderly singers and non-singers. These findings support previous research which suggested that singing exercises as well as general physical conditioning exercises can improve vocal functioning and impact the acoustic and perceptual changes associated with aging (Harries, 2006; Mueller, 1997; Ringel & Chodzko-Zajko, 1987; Sataloff, 1998, 2000, 2005; Sataloff, Caputo-Rosen, Hawkshaw, & Spiegel, 1997; Xue, 1995). Stemple, Lee, D'Amico & Pickup (1994) suggested that vocal function exercises and resonant voice

therapy techniques serve to establish a more normal relationship among respiration, phonation and resonance in the elderly. Practical implications of the present research include further support for the notion that a gradual decline of vocal function is not necessarily an inevitable part of normal aging. Therefore, it is necessary for voice practitioners to know how to distinguish changes that are precipitated by the normal aging process from pathology so that adequate information can be provided to individuals who seek our assistance. It is incumbent upon practitioners in the fields of voice and voice therapy to utilize the knowledge of the aging process to improve vocal functioning and potentially the quality of life of the elderly.

Summary and Conclusion

Among the literature indicating that there are differences in the acoustic and perceptual measures of the voices of younger singers and older singers, few data are available on the effects of singing when comparing older singers to older non-singers. The present study was an attempt in this direction and yielded significant findings with regard to the acoustic and perceptual differences between elderly singers and non-singers. The results of this study indicate that:

1. Listeners perceived elderly singers and non-singers to be younger than their actual ages, and singers were perceived to be significantly younger than non-singers.
2. There was a significant difference between singers and non-singers with regard to intensity, with singers demonstrating significantly greater intensity than non-singers.
3. There was a significant difference between singers and non-singers with regard to

jitter, with singers demonstrating significantly less jitter than non-singers.

4. There was a significant positive correlation between perceived age and jitter in male singers, male non-singers and female singers.
5. There was a significant negative correlation between perceived age and intensity in female non-singers.

Practical Implications

Currently, research on the aging voice has focused on establishing a knowledge base with regard to trends in the changes that occur in the voice in the normal course of aging. Numerous studies have indicated that there are acoustic changes in the voice which tend to occur with aging. Information regarding how to differentiate changes related to normal aging from changes that may signal disorder is emerging. We have a substantial knowledge base to support the premise that aging is a highly individualized process and that biological age may be a more accurate indicator of overall function than chronological age. We have yet to establish precisely which acoustic or perceptual markers will differentiate an “old” sounding voice from a “young” sounding voice. The large effect sizes with regard to jitter and intensity differences between singers and non-singers indicate that there is practical significance to the use of these variables in examining differences between the two groups.

The premise that deterioration of voice is simply something to which one must adjust is being challenged. Information regarding the value of singing and vocal function exercises in preserving a more “youthful” sounding voice continues to

emerge (Harries, 2006; Sataloff, 2000, 2005; Sulter, et al., 1995; Sundberg, 2003).

The present research supports these findings. Further investigation is needed to discover the effectiveness of vocal exercise on the aging voice.

Limitations of the Study

The present study is limited by the small number of subjects. Continued study of listener variables that contribute to perception of speaker age is needed in order to more precisely define this measure. Validity and reliability studies of the participant questionnaire items in Appendix A are required in order to establish applicability to future research. Additional data are needed to support the correlation between perceived age and jitter in male singers, male non-singers and female singers as well as the correlation between perceived age and intensity in female non-singers.

Although further research is needed to substantiate the findings of this study in a larger population, the differences observed have significant implications for the study of the aging voice. The present research has demonstrated the importance of comparing separate groups of elderly participants when investigating acoustic and perceptual correlates of vocal aging. Future research must consider the great variability among the elderly and the factors that contribute to this variability.

Implications for Future Research

Future research may focus on determination of the validity and reliability of questionnaire items used to qualify participants for inclusion in studies of the aging voice. Research questions for future studies may include investigation of the effects of selected vocal exercises on the acoustic and perceptual parameters of the aging

voice in order to refine our understanding of the relationship between vocal exercise and vocal function. An ABAB study design could be used to examine the effect of vocal exercise on listener age judgments and acoustic parameters of voice. A single group of elderly non-singers could be recruited for a study in which listener age judgments and acoustic variables would be measured to serve as baseline data followed by alternating prescribed periods of participation in and then withdrawal of vocal exercise. Future studies of the aging voice could include collaboration with fellow professionals who are interested in the care of the speaking and singing voice. Continued collaboration between otolaryngologists and singing voice teachers is likely to yield valuable information for researchers and practitioners. It is anticipated that collaboration between voice specialists will do much to further the understanding of the aging voice and provide the theoretical framework from which practical techniques can be developed to enhance the vocal functioning of an ever increasing aging population.

APPENDICES

Appendix A

Appendix A

Speaker Participant Questionnaire

Please answer each of the following questions:

1. What is your age? _____

2. What is the first language you learned? _____

3. How would you characterize your current health? (circle one)

Poor

Fair

Good

Excellent

If poor/fair, why? _____

4. Do you currently participate in singing with a choir? YES NO

If no, have you ever sung with a choir? YES NO If yes, how long ago?

If yes, how often do you sing with the choir? (including rehearsals and performances)

What voice part do you sing? _____

In how many choirs do you sing now? _____

For how long have you sung with the choir(s)? _____

6. Have you had any formal voice training? YES NO

If yes, for how long did you take voice lessons? _____

How recently did you take voice lessons? _____

7. Do you smoke, or have you smoked in the past ten years? YES NO

If yes, for how long have you smoked? _____

8. Do you currently take any prescription or over-the-counter medications regularly?

YES NO

If yes, what medications and how often?

Medication	Reason Taken	How often

9. Have you experienced any problems with your voice during the past three years?

YES NO

If yes, describe type of problem, when experienced and how it was treated: _____

10. Are you experiencing any problems with your voice now?

YES NO

If yes, describe type of problem(s) and how they are being treated:

Appendix B

Appendix B

PHYSICAL ACTIVITY STAGING (Nigg et al., 2005)

REGULAR PHYSICAL ACTIVITY: For physical activity to be considered “regular”, it must be done for 30 minutes at a time (or more) per day, and be done at least four days per week. The intensity of activity does not have to be vigorous but should be enough to increase your heart rate and/or breathing level somewhat. Examples of activities could include brisk walking, leisure biking swimming, line dancing, and aerobics classes or any other activities with a similar intensity level.

According to the above definition:

1. Do you currently engage in regular physical activity?	Yes	No
2. Do you intend to engage in regular physical activity in the next six months?	Yes	No
3. Do you intend to engage in regular physical activity in the next 30 days?	Yes	No
4. Have you been regularly physically active for the past six months?	Yes	No

Appendix C

Appendix C

Speaker Participant Consent Form

Consent Form: Acoustic voice measures of older voices

I want to do research on the voice characteristics of older people. I want to do this because I want to contribute to the knowledge and understanding of the effects of age on the human voice. I would like you to take part in this project. If you decide to do this, you will be asked to make audio recordings of your voice for later analysis. Your participation will require about one hour of your time. You will only need to meet with me once.

Your privacy will be protected in this project. No personally identifying information will be included in the audio recording or in the report of the study. If you take part in this project, you will be assisting voice researchers and voice therapists in their understanding of the voice. Taking part in this project is entirely up to you, and no one will hold it against you if you decide not to do it. If you take part, you may stop at any time by informing me in person, or by phone.

If you want to know more about this research project, please call me, Dr. Peter Mueller or Dr. Robert Pierce at (330)672-2672. This project has been approved by Kent State University. If you have questions about Kent State University's rules for research, please call Dr. Peter Tandy, Vice President and Dean, Division of Research and Graduate Studies (Tel. 330.672.2704). You will get a copy of this consent form.

Sincerely,

Barbara Prakup
Doctoral Candidate
Kent State University

CONSENT STATEMENT: I agree to take part in this project. I know what I will have to do and that I can stop at any time.

Signature

Date

Appendix D

Appendix D

AUDIO/VIDEOTAPE CONSENT FORM

I agree to audio recording at _____
Location

on _____
Date

Signature _____ Date _____

I have been told that I have the right to hear the audio recording before it is used. I have decided that I:

_____ want to hear the recording _____ do not want to hear the recording

Sign now below if you do not want to hear the recording. If you want to hear the recording, you will be asked to sign after hearing it.

Barbara Prakup, Dr. Peter Mueller, Dr. Robert Pierce and other researchers approved by Kent State University may / may not use the recording made of me. The original recording or copies may be used for:

___ this research project

___ teacher education

___ presentation at professional meetings

Signature _____ Date _____

Address: _____

Appendix E

Appendix E

Listener Participant Consent Form

Consent Form: Acoustic voice measures of older voices

I want to do research on the voice characteristics of people. I want to do this because I would like to contribute to the knowledge and understanding of the human voice. I would like you to take part in this project. If you decide to do this, you will be asked listen to recorded voice samples and judge how old people are. Your participation will require about one hour of your time. You will only need to meet with me once.

Your privacy will be protected in this project. No personally identifying information will be included on the age judgment data sheets or in the report of the study. If you take part in this project, you will be assisting voice researchers and voice therapists in their understanding of the voice. Taking part in this project is entirely up to you, and no one will hold it against you if you decide not to do it. If you take part, you may stop at any time by informing me in person, or by phone.

If you want to know more about this research project, please call me, Dr. Peter Mueller or Dr. Robert Pierce at (330)672-2672. This project has been approved by Kent State University. If you have questions about Kent State University's rules for research, please call Dr. Peter Tandy, Vice President and Dean, Division of Research and Graduate Studies (Tel. 330.672.2704). You will get a copy of this consent form.

Sincerely,

Barbara Prakup
Doctoral Candidate
Kent State University

CONSENT STATEMENT: I agree to take part in this project. I know what I will have to do and that I can stop at any time.

Signature

Date

Appendix F

Appendix F

Instructions for Speaker Participants

Welcome: Thank you for agreeing to participate today. First, I will do a hearing screening to check your hearing. If you pass the hearing screening, I'll ask you to say some sounds.

Hearing Screening: You will hear a series of tones, first in one ear and then in the other. Some may be very quiet. Raise your hand whenever you hear a sound, even if it is very quiet. Do you have any questions?

Vowel Production Task: I would like you to make the /a/ sound for at least five seconds. I will hold up my fingers to count out five seconds for you. Take a deep breath, and make the /a/ sound as if your doctor said "Say ah". Make the sound at a comfortable loudness and pitch. I will ask you to do this three times. Do you have any questions? Take a breath and say /a/. Good. Now I would like you to do it again the same way. Good. Now one more time, just like the previous ones.

Appendix G

Appendix G

Instructions for Listener Participants

Welcome: Thank you for agreeing to participate today. First, I will do a hearing screening to check your hearing. If you pass the hearing screening, I would like you to listen to some voices played over headphones.

Hearing Screening: You will hear a series of tones, first in one ear and then in the other. Some may be very quiet. Raise your hand whenever you hear a sound, even if it is very quiet. Do you have any questions?

Listening Task: You are about to hear a recording of a group of people producing the vowel /a/. Each person will say the /a/ sound for only two seconds. There will be a four-second pause between each sound. After you listen to each vowel sound, please write your closest age estimation (in years) on the response form. Be sure to make an age estimation of each person you hear. If you are not sure, you may guess. After you mark each sheet, turn it over so you can concentrate on the next voice. Do you have any questions?

Appendix H

Appendix H
Investigator Checklist

Speaker Participants

- _____ Informed Consent
- _____ Questionnaire
- _____ Hearing Screening
- _____ Mic. – Placed @ level of mandible 4cm from mouth - 45° off center
- _____ SLM – Environment @ ≤ 50 dB
- _____ Instructions

Listener Participants

- _____ Informed Consent
- _____ Hearing Screening
- _____ Instructions

Appendix I

Appendix I

IRB Approval Form

KENT STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD
APPLICATION FOR APPROVAL TO USE HUMAN RESEARCH PARTICIPANTS

Send completed forms to one of the reviewers designated for your Department or Katherine Light, Research and Graduate Studies, 113 University Auditorium

LOG NUMBER 07-221

Form can be downloaded from <http://www.kent.edu/rags-alpha/forms>

Please type all information. **HANDWRITTEN FORMS WILL NOT BE ACCEPTED.** Move through the document using TAB or Mouse. Do not use the enter Key. To mark a box, click with the mouse.

Name: Barbara Prakup	Address: 104A Music & Speech Building	Email: bprakup@kent
Telephone: (330) 672-2672		

Department: Speech Pathology and Audiology	FacultyRank/StudentStatus: Doctoral Candidate
---	--

Project Title: Acoustic voice measures of older voices

Type of Project: ☐ FACULTY RESEARCH ☐ External Funded (Agency:) Include copy of proposal
☒ STUDENT DIRECTED RESEARCH (Advisor: R. Rich)
☐ Thesis ☒ Dissertation ☐ Course Requirement (Course #:)
☐ Other (Specify:)

Duration of Project: Starting Date: 12/1/2006 (But not before approval is obtained)
Ending Date: 7/27/2007

I certify that the research procedures for this project and the method of obtaining consent (if any), as approved by the Kent University Institutional Review Board, will be followed during the period covered by this research project. Any future of will be submitted for Board review and approval prior to implementation.

If this project involves approval/permission from other institutions, the principal investigator (and the faculty advisor if the student) must sign below to certify the following statement: "I/we will not begin research at other institutions before I obtained their permission to do so."

<u>Barbara Prakup</u> <u>11-8-2006</u> Principal Investigator Date	<u>Richard Klich</u> <u>11/9/06</u> Faculty Advisor (If PI is a student) Date
--	---

Action Taken:
By REVIEWER :

<input type="checkbox"/> Level I, Category <input checked="" type="checkbox"/> Level II, Category <u>1a</u> <input type="checkbox"/> Level III, To Full Board Project Involves: <input type="checkbox"/> Deception <input type="checkbox"/> Identifiable medical information <input type="checkbox"/> Waiver of Consent	<input type="checkbox"/> Approved, Level I <input checked="" type="checkbox"/> Approved, Level II IRB Comments:
--	---

<u>[Signature]</u> <u>11-21-06</u> Primary Reviewer Date	<u>Katherine Light</u> <u>11/9/06</u> Administrator, IRB Date
<u>Don A. Wilson</u> <u>11-28-06</u> Co-Reviewer (Level II) Date	

IRB Level III Action:
☐ Approved ☐ Disapproved ☐ Contingent Approval (Comments or Contingencies):
Stan Wearden 1/3/07 Change John West to Pete
Chairperson, IRB Date
per phone conversation
1/3/07

Orig
KK Sec'd
11/29/06 IRB
meeting

Appendix J

Appendix J

Individual Acoustic Data – Males

PARTICIPANT	FO	JITTER	SHIMMER	INTENSITY
MS 1	130.050	0.373	0.368	56.823
MS 2	138.293	0.158	0.121	67.283
MS 3	127.884	0.220	0.166	63.782
MS 4	115.190	0.446	0.147	68.776
MS 5	137.306	0.235	0.104	61.611
MS 6	125.309	0.501	0.229	64.692
MS 7	130.837	0.167	0.269	63.708
MS 8	125.425	0.515	0.226	64.658
MS 9	126.151	0.531	0.479	65.136
MS 10	143.883	0.134	0.143	66.786
MS 11	127.915	0.234	0.152	66.151
MS 12	114.367	0.419	0.205	64.131
MS 13	130.082	0.370	0.175	66.465
MS 14	106.238	0.578	0.294	59.827
MS 15	141.639	0.229	0.254	68.050
	FO	JITTER	SHIMMER	INTENSITY
MNS 1	119.567	0.400	0.215	56.590
MNS 2	93.774	0.617	0.841	60.914
MNS 3	149.639	0.762	0.256	56.786
MNS 4	143.947	0.368	0.187	55.186
MNS 5	141.689	0.355	0.199	59.284
MNS 6	141.707	0.873	0.566	58.569
MNS 7	143.246	0.451	0.423	58.738
MNS 8	143.735	0.318	0.181	52.780
MNS 9	158.697	0.462	0.375	57.106
MNS 10	154.800	0.392	0.223	56.393
MNS 11	91.606	0.866	0.980	51.753
MNS 12	141.753	0.583	0.665	56.070
MNS 13	140.368	0.827	0.389	54.490
MNS 14	151.553	0.411	0.169	58.369
MNS 15	123.828	0.198	0.080	62.196

MS – Male Singer

MNS – Male Non-singer

Appendix K

Appendix K

Individual Acoustic Data – Females

PARTICIPANT	FO	JITTER	SHIMMER	INTENSITY
FS 1	292.632	0.251	0.679	65.493
FS 2	204.943	0.306	0.122	58.521
FS 3	292.039	0.201	0.376	65.866
FS 4	188.320	0.315	0.132	62.635
FS 5	253.125	0.152	0.317	62.820
FS 6	215.082	0.171	0.116	60.675
FS 7	251.401	0.269	0.136	61.028
FS 8	209.883	0.289	0.110	65.546
FS 9	292.607	0.223	0.485	65.536
FS 10	262.038	0.261	0.676	61.708
FS 11	293.108	0.330	0.568	65.326
FS 12	188.395	0.310	0.131	62.667
FS 13	213.624	0.357	0.537	57.724
FS 14	221.778	0.188	0.142	61.180
FS 15	189.391	0.223	0.115	62.619
	FO	JITTER	SHIMMER	INTENSITY
FNS 1	214.753	0.622	0.184	64.447
FNS 2	219.353	0.292	0.144	58.952
FNS 3	290.413	0.465	0.287	61.126
FNS 4	158.066	0.397	0.163	64.092
FNS 5	203.818	0.263	0.226	58.892
FNS 6	219.876	0.250	0.158	59.298
FNS 7	165.980	0.184	0.110	55.124
FNS 8	307.199	0.348	0.475	52.348
FNS 9	218.752	0.267	0.141	58.525
FNS 10	184.808	0.510	0.306	53.271
FNS 11	289.267	0.661	0.369	60.423
FNS 12	128.555	0.704	0.393	58.637
FNS 13	196.099	0.336	0.245	59.562
FNS 14	258.443	0.566	0.255	55.020
FNS 15	186.535	0.567	0.491	57.007

FS – Female Singer

FNS – Female Non-singer

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