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The Affects of Vocal Fatigue on Fundamental Frequency and Frequency Range in Actresses as Opposed to Non-Actresses

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THESIS APPROVAL

The abstract and thesis of Ruth Ann Jenkins for the Master of Science in Speech Communication: Speech and Hearing Science were presented May 31, 1995, and accepted by the thesis committee and the department.

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ABSTRACT

An abstract of the thesis of Ruth Ann Jenkins for the Master of Science in Speech Communication: Speech and Hearing Science presented May 31, 1995.

Title: The Affects of Vocal Fatigue on Fundamental Frequency and Frequency Range in Actresses as Opposed to Non-Actresses.

Differences may exist between the voice qualities of those who professionally use and train their voices and those who do not. The examination of fundamental frequency and frequency range in actresses and non-actresses is integral to determining voice quality differences in these populations. These differences, whether the result of frequent use or training of the voice, may exist relative to fatiguing conditions such as may be experienced by actresses in the course of their work. Fatigue has been shown to produce greater effects in normals than in performers, particularly in singers (Gelfer, Andrews, and Schmidt, 1991). Little research has been found comparing actresses to non-actresses in such an interaction effect. In order to determine whether a separate set of normative values should be sought for actresses, it is first necessary to determine whether significant differences exist between these populations in voice quality parameters.

The purpose of the present study was to determine whether or not significant changes in fundamental frequency and frequency range occurred in non-actresses relative to actresses as a result of fatigue. The subjects for the study included ten actresses between the ages of 20 and 30 who had a minimum of one quarter of voice training and three years of acting experience and ten women of the same age group who had no voice training or experience in acting. Each subject passed a puretone audiometric screening, had a negative history of voice disorders, and had not smoked within the last year.

These two groups were evaluated for: 1) fundamental frequency in prolonged productions of the vowel /a/; 2) speaking fundamental frequency in connected speech; 3) frequency range in sung scales; and 4) frequency range in connected speech.

Data was statistically analyzed using one way ANOVA tests with repeated measures. No significant interactions occurred between group and time, suggesting that non-actresses did not produce a greater shift than did actresses in fundamental frequency or frequency range as a result of fatigue. These results contradicted some findings and supported other findings of previous research based on similar samples.

THE AFFECTS OF VOCAL FATIGUE ON FUNDAMENTAL FREQUENCY AND FREQUENCY RANGE IN ACTRESSES AS OPPOSED TO NON-ACTRESSES

by

RUTH ANN JENKINS

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INTRODUCTION AND STATEMENT OF PURPOSE

INTRODUCTION

When a client is assessed for vocal pathologies, several parameters are typically tested. Two of the frequently used parameters are fundamental frequency and frequency range. The contention of this study is that actors may differ in these parameters from others because of their frequent voice use and, possibly, their vocal training. Although this study did not attempt to provide normative data, if a significant difference were found between the voices of actors and normals, it would have suggested that a separate set of normative data should be sought for actors on these parameters.

STATEMENT OF PURPOSE

The purpose of this study was to investigate the differences in voice quality, as measured by fundamental frequency in steady state vowels and connected speech and frequency range in sung scales and connected speech, before and after a fatiguing task in actresses as opposed to non-actresses. The importance of examining this hypothesis lies in the fact that actors do represent a significant proportion of professional voice users seen for vocal dysfunction (Koufman & Blalock, 1988). Also, because of their experience through frequent voice use, and possibly their training, the standards by which their voices are judged may need to be different from those used for persons without experience or training. If a significant shift had occurred in the non-actresses' speaking voices, relative to the speaking voices of the actresses, this research would have suggested that fatiguing factors may produce larger differences in fundamental frequency and frequency range in normals than in actors. This would in turn have suggested that the normative data given in previous literature may be insufficient for use with actors who present with vocal problems. This would imply a need for further research to establish a separate set of data to be used clinically with this population.

Research Questions

The following questions were addressed:

1. Does fundamental frequency as demonstrated in steady state vowels show a more significant shift after a fatiguing vocal task in non-actresses than in actresses?

2. Does fundamental frequency as demonstrated in connected speech show a more significant shift after a fatiguing vocal task in non-actresses than in actresses?

3. Does frequency range in sung scales show a more significant shift after a fatiguing vocal task in non-actresses than in actresses?

4. Does frequency range in connected speech show a more significant shift after a fatiguing vocal task in non-actresses than in actresses?

Hypotheses

The research hypothesis was: A difference will exist in endurance factors such that fatiguing conditions will produce greater changes in fundamental frequency and frequency range in non-actresses than in actresses. The null hypothesis stated that: There will not be a significant affect on non-actresses' speaking voices, relative to the speaking voices of actresses, on measures of fundamental frequency in steady state vowels and connected speech, nor frequency range in sung scales and connected speech after one hour long reading monologues are produced at stable intensities representing 80% of the subjects' maximum intensity levels.

DEFINITION OF TERMS

Actor/Actress: Persons who perform in theatrical settings. The term "actors" was used primarily in the review of the literature and in some instances elsewhere when referring to this population of performers as a whole. For the purpose of this study, all of the "acting" subjects were female, so when discussing these specific subjects the term "actresses" was used.

Fatiguing Task: This is a verbal task designed to fatigue the voice such that measurements of parameters, in this case fundamental frequency and frequency range, may be seen to change with respect to the subject's normal measurements. The task in this research was a one hour reading task consistently performed at 80% of the subject's recorded maximum intensity.

Frequency Range: This is the speaker's entire vocal range as measured in hertz. For the purposes of this study it was measured in a sung scale including falsetto, but excluding glottal fry and in connected speech (using the second sentence of a standard passage - The Rainbow Passage). The normal frequency range for women, ages 20-29 is 144-1,256 Hz in sung scales (Brown, Morris, Hicks, & Howell, 1993) and 192-275 Hz in reading tasks (Stoicheff, 1981).

Fundamental Frequency (Fo): This is the habitual pitch at which the subject phonates. Fo was measured in steady state vowels (|a| in this study) from which a 100-ms segment was analyzed. Means were used for comparison as seen in a similar previous study (Gelfer, Andrews, Schmidt, 1991). The mean for women ages 20-29 is 213.9 Hz, with a standard deviation of (35.9 Hz.) in steady state productions of |a| (Gelfer, et. al., 1991).

Maximum Intensity: The loudest sound the subject can produce in decibels (dB SPL), without hurting the voice . The mean maximum intensity level for women ages 20-35 in a comparison study was found to be 63.3 dB when analyzed from one sentence of the Rainbow Passage and 3 seconds of extemporaneous speech (Brown, Morris, Hicks, & Howell, 1993).

Speaking Fundamental Frequency (SFF): This is the habitual pitch at which the subject produces connected speech. SFF was measured in connected speech (a standard passage - the first paragraph of the

Rainbow Passage in this study) from which the second sentence was analyzed for a mean frequency. The mean for women ages 20-29 is 224.3 Hz in reading tasks with a standard deviation of 3.8 semitones (Stoicheff, 1981).

Steady State Vowel: A prolonged production of a vowel, maintained for at least 3 seconds. In this case the vowel used was /a/.

CHAPTER II

REVIEW OF THE LITERATURE

The concern of the current study is that actors, because they have greater than usual vocal demands and training may not demonstrate fatigue as readily as normals in the acoustic measurements of fundamental frequency and frequency range. This chapter reviews literature discussing the possibility of vocal fatigue in normals, singers, and actors, helping to establish the validity of the current research. The literature examined also discusses differences in trained and untrained voices, and the validity of using fundamental frequency and frequency range, as tools for measuring vocal quality changes brought about by fatigue.

VOCAL FATIGUE

Vocal Fatigue in Normals

Affects of vocal fatigue on normals have not been greatly studied. In a study on functional voice disorders (Bridger & Epstein, 1983), the records of 109 patients presenting with functional voice disorders over four years were examined. They found no evidence that excessive use of the voice was an etiologic factor. However, they did not explain in any way how this was assessed. One assumes that they may have looked at occupational history but there was no way to assess the amount of voice use outside of the work environment.

If vocally untrained persons of any non-performance profession are considered normals, there is certainly evidence that excessive use of the voice is fatiguing. In studies of various occupations/activities where excessive demands are commonly made upon the voice, fatigue has been shown to contribute to vocal pathologies. Examples of some normal populations at risk are teachers (Sapir, Keidar, & Mathers-Schmidt, 1993); cheerleaders (Campbell, Reich, Klockars, & McHenry, 1988); and army drill sergeants (Sapir, Atias, & Shahar, 1992). These studies, though all descriptive in nature, related excessive use and/or loudness of the voice to vocal disorders in normals. Both descriptive and experimental research have examined vocal fatigue in performers.

Vocal Fatigue in Performers

Singers' voices have been studied to a much greater extent than those of actors. In a survey of vocal and pedagogy majors in a university setting, 23 of 60 subjects assessed were found to have voice disorders (Galloway & Berry, 1981). This percentage exceeds the mean national prevalence for voice disorders by 56.5% according to those authors. The quality problem most frequently observed was hoarseness. Hyponasality and excessively low habitual pitch were also common problems. The authors suggested that abusive habits, misuse, and insufficient training were all causal factors. Another survey study using 79 female, college voice majors (singers), found that 61% of the subjects had multiple symptoms of vocal attrition (Sapir, 1993). The top three symptoms described by the subjects were: dryness of the throat, throat tightness, and vocal fatigue. This study also indicated that there was a general tendency for the subjects to "talk excessively, rapidly, loudly, and/or in a low pitch." The excessiveness and loudness of speech relate to the fatigue task that was used in the current study.

Though no empirical evidence has been found on the subject, it is likely that the occurrence of voice disorders in actors is similar to that in singers. The demands of acting on the voice are many according to Raphael (1991). Union actors work 8 to 12 hours per day, and those who are not union members frequently have full time jobs in addition to their rehearsal and performance schedules. Actors who tour are subjected to changes of temperature, humidity and altitude which may affect the voice. The size of performance spaces vary and can require extreme projection. Competing noise such as music or sound effects as well as smoke or fog effects may also influence the use of the voice. The expression of a wide range of emotions in a dynamic fashion and the production of wider than usual variations in loudness, pitch, rhythm, and quality are also important factors in considering the actor's voice. Singing is required of actors in many roles. Achieving a successful career in acting sometimes requires the continued use of an abusive voice that the actor has used to "sell" her/himself. Finally, due to the competitive nature of acting, many in the profession do not protest vocally abusive situations for fear of losing an important role. It may also be out of fear of jeopardizing their careers that actors will allow fatiguing conditions to damage their voices and not seek clinical help until it is absolutely necessary.

No literature has been found discussing the proportion of voice clients seen in clinics or private practice who are actors in reference to the total population of persons with voice disorders. However, in a study on vocal fatigue and dysphonia in professional voice users, (Koufman & Blalock, 1988) 8 of 67 professional voice users seen for vocal dysfunction were actors, representing the second largest group behind singers. They presented largely with dysphonia, pitch aberration, and/or vocal fatigue. Other problems noted were: laryngeal tension, poor speech breath support, excessively low pitched voices, and odynophonia (pain upon phonation). These disordered subjects, broken into two groups based on extent of voice use per career, were assessed against a group of vocally disordered nonprofessionals and a group of normals for the following vocal parameters: fundamental frequency in steady state vowels and a standard passage reading, respiratory adequacy in s/z ratios, and musculoskeletal tension based upon clinical palpation. The latter two parameters were not examined statistically. The professional voice users demonstrated significantly lower Fo than nonprofessionals and normals. This was attributed to positive social valuation of lower speaking voices. Vocal range of the disordered professionals was found to be significantly larger than that of the disordered nonprofessionals, and all disordered subjects had significantly smaller frequency ranges than normal subjects. In reference to the current study, this information demonstrates that actors are significant among the population of professional voice users seeking help for voice disorders. Secondly, it suggests that decreased frequency range may be related to behaviors that result in overall vocal fatigue. Finally, it implies that differences may exist in frequency parameters between nonprofessionals and professional voice users.

Another piece of research examined the risk of vocal fatigue in actors. Novak, Dlouha, Capkova and Vohradnik (1991) suggested that actors are subject to vocal fatigue after performances. They evaluated fundamental frequency, the center of gravity of the frequency spectrum, and the skewness of the straight line of formant regions to examine voice fatigue. Subjects were 45 actors, who were well trained speakers, with no vocal pathologies. Tape recordings were made of each subject immediately before and after theatrical performances and analyzed for the above parameters. Although significant differences did not occur overall, several subjects showed evidence of hypotony of the laryngeal muscles as seen in changes of fundamental frequency and increased skewness of the straight line of formant regions. It was noted that the theatre in which the performance occurred had poor acoustics, and that this increased vocal effort, and contributed to fatigue. Further research on the affects of vocal demand on actors' voices is warranted.

A third study (Scherer, Titze, Raphael, & Wood, 1985) used two vocally trained subjects, one male singer and one female theatre voice coach with acting experience. The authors examined vocal fatigue produced by loud reading tasks in which the subjects were stopped every 15 minutes to record vowel productions of |a| and to perceptually rate their voices. There were 8 diagnostic sessions (two hours of speaking tasks) completed per subject. Fiberoptic exams were done pre and post-testing. The results showed little acoustic difference over time in measures of jitter, shimmer, or harmonics-to-noise ratio, suggesting, as the authors stated, the need for more sensitive measures. Perceptual data indicated a worsening voice quality over time. The fiberoptic studies did indicate increased swelling and slight bowing of the vocal folds. This study implied that fatigue may produce vocal changes over time. The variables of the current study, Fo and frequency range, were not examined in the Scherer, et al. study, but given the tissue changes noted, it is possible that some affect on those parameters may have taken place. Apart from the effects of fatigue, differences based on amount of use, and possibly training, were examined in the current study. The majority of research comparing trained and untrained voices has been done with singers.

TRAINED VS. UNTRAINED VOICES

Trained Singers' vs. Untrained Voices

The voices of trained singers have frequently been compared to those of untrained persons. One study (Weidin & Ogren, 1982) looked at the differences in voice brought about by training by examining fundamental frequency before and after a 5-day intensive voice training program given to three groups, professional singers, untrained normals, and persons with "phonasthenic symptoms" (symptoms of voice disorder). Results showed the most significant increase in fundamental frequency and frequency range occurred in the normal and phonasthenic subjects. It was determined that this program of training, unfortunately not detailed in the article, was effective in bringing pitch to an optimal range and in extending the pitch range. The professional singers were hypothesized to have shown less change because of their previous training.

Wedin, Leanderson and Wedin (1978) showed significant improvement in singers' volume and sonority after an intensive one week vocal training program. They used long term average spectrum analysis, a form of analysis which provides a mean of spectra from all the sounds of a lengthy sample (Baken, 1987), and subjective ratings to assess the singing voices of ten professional singing teachers. They used three singing tasks and one speech task recorded before and after training. Of the forty post training recordings, thirty-three were found to demonstrate significant improvement ($p<.01$) in "volume, sonority, and stability". This suggested that training can make a difference in the speaking voice.

In another study (Awan, 1991), trained singers were compared with untrained vocalists on measures of vocal frequency, frequency range, and maximum, minimum, and comfortable vocal intensities. Data from 20 subjects in each group were compared for these parameters in sustained phonation of the vowel /a/. The results showed greater frequency ranges as well as greater means of maximum, minimum and comfort level intensities in the trained subjects. This was interpreted to mean that vocal training has positive affects on the voice, making it more flexible and providing more usable range in frequency and intensity. The study also suggested that the sustained vowel phonation technique of evaluation is useful in showing vocal profiles in assessment and plotting vocal change during intervention. Despite the difference in population, this research lent credibility to the basis of the current study and to the use of fundamental frequency as a tool for examining the voice.

In a study conducted by Gelfer, Andrews, and Schmidt (1991), it was hypothesized that one hour of constant loud reading would have a greater affect on the speaking and singing voices of untrained singers than on those of trained singers. The variables examined in pre and post-test evaluations were fundamental frequency (Fo), intensity, jitter ratio, shimmer, and signal to noise ratio (SNR). These evaluations consisted of sustained vowels (|i|, |a|, and |u|), readings of the Rainbow Passage, and singing of the Star Spangled Banner. Following the pretest session, the total speaking intensity range was determined by having each subject read the Rainbow Passage as softly (without whispering) and as loudly (without shouting) as possible. From these readings, an 80% maximal intensity was determined for each individual. This intensity level was maintained during the 1 hour reading/fatiguing task, by having the experimenter cue the subjects when they fell above or below that range. After the fatiguing task, the post-test measures, which matched the pre-test measures, were completed.

Using two-tailed t-tests comparisons and unspecified correlational statistics it was found that neither positive nor negative changes in trained subjects' voices reached a significant level on any variable except SNR. SNR decreased in the post-test singing sample, a sign of worsening vocal quality. The untrained singers showed significant negative vocal changes with an increase in Fo, overall increased inconsistency in fundamental frequency, increased intensity, and decreased SNR. It was concluded that, relative to trained singers, untrained voices were more negatively affected by the reading task. The authors suggested that: 1) vocal training does generalize between singing and speaking situations; 2) the task used in this study could be clinically useful in identifying vocal endurance problems and; 3) more in-depth diagnostic batteries are needed for diagnosis of voice disorders amongst clients who are trained singers.

The current study is similar in methodology to the Gelfer, et al. (1991) study and focused on questions similar to the latter two implications they made, relative to actors. Similarities between the Gelfer, et al. study and the current study include: 1) fundamental frequency as a dependent variable, 2) the use of steady state vowels and connected speech for assessment, and 3) the use of a one hour long and loud reading task to produce fatigue. Differences in the current study, include: 1) the lack of assessment of jitter, shimmer and signal-to-noise ratio, 2) the addition of the assessment of frequency range, 3) the use of sung scales rather than a song in pre and post-testing, and 4) the use of a one-way ANOVA with repeated measures, rather than t-test comparisons for statistical analysis. The Gelfer, et al. study was chosen as a partial model because it seems likely, given similar vocal demands between singers and actors, that actors will, like singers, exhibit differences compared to normals on measures of various vocal parameters such as fundamental frequency and frequency range.

Trained Actors' vs. Untrained Normals' Voices

Training is not, in and of itself, being examined as an independent variable in the current study due to validity issues. It is difficult to know if the hypothesized lack of difference between pre and post fatigue testing in actors is truly the result of training, or merely the result of increased endurance due to the vocal experience that comes with use. However, because either training, experience, or some combination of both are hypothesized to contribute to increased endurance of the actor's voice, it is necessary to discuss research findings on results of vocal training in actors. The level of training of subjects in the current study was difficult to compare with those in other studies because most previous studies have not specified exact levels of training and because the actresses used for the current research varied somewhat in their training. Nonetheless, research has suggested that the voice training actors receive does make a difference in vocal strength.

Feudo, Harvey and Aronson (1992) studied maximum exhalation time, maximum phonation time, and frequency range, mean speaking frequency, mean intensity, and peak intensity in reading and monologue tasks over a period of 12 months. Their subjects were 44 actors who were enrolled in a Master's degree program for theatre. The subjects were evaluated at the beginning of the training program and at the end of the first, second, and in some subjects the third years of the program. Unfortunately, no exact description of the voice training classes was provided. The study found substantial increases in maximum exhalation and maximum phonation time, slight expansion of frequency range, an increase in mean frequency, and an overall increase in mean intensity. These results were said to "reflect enhancement of physiologic endurance and development of range." This lends some credence to the idea that there is a difference between the trained and untrained voice. In the current study training was controlled for to the largest degree possible by the relative homogeneity of subjects selected. This was accomplished by surveying each potential subject as to: 1) years of acting experience (a minimum of 3 for the actresses, and none for the normals), 2) number of voice-specific training classes (1 quarter required for the actresses, and none for the normals).

One piece of research was found that looked at both fatiguing affects and the differences in a trained and an untrained voice. Scherer, Titze, Raphael, Wood, Ramig, and Blager (1986) examined the affects of vocal fatigue on shimmer and jitter in one trained speaker who was a theatre voice coach with experience in acting and one untrained speaker. Both subjects were females and were nearly the same age. The subjects read in nearly monotone conditions with the pitch maintained one octave above the lowest note in their individual range. Per the given pitch, the sound pressure level was set at 77% of maximal intensity for the untrained subject and 82% for the trained. The reason for this difference was not explained. In the pretask examination, the subjects produced the vowel /a/ seven times, rated their voices on a numerical self perception scale, and answered questions describing the quality of their voices and emotional status. They were also given fiberoptic exams of their laryngeal structures. The subjects read in successive 15 minute increments, each divided by a testing period including all of the above parameters, except the fiberoptic exam. When a subject felt she could no longer continue due to discomfort, the fatiguing tasks were stopped. The final assessment matched the initial assessment. The untrained subject asked to discontinue the procedure after 6 intervals (one and a half hour). The trained subject completed 10 intervals (two and a half hours). No significant differences were found in acoustic measures for the untrained subject, but her self ratings and answers to perceptual questions indicated a worsening voice quality. The vocally trained subject indicated symptoms of vocal fatigue and exhibited significant changes in shimmer and jitter, but only after a longer period of reading than the untrained subject underwent. It should also be noted that at about the point in time when the untrained subject discontinued the task, the trained subject stated that her voice felt "warmed up" to the tasks. A decrease in shimmer and jitter at that point confirmed an improvement in vocal quality.

In relation to the current study, the Scherer, et al. study did find that the untrained subject appeared to fatigue more quickly. Although no significant acoustic change occurred for that subject, it is difficult to compare her quality with that of the trained speaker, as they did not complete the same number of fatiguing intervals. Also, since no measurements of Fo or frequency range were made, no direct comparison can be made to the current study.

SUMMARY

The literature reviewed supports the idea that fatigue can produce differences in the voices of performers and normals. Both singers and actors have frequently demonstrated symptoms of voice disorders (Galloway & Berry, 1981; Koufman & Blalock, 1988) which helps support the current study in its contention that actors may represent a population of vocally disordered patients, worthy of consideration. The voices of trained and experienced singers had been noted to be less susceptible to fatigue than those of untrained persons (Gelfer, Andrews, & Schmidt, 1991), and given that evidence has also suggested that training may enhance the development and range of actors' voices (Fuedo, Harvey, & Aronson, 1992), it is reasonable to hypothesize that vocal fatigue will cause more significant affects in the voices of non-actresses than in those of actresses.

CHAPTER III

METHODS AND PROCEDURES

Subjects

The subjects for this study were 20 females ranging in age from 20 - 30 years old. Ten of these subjects were non-smoking actresses who had a minimum of three years of acting experience, and a minimum of one academic quarter of voice training. These subjects were garnered through posted notices (see Appendix B) in the Threater Arts Department at Portland State University (PSU), through verbal presentations to theatre voice and acting classes by the researcher, and through advertisements in the PSU Vanguard and Oregonian newspapers. It was the researcher's original intention to use actresses from a single training program (the PSU Theater Arts Department). This was not possible because the vast majority of actresses who met the age and experience qualifications were smokers and therefore could not be included.

The remaining ten subjects were vocally untrained non-smoking women of the same age group. None of the women in this "normal" sample had any previous experience in acting nor any training in speaking or singing voice. These subjects were garnered from notices distributed by participating professors in the Psychology Department at PSU (see Appendix C) and through verbal presentations by the researcher in psychology classes. In the written notices and verbal presentations to both groups, the researcher described the tasks involved in the study without stating the purpose or expected outcomes. The demographic information on all subjects is presented in Table I.

Factors which were considered to produce extraneous variation in fundamental frequency and frequency range were controlled for by using a brief screening form (see Appendix E). All subjects having colds or sinus infections at the time of testing were re-scheduled. No subjects had any current or previously diagnosed voice disorders, chronic voice problems, or chronic respiratory tract difficulties. No subjects had smoked in at least the last 12 months. No subjects were premenstrual at the time of testing. They all had hearing within the normal range of 0 to 25 dB HL at 500, 1,000, 2,000 and 4,000 Hz as determined by screening with a calibrated, portable audiometer in a quiet area. All subjects signed an informed consent form (see Appendix D) before any data was collected. All subjects were paid for their participation.

Instrumentation

Pre and post-fatigue task samples were recorded on digital audio tape (DAT) using a Sharp SXD200 digital audio tape recorder. A Tascam M-50 sound mixing board was used to balance the signal coming into the DAT recorder. Before and after each data collection session a 1,000 Hz reference tone was recorded onto the tape from a Wavetek, Model 19, 2 MHZ sweep function generator.

TABLE I

DEMOGRAPHICS OF ACTRESSES AND NON-ACTRESSES

Actresses

#	Age	Quarters of Voice Training	Quarters of Singing Training	Years of Acting Experience
1	25	2	2	7
2	21	2	0	3
3	27	1	1	5
4	22	1	0	3
5	24	5*	0	6
6	30	6*	12*	12
7	22	5*	10*	4
8	24	9*	0	6
9	28	3	1	10
10	30	2	3	12
MEAN	25.3	3.1	2.9	6.8

* = Equivalent number of quarters taken from subject reports of years or semesters.

Non-Actresses

#	Age	Quarters of Voice Training	Quarters of Singing Training	Years of Acting Experience
1	21	0	0	0
2	22	0	0	0
3	26	0	0	0
4	25	0	0	0
5	21	0	0	0
6	23	0	0	0
7	20	0	0	0
8	20	0	0	0
9	22	0	0	0
10	20	0	0	0
MEAN	22.0	0	0	0

The pre and post-test measures were recorded in a sound treated booth using a Neuiman condenser microphone. Mouth to microphone distance was maintained at five inches for these samples. Maximum intensity level was recorded from a calibrated Bruel and Kjaer, model 2203, sound level meter after the pretest condition using two readings of The Rainbow Passage. It was also used by the experimenter to cue subjects for maintaining intensity at a constant level during the fatigue task. The sound level meter was kept at a constant distance of 12 inches from the speaker's mouth. The Bruel and Kjaer, model 1616, 1/3 octave filter was attached to the sound level meter and set at 10,000 hz in order to filter out signals that did not represent the speaker's fundamental frequency. Therefore, the sound level meter itself was set to "External Filter". The microphone used on the sound level meter was a free field microphone. A Radio Shack LCD quartz stopwatch was used to time the readings.

Given the computerized voice analysis systems available, it was necessary to calculate fundamental frequency and frequency range on two separate programs. Fundamental frequency, as produced in steady state vowel prolongations and a reading passage was calculated by the Computer Assisted Speech Evaluation and Rehabilitation program, hereafter referred to as CASPER (Till, 1990). This was done at the Veteran's Administration Hospital of Portland. A Panasonic SV3700 digital audio tape player was used to play the tapes. A 486 computer with a built in card for digitizing the samples to be analyzed, was used to run the CASPER program.

Frequency range as demonstrated in sung scales and a reading passage was calculated by digitizing the signal on a Tucker Davis Technologies DD1, 2 channel, 16 bit A/D board and then analyzing the signal using the Canadian Speech Environmental Research Software, hereafter referred to as CSRE (Kheirallah, 1993). This program was run on a 486 computer at Portland State University. A Denon DTR-80P digital audio tape player was used to play the tapes.

PROCEDURES

Data Collection

Subjects participated in pre and post-task data collection sessions with a fatiguing task in between. Prior to the first data collection session, for each subject, written consent was attained, the screening questionnaire (Appendix C) was completed, the hearing screening was done, and the protocols for the tasks were explained. Also, before data collection took place, a 1,000 hz reference tone was recorded on one channel of the DAT.

The pretask data collection consisted of recording samples for each subject on a high quality tape in the sound treated booth, as previously mentioned, on: 1) measurements of fundamental frequency determined in the context of a steady state production of /a/ repeated three times, and a reading of the first paragraph of the Rainbow Passage; and 2) measurements of frequency range as determined by a sung scale repeated 3 times, and the reading of the first paragraph of the Rainbow Passage. In the prolonged vowel task the subjects were asked to produce the vowel /a/ at a comfortable speaking pitch, continuing it for as long as possible. They were given a demonstration and the task was repeated three times. In the connected speech task, the subjects were given a copy of a standardized passage, "The Rainbow Passage" (See Appendix G) and asked to read it once at a comfortable pitch and loudness level. In the sung scale tasks the subjects were first asked to produce their scale from a comfortable pitch to their highest pitch, including falsetto, on a glissando. They were then asked to produce their low scale from a comfortable pitch to their lowest pitch, excluding the glottal fry register. In both scale tasks subjects were given a model by the examiner and then asked to complete the task three times. The examiner used hand signals for stopping and starting all tasks, and for cueing subjects if it appeared the subjects had not reached the highest and lowest points in their singing ranges. A detailed description of the instructions is found in the protocol (Appendix E).

A pre-task level of maximum intensity was established with a calibrated sound level meter during two more readings of the Rainbow Passage. For this measure, the subjects were asked to read once at their minimal loudness without whispering and once at their maximal loudness without shouting. A demonstration was provided by the researcher. The sound level meter was kept at a distance of 12 inches from the subject's mouth. The 80% point between minimum and maximum intensity was calculated for use during the fatigue task as suggested by previous research (Gelfer, et al., 1991; Scherer, et. al, 1986). The following formula was used to determine the 80% point within the range of intensity, where minimum intensity is represented as *i min.* and maximum intensity is represented as *i max.* :

$$i\ min. + [\ (i\ max. - i\ min.) \times .8] = task\ \ volume$$

As an example, if a subject's minimum volume was 26 dB SPL and her maximum volume was 64 dB SPL, the formula would read as:

$$26 + [\ (64 - 26) \times .8] = 56.4$$

In that example, the intensity level to be maintained in the fatiguing task would therefore be 56.4 db SPL.

The fatigue task consisted of a one hour oral reading performance from a large print (for optimal reading ease) book. The book used was <u>Having Our Say: The Delaney Sisters' First One Hundred Years</u> (Delaney, Delaney, & Hearth, 1993). This was performed by each subject in the same soundproof booth where the pretask and post-task measures were done, to avoid time lapse between the task and post-task measurements. During this task the intensity measurements were taken at a stable distance of 12 inches, as suggested in the literature (Gelfer, et al., 1991), and the experimenter cued the subjects to maintain a stable intensity, reflecting 80% of their maximum intensity as previously measured. Because intensity changes with varying consonant and vowel sounds in connected speech, the standard for cueing the subjects to increase or decrease intensity was based on their production being greater than 2 db SPL away from their maximum intensity for more than 10 seconds at a time. A one minute break, in which the subjects were asked to remain silent, was given half way through the task as suggested in previous research (Gelfer, et al., 1991). Subjects were informed before beginning that if at any time during the task, they indicated on a message pad that they were in too much discomfort to continue, the task could be stopped. This did not occur with any subject.

The post-fatigue data collection process matched the pre fatigue process. The subjects were not allowed to talk or otherwise phonate between the fatiguing task and post-testing. The post-testing began less than 2 minutes after the fatiguing task was finished.

Data Analysis

The 1,000 Hz. reference tone for each sample was analyzed for calibration purposes. The third trial (pre and post-task) of each subject's steady state vowel and sung scale were analyzed to attain maximal performance as suggested in the literature (Neiman & Edeson, 1981). Fundamental frequency was analyzed using the CASPER system, while the CSRE was used to analyze frequency range. Neither system is capable of making both calculations.

For the fundamental frequency (Fo) taken from the vowel, a 100 ms sample was extracted by the program from a 5 second sample taken at the beginning of the production. The sampling rate was 20,000 Hz The prolonged vowel analysis function of the CASPER program calculated a mean frequency.

Because the CASPER program will only allow for 30 seconds of sampling in connected speech, only the second sentence of the first paragraph of "The Rainbow Passage" was analyzed in measuring speaking fundamental frequency (SFF). Several authors, as cited by Baken (1987) in his discussion of the measurement of SFF, found that the second sentence of "The Rainbow Passage" correlated highly (r=.99) with the entire first paragraph in measuring SFF. A sampling rate of 20,000 Hz was used. The extracted sentences were analyzed using the acoustic monologue analysis function of the CASPER program, which calculated a mean SFF.

Frequency range measurements were analyzed using the CSRE program. Data from the pre and post-task measurements were evaluated by digitizing the signals on the A/D board, with the high pass filter set at 10 K and then analyzing the signal using the pitch and spectral functions of the CSRE. The first measurement to be analyzed for frequency range was taken from the same sentence extraction as that used for SFF. The sentence was analyzed by the pitch function of the CSRE at a sampling rate of 20,000 Hz. The waveform viewport was examined by the researcher to find the highest and lowest frequency areas. In doing this the comb filter was set at 1,000 Hz in order to filter out extraneous frequencies that did not represent the true speech sample.

The second measurement that was analyzed for frequency range was that taken from the third production of the subject's sung vocal scale. The highest and lowest notes produced by the subject were analyzed separately using the spectral function of the CSRE at a sampling rate of 40,000 Hz. The waveform viewport was examined by the researcher for the highest and lowest frequencies in the respective samples.

All Fo and SFF measurements were printed out by the computer running the CASPER system. All frequency range measurements were hand written onto a data sheet by the examiner. Because human judgment is required in choosing the most reliable numbers representing the range in both connected speech and sung scale tasks, interrater and intrarater reliability measures were performed. Therefore, 20% of the samples used for frequency range analysis were saved to the hard drive of the computer for re-analysis at a later time.

VALIDITY

Method Validity

Much of the research examined in the review of literature used fundamental frequency and/or frequency range as a method of studying the voice. Titze (1994), in his discussion of standards of acoustic analysis states that measurement of fundamental frequency is necessary for most acoustic measures of vocal utterances. Gould and Korovin (1994), in their article regarding voice measurements, suggested that fundamental frequency provides clues to abnormalities, but does not establish the cause of given vocal problems. Pabon and Plomp (1988) in their research on automatic phonetogram recording, found that comparisons of voice values were more meaningful when information on both fundamental frequency and intensity were available. The current study did address intensity, but only as part of the fatiguing task condition, not as an dependent variable.

The parameters being examined in the current study were considered to be valid because they have been seen to measure differences in experience/training as discussed in more depth in the review of the literature. Professional voice users, including actors were seen to demonstrate lower Fo and greater frequency range (Koufman & Blalock, 1988). Trained singers were also found to have greater frequency ranges than untrained persons in a study by Awan (1991). Fuedo, Harvey and Aronson (1992) demonstrated a slight increase in frequency range after a vocal training program with actors.

Differences have also been demonstrated in frequency range as a result of fatigue, as discussed in the reference to the Koufman & Blalock article (1988) in the review of the literature. These authors found that all disordered subjects, those experiencing symptoms of vocal fatigue, had significantly smaller frequency ranges than normal subjects. The fact that this study also showed the disordered professionals to have significantly larger vocal ranges than disordered nonprofessionals also demonstrates an interaction affect between (fatigue related) disorders and training/experience.

Fundamental frequency and frequency range have been demonstrated to differ quite obviously based on sex (Fitch & Holbrook, 1970) and to a lesser extent based on age (Hollien & Shipp, 1972; Ptacek, et al., 1966; Stoicheff, 1981). Also, smoking has been seen to lower Fo (Gilbert & Weismer, 1974). The premenstrual condition has been shown to lower Fo and increase hoarseness (Prater & Swift, 1984). Therefore, internal validity was addressed in the subject selection of this study by choosing all female subjects within a certain age range who were non-smokers and were more than five days premenstrual. Internal validity was also kept by using the same instructions for each subject. The instructions were written so as not to be leading and subjects were not informed about the purpose of the study. All subjects were asked not to dramatize the reading in order to avoid uncontrollable vocal variables that might effect frequency.

RELIABILITY

Method reliability was approached in three ways. Before each subject's task recordings, a 1,000 Hz reference tone was recorded on each tape for calibration purposes. Also, because there is room for human error in choosing the frequencies that most accurately reflect frequency range from the viewports of the CSRE pitch and spectral analysis, intrarater and interrater reliability were conducted.

Intrarater Reliability

Intrarater reliability for frequency range data was calculated by the performance of a second rating by the researcher which took place four weeks after the initial rating. Pearson correlation coefficients were calculated.

Interrater Reliability

Interrater reliability for frequency range data was calculated by having a second trained rater, a Portland State University professor from the Communication Sciences and Disorders Program, examine the sample and record frequency data. Pearson correlation coefficients were calculated.

STATISTICAL ANALYSIS

Because the data to be collected was based on ratio and interval scales, parametric statistics were used. In specific ANOVA tests were used to examine group main effects, time main effects, and group by time interactions. Eight separate one-way ANOVA tests with repeated measures were conducted. These eight ANOVA tests reflect pre and post-task measurements of the following dependent variables: fundamental frequency in steady state vowels, fundamental frequency in connected speech, the highest frequency in connected speech, the lowest frequency in connected speech, frequency range in connected speech, the highest frequency in sung scales, the lowest frequency in sung scales, and frequency range in sung scales. The level for significance of these measures was set at $p < .05$. All statistical analysis was completed on the SPSS program (Norusis, 1993).

The ANOVA procedure requires that the population be normally distributed. With a sample size of twenty, this cannot be assumed. Therefore, to achieve more robust results, non-parametric statistics were also calculated. Because the one-way ANOVA is the generalization of the pooled-t procedure, the f test used in ANOVA calculations can be used as the t-test equivalent. Therefore, it is possible to use the Mann Whitney U and the Wilcoxon Rank Sum tests as the nonparametric equivalents of ANOVA tests. The Mann Whitney U was used as the non-parametric equivalent of the 2 sample t-tests used in the ANOVA to examine main effects of group and group by time interaction. The Wilcoxon Rank Sum test was used as the non-parametric equivalent of the matched pairs t-tests used in the Anova to examine main effects of time. The results of the non-parametric tests matched the results of the parametric tests. All results found statistically significant through non-parametric statistics were also found to be significant using parametric statistics. Similarly, results not reaching statistical significance in non-parametric statistics did not achieve significance in parametric statistics. Therefore, since the results of the parametric tests were found to be robust, the parametric terms were used in the results and discussions sections.

Summary

The procedures presented above and the statistical measures used to examine the results would reliably show a difference, if one existed, in the affects of vocal fatigue on the fundamental frequency and frequency ranges of trained actors as opposed to untrained normals. If such a difference occurred this would suggest the need for separate normative data to be used clinically with actors.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

The objective of this study was to gain greater knowledge of the differences between actresses and non-actresses in fundamental frequency and frequency range relative to vocal fatigue. To achieve this objective four research questions were asked.

The first question was: Does fundamental frequency as demonstrated in steady state vowels show a more significant shift after a fatiguing vocal task in non-actresses than in actresses? The Fo taken from the prolonged production of /a/ for individual actresses and non-actresses and their group means before and after the fatiguing task are presented in Table II. The mean difference between groups as it interacted with the fatiguing task was 8.46 hz. This difference was not statistically significant ($F=.74$; $df=1,18$; $p=.402$).

The second question was: Does fundamental frequency as demonstrated in connected speech show a more significant shift after a fatiguing vocal task in non-actresses than in actresses? The SFF taken from the second sentence of "The Rainbow Passage" for individual actresses and non-actresses and their group means for this task pre and post-testing are presented in Table III. The mean

TABLE II

VOWEL FUNDAMENTAL FREQUENCY (Fo) FOR ACTRESSES AND NON-ACTRESSES IN HERTZ

Actresses				
Vowel Fo	Mean	SD	Minimum	Maximum
Pre-Task	236.15	15.31	220.2	277.6
Post-Task	245.82	19.15	220.8	276.6
Difference	9.67	15.39	-12.1	32.2
Non-Actresses				
Vowel Fo	Mean	SD	Minimum	Maximum
Pre-Task	238.15	17.83	213.3	275.5
Post-Task	239.36	18.55	212.4	271.3
Difference	1.21	27.06	-48.3	33.3

TABLE III

CONNECTED SPEECH FUNDAMENTAL FREQUENCY (SFF) FOR ACTRESSES AND NON-ACTRESSES IN HERTZ

Actresses				
SFF	Mean	SD	Minimum	Maximum
Pre-Task	214.38	11.62	197.2	233.1
Post-Task	232.50	20.38	188.7	253.0
Difference	18.12	12.66	-8.5	36.2
Non-Actresses				
SFF	Mean	SD	Minimum	Maximum
Pre-Task	209.80	12.48	188.2	226.0
Post-Task	225.56	13.59	205.2	243.1
Difference	15.76	21.50	-16.8	49.7

difference between groups as it interacted with the fatiguing task was 2.36 hz. This difference was not statistically significant ($F=.09$; $df=1,18$; $p=.768$)

The third question was: Does frequency range in sung scales show a more significant shift after a fatiguing vocal task in non-actresses than in actresses? The frequency range for sung scales taken from actresses and non-actresses and the related group means pre and post-testing are presented in Table IV. The mean difference between groups as it interacted with the fatiguing task was 49.5 hz. This difference was not statistically significant ($F=.59$; $df=1,18$; $p=.452$).

The fourth question was: Does frequency range in connected speech show a more significant shift after a fatiguing vocal task in non-actresses than in actresses? The frequency range taken from the second sentence of "The Rainbow Passage" for each actress and non-actress and their group means pre and post-testing are presented in Table V. The mean difference between groups as it interacted with the fatiguing task was 5.41. This difference was not statistically significant ($F=.22$; $df=1,18$, $p=.647$).

<u>Intrarater Reliability Results</u>

Pearson correlation coefficients were calculated from the initial and later ratings of the researcher on frequency range data. Agreement between ratings was as follows: 1) 99% agreement for

TABLE IV

FREQUENCY RANGE OF ACTRESSES AND NON-ACTRESSES IN SUNG SCALES IN HERTZ

		Actresses		
Sung Scale Range	Mean	SD	Minimum	Maximum
Pre-Task	1079.1	164.69	781.0	1289.0
Post-Task	1137.3	192.17	800.0	1415.0
Difference	58.2	104.73	-172.0	196.0

		Non-Actresses		
Sung Scale Range	Mean	SD	Minimum	Maximum
Pre-Task	1013.8	309.7	708.0	1601.0
Post-Task	1022.5	281.93	508.0	1445.0
Difference	8.7	174.87	-273.0	313.0

TABLE V

FREQUENCY RANGE OF ACTRESSES AND NON-ACTRESSES IN CONNECTED SPEECH IN HERTZ

		Actresses		
Connected Speech Range	Mean	SD	Minimum	Maximum
Pre-Task	160.57	22.43	129.7	195.1
Post-Task	168.68	26.26	123.7	204.7
Difference	8.11	15.52	-24.0	25.2

		Non-Actresses		
Connected Speech Range	Mean	SD	Minimum	Maximum
Pre-Task	139.24	39.64	72.0	189.7
Post-Task	141.94	25.53	103.9	181.7
Difference	2.70	33.25	-53.0	47.8

frequency range in connected speech in both pre and post-test samples; 2) 99% agreement in pretest singing range; 3) 49% agreement in post-test singing range. The low rate of agreement in the last of the parameters was partially due to the small sample size. Since the ratings were counted as either entirely correct or wrong, and the samples were from four subjects, the agreement tended to be either very high or very low. The subjectivity of this type of evaluation is also increased by the fact that the algorithms for calculating frequency, particularly in female voices, are not highly dependable (Kheirallah, personal communication, 1995; Kent & Read, 1993).

Interrater Reliability Results

Pearson correlation coefficients were calculated from the initial ratings of the researcher and ratings by a second trained rater on frequency range data. Interrater reliability agreement between ratings was as follows: 1) 94% agreement in connected speech in pretest samples; 2) 69% agreement in connected speech in post-test samples; 3) 96% agreement in singing scales in pretest samples; and 4) 100% agreement in singing scales in post-test samples. The low rate of reliability in connected speech in post-test samples was partially a result of the small sample size and the strict judgement of accuracy as discussed above regarding intrarater reliability. Again, the somewhat limited capability of current technology to evaluate frequency parameters may play a part in the discrepancy. It may also be the result of the fact that the frequency data was more scattered in post-test samples (possibly demonstrating increased jitter), therefore judgements were more subjective.

Conclusions

The null hypothesis stated that: There will not be a significant affect on non-actresses' speaking voices, relative to the speaking voices of actresses, on measures of fundamental frequency in steady state vowels and connected speech, nor on measures of frequency range in sung scales and connected speech after a fatiguing task. The results of ANOVA tests for between-subjects effects are presented in table VI. None of the F values were found to be significant at the $p < .05$ level for interactions between group and time (pre/post fatiguing). Therefore, it was not possible to reject the null hypothesis.

TABLE VI

SUMMARY OF ANOVA RESULTS TO TEST FOR DIFFERENCES BETWEEN ACTRESSES AND NON-ACTRESSES IN PRE-TASK AND POST-TASK MEASURES OF FUNDAMENTAL FREQUENCY AND FREQUENCY RANGE

Variable	df	MS	F	p
Vowel Fo				
Groups	1	178.93	.74	.402
Error	18	242.35		
Connected Speech Fo				
Groups	1	13.92	.09	.768
Error	18	155.62		
Singing Range				
Groups	1	6125.63	.59	.452
Error	18	10,386.83		
Connected Speech Range				
Groups	1	73.17	.22	.647
Error	18	336.60		

DISCUSSION

Comparison between pretest and post-test measures revealed no statistically significant differences between groups in fundamental frequency nor in range in the current study. However, it should be noted that the small sample size reduces the power of the statistics. The inability of the study to reject the null hypothesis may simply mean that in this specific, small sample, the differences were insignificant.

The data were also examined from a clinical standpoint, and were again found to be insignificant. A change of three or fewer semitones (ST) in Fo and SFF has been found to be a normal deviation (Coleman & Markham, 1991). Upon converting the hertz values used in the current study to semitones, no variation within or between groups in Fo or SFF was greater than 2.1 ST. A change of 2 or fewer ST in frequency range has been found to be a normal deviation (Gelfer, 1989). When converting hertz values in the current study to semitones, no variation within or between groups in frequency range was found to be greater than .41 ST.

The actresses used in the study had a mean of 6.8 years of acting experience and 3.1 quarters of voice training. The statistical and clinical results of this study suggest that despite the differences in vocal use, experience, and training, actresses are not necessarily any more (or less) vocally durable or consistent than less vocally experienced women.

The data in this study contradict some previous findings and support others. Although no research was found measuring the interaction effect of group over time using actresses for frequency parameters, two studies examined had similar objectives. Gelfer, Andrews, and Schmidt (1991) found significant changes, namely an increase in Fo and increased inconsistency of Fo in prolonged vowel productions after fatiguing tasks in untrained singers, but not in trained singers. In the current study no significant change was seen for either group in Fo after a similar fatigue task.

In another study (Scherer, Titze, Raphael, Wood, Ramig, & Blager,1986), the researchers failed, as the current study did, to find significant differences on acoustic measures, albeit different parameters (jitter, shimmer, and signal to noise ratio), between an actress and a non-actress. They used a fatiguing condition similar to the one used in the present study.

Because so little information exists in this area, it is not possible to draw further comparisons with the insignificant results of the interaction between the two groups and fatigue in the current study. Beyond interaction effects, the main effects of group and of time were examined and will be discussed in the research implications section.

CHAPTER V

SUMMARY AND IMPLICATIONS

SUMMARY

Research has suggested that differences exist between the voice qualities of those who professionally use and train their voices and those who do not. Performers, including both singers and actors have been found to have significantly different fundamental frequencies and frequency ranges (Weiden & Ogren, 1982; Awan, 1991; and Awan, 1993). These differences, whether the result of frequent use or training of the voice have also been said to exit relative to fatiguing conditions. Fatigue has been shown to produce greater effects in normals than in performers, singers in particular (Gelfer, Andrews, and Schmidt, 1991). No research has been found comparing actors to non-actors in such an interaction effect.

The purpose of the present study was to determine whether or not significant changes in Fo and frequency range occurred in non-actresses relative to actresses. The subjects for the study included ten actresses between the ages of 20 and 30 who had a minimum of one quarter of voice training and three years of acting experience and ten other women of the same age group who had no voice training or experience in acting.

These two groups were evaluated for: 1) fundamental frequency in prolonged productions of the vowel lal; 1) speaking fundamental frequency in connected speech using a standardized reading passage; 3) frequency range in sung scales; and 4) frequency range in connected speech using a standardized reading passage. This evaluation took place twice, once before and once after a fatiguing task consisting of an hour long reading task at a consistently loud level.

All pre and post-test samples were recorded on digital audio tape and then evaluated with computerized voice analysis systems. The CASPER program was used to analyze Fo and SFF. The CSRE program was used to analyze frequency range.

Data was statistically analyzed using one way ANOVA tests with repeated measures. No significant interactions occurred between group and time, suggesting that non-actresses did not produce a greater shift than did actresses in fundamental frequency or frequency range as a result of fatigue. Neither were any main effects of group found to be significant. Therefore, the two subject samples cannot be said to have demonstrated a difference in any frequency variable in either pre or post-testing conditions.

The data did show main effects of time in fundamental frequency in connected speech (SFF) and in the maximal high and low ends of frequency range in connected speech. For these three variables it can be said that both groups varied significantly from pre to post-testing. For both groups the shift demonstrated an increase in pitch since the fundamental frequency and both the high and low ends of the range increased from the pre to post-test conditions.

IMPLICATIONS

Research

The data in the current study do not suggest a difference in vocal durability or vocal consistence between actresses and non-actresses. The non-actresses did not differ significantly from actresses in measures of fundamental frequency or frequency range as a result of being vocally fatigued. Previous research showing differences between trained and untrained voices has been primarily conducted with professional singers (Gelfer, Andrews, & Schmidt, 1991; Awan, 1991, Awan, 1993). Most studies which have examined actors versus normals have either not examined frequency (Scherer, Titze, Raphael, Ramig, & Blager,1986) or have not used fatiguing conditions to examine change (Wedin & Ogren, 1982). One study which did look at both subject populations and fatigue used subjects who had been diagnosed as vocally disordered. The current study addressed questions which had not been previously addressed. The fact that no significant results were obtained suggests several possibilities for future research.

In order to produce more reliable and statistically powerful results, it would be necessary to study a larger sample. A sample size of 40 subjects per group would yield more robust results. Ideally, this would include actors/actresses who have all completed very similar training and are currently performing and non-actresses who match them in age. This is however an unrealistic expectation for an area such as Portland unless the sample were to be collected over a large period of time. A city with a larger number of continuously active repertory theatres, such as Chicago, Los Angeles, or New York might be a better choice. Cigarette smoking is a difficult variable to avoid in the actress population. The effects of smoking open up another entire realm of study within this population. Another primary change in subject population would be the inclusion of, or a separate study on men.

Studying actors (males) and non-actors in a separate study or as a variable in the same study with actresses would be valuable in producing a more complete picture of differences related to fatigue. According to Kent and Read (1993) the results of frequency studies on females, especially in singing scales, are less reliable, probably because there is more distortion of the signal in the higher ranges. Fundamental frequency and frequency range are difficult to study and do not present a complete picture of vocal change over time.

In addition to studying Fo and frequency range, it would be interesting to examine jitter, shimmer, and signal to noise ratio within the same piece of research. None of the studies found on actors versus normals have done this. While this vastly increases the number of research questions and statistical computations, the gathering of data would remain the same, since those measures can be taken from the same tasks used in this study. Also programs such as CASPER and CSRE can evaluate those parameters while computing frequency. Other parameters to be studied might include differences in subjects' perceptions of their voices over time and actual tissue change.

In a study by Scherer et al, (1986), the subjects were evaluated for perceptual differences and tissue changes, as well as on acoustic measures. The authors found that the non-actress fatigued more rapidly and on a scale of 1 to 100, with 100 being the "best the voice ever felt," picked a number toward the lower end of the continuum. She also verbally indicated more symptoms of vocal fatigue than did the actress. Interestingly, the actress described her voice as feeling "warmed-up" at the same point in time at which the non-actress discontinued the fatiguing task out of discomfort. The current study, while not measuring these parameters statistically, did attempt to gain similar information from the subjects. On a scale of 1 to 9, with 9 being the "best the voice ever felt", the non-actresses had a mean of 4.2, while the actresses had a mean of 6.2. Also the non-actresses reported more symptoms of fatigue including hoarseness and the feeling of the voice being tired, while the actresses mostly reported only dryness. Four of the ten actresses also stated that their voices felt "warmed-up," an interesting parallel to the Scherer, et al study. These types of perceptions would have to be ranked in order to be studied for significance.

In studying the lack of significance achieved in the current study, questions arise about the validity of the tasks. First, it is possible that the task of a one hour prolonged reading was not sufficient to produce acoustic changes. In examining the main effects of time, some changes were found to be significant in both groups. In three parameters the F value was found to be significant at the $p < .05$ level over time, within subject groups. The fundamental frequency value in connected speech was shown to change significantly in both groups after the fatiguing task ($F=18.44$; $df=1,18$, $p<.0001$). The high end of the range used in connected speech was shown to increase significantly after the reading task in both subject groups ($F=15.62$; $df=1, 18$; $p=.001$). Finally, the low end of the frequency range used in connected speech was shown to increase significantly after the fatiguing task in both groups ($F=14.47$; $df=1,18$; $p=.001$). In relationship to previous research (Gelfer, et al, 1991) the data agree with findings showing an overall increase in frequency as the result of fatigue. Yet, despite this no evidence was found that could separate the groups in the effects of fatigue. It may be that the task was not long enough, but there are other possibilities for task insufficiency.

Scherer (personal communication, 1994) suggested that a greater level of fatigue would occur if the subjects were required to produce the loud vocal task in a very narrow frequency range. In specific he stated that a high pitched, monotonous voice would create the greatest fatigue. No attempt was made to control pitch in the current study. It might be very helpful to control pitch, not only to increase the fatigue, but to keep the subjects at a more consistent intensity level. One of the most difficult parts of the current study, particularly in working with the non-actresses, was keeping subjects at their preset loudness. The intensity level would be easier to cue for and to achieve, if the subjects were required to speak in a monotone voice because there would be less fluctuation. Apart from possible task inadequacy, there remains the question of reliability of frequency evaluation tools.

Achieving consistent and accurate results in the measurement of fundamental frequency and frequency range is difficult, even with the current advances in technology. The correlation coefficients for reliability in the current study were high for most parameters, but varied from as low as 49.2% to 100%. Filtering out high frequencies was done in the evaluation process to "make fundamental periods easier to identify" (Kent & Read, 1992). The use of different programs for evaluation of fundamental frequency and frequency range was necessary, but could be said to introduce error. Two different forms of analysis, pitch and spectral, were needed to examine frequency range because of the difference in samples (connected speech and sung scales). While the pitch analysis would seem to be the obvious choice when examining frequency, the spectral analysis was chosen as being more reliable for the sung scales based on information from developer of the CSRE itself, Sam Kheirallah of AVAAZ Innovations, Inc. (personal communication, 1995) and the suggestions of Kent and Read (1993). Both sources found pitch analysis from sung samples to be difficult to evaluate, especially in female subjects. Kheirallah stated that "pitch algorithms work best for adult male voices" and that female singing voices were particularly difficult to evaluate through pitch analysis. Kent and Read suggested spectral analysis. It is unfortunate that the methods of calculating frequency parameters remain somewhat unreliable. With further research and development, it is to be hoped that studies of the nature of the current one will be more reliable in their results.

Clinical

The knowledge gained from the current study has some practical usefulness. Given that the results of the ANOVA tests for interaction between group and time (pre and post-testing) were not significant, the contention that non-actresses would produce more significant changes in fundamental frequency and frequency range than actresses cannot be said to have been demonstrated. Therefore, it remains uncertain as to whether it is valuable to attempt to seek out separate normative information on frequency parameters for actors to be used in the evaluation of those professionals who seek help for vocal disorders.

Fatigue, such as may be experienced by actresses within their professional roles may be difficult to test clinically. It is apparent, based on the current study and previous research (Scherer, et al., 1986; Gelfer, et al., 1991) that fundamental frequency and frequency range are, in and of themselves, insufficient indicators of change and that measures of jitter, shimmer, and signal to noise ratio as well as laryngoscopic evaluation for tissue changes are necessary to accurately evaluate and diagnose voice disorders.

Finally, if changes in fundamental frequency and frequency range over time are to be used in clinical examinations, it is important to determine what constitutes a negative shift.

Fundamental frequency has been shown to increase with fatigue both in this study and in that of Gelfer, et al. (1991). In the latter study this increase was significant only in vocally untrained persons, not in singers, while in the current study it was significant in connected speech, in both groups. Contrary to this information, vocally disordered professionals have been seen to demonstrate lower Fo than normals (Koufman & Blalock, 1988). Also in studies on the effects of training, an increase in Fo in normals and actors has been seen as a positive change. Clearly there is some discrepancy in the literature about what is meant by a negative shift in Fo. Studies have indicated that a normal shift in Fo and SFF could be as large as three semitones (Coleman & Markham, 1991). It seems likely, given current discrepancies that the size of the shift may be more important than the direction. However, the meaningfulness of the direction of shift requires further study as it would be clinically useful in making diagnoses to know what type of a shift is to be considered vocally dangerous. It is also necessary to examine the shifts occurring in range due to fatigue.

A decrease in range has been demonstrated to indicate worsening vocal quality both in actors and normals (Koufman & Blalock, 1988), with a more significant decrease in normals. A normal shift in frequency range could be as large as two semitones when subjects are measured within the same day (Gelfer, 1989). In the current study both sets of subjects shifted their ranges to higher frequencies after the fatigue task, but neither had a significant decrease in range. This refutes the results of the Koufman and

Blalock study, but whereas the subjects in the other study had been previously diagnosed with varying vocal disorders, the subjects in the current study may not have been truly fatigued and were presumably not disordered. More research on frequency parameters in vocally disordered patients would be useful in making clinical decisions about these types of patients.

In order to aid clinicians who see vocally disordered actors, further normative values may need to be sought. Although the results of the current study do not show significant differences between actresses and other women in frequency parameters as a result of fatigue, other variables need to be explored. More stringent task forms and vocal analysis tools need to be developed to examine frequency and a larger array of parameters including: jitter, shimmer, signal to noise ratio, and tissue changes, need to be studied in this population.

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APPENDIX A

HUMAN SUBJECTS RESEARCH FORM

OFFICE OF GRADUATE STUDIES AND RESEARCH
Research and Sponsored Projects

DATE: November 17, 1994

TO: Ruth Jenkins Social Security #: 295-64-1422

FROM: Laurie Skokan, Chair, HSRRC 1994-1995

RE: HSRRC Approval of Your Application titled "The Effects of Vocal Fatigue on Fundamental Frequency and Frequency Range in Vocally Trained Actresses"

In accordance with your request, the Human Subjects Research Review Committee has reviewed your proposal referenced above for compliance with DHHS policies and regulations covering the protection of human subjects. The committee is satisfied that your provisions for protecting the rights and welfare of all subjects participating in the research are adequate, and your project is approved.

Any changes in the proposed study, or any unanticipated problems involving risk to subjects, should be reported to the Human Subjects Research Review Committee. An annual report of the status of the project is required.

c. Maureen Orr Eldred
Project Advisor

approval.mem

APPENDIX B

NOTICES FOR SUBJECT GATHERING - ACTRESSES

NOTICES FOR SUBJECT GATHERING - ACTRESSES

Actresses, between the ages of 20 and 30 needed for voice research. You are eligible for this study if you: 1) have completed at least one quarter of voice training; 2) have at least three years of acting experience; 3) have had no serious voice or respiratory problems; and 4) have not smoked in the last calendar year. Two hours of your time are all that is needed. Please call Ruth Jenkins at 236-8888 if you are interested. Thank you so much for your interest.

APPENDIX C

NOTICES FOR SUBJECT GATHERING - NON-ACTRESSES

NOTICES FOR SUBJECT GATHERING - NON-ACTRESSES

Female students, between the ages of 20 and 30 needed for voice research. You are eligible for this study if you: 1) are not an actor, singer, or otherwise involved in large amounts of public speaking; 2) have never had speaking or singing voice training of any kind; 3) have had no serious voice or respiratory problems; and 4) have not smoked in the last calendar year. Two hours of your time are all that is needed. Please call Ruth Jenkins at 236-8888 if you are interested. Thank you so much for your interest.

APPENDIX D

INFORMED CONSENT FORM

INFORMED CONSENT FORM

I, ______________________________________, agree to take part in this research project on voice parameters in vocally trained actors versus vocally untrained persons.

I understand that this study is being conducted by Ruth Jenkins for her Master's Thesis in the Speech Communication Department and that John A. Tetnowski, Ph.D. is the advisor for this project.

I understand that the study requires that I perform the following tasks: producing vowels, singing a scale, reading passages softly and loudly, and reading for one hour with a fairly loud voice. The exact procedures will be described to me during testing.

I understand that, because of this study, I will have to give approximately two hours of my time and may experience some dryness and/or soreness of the throat for a brief time after the testing. I understand that the risk for long term affects is very low, research using the same methods in the past created no long term affects in subjects.

Ruth Jenkins has told me that the purpose of the study is to examine the fundamental frequency and frequency range, which are commonly known as pitch and pitch range.

I understand that I will receive ten dollars when I have completed my portion of the study. The study may help to increase knowledge that may help others in the future.

Ruth Jenkins has offered to answer any questions I have about the study and what I am expected to do.

She has promised that all information I give will be kept confidential to the extent permitted by law, and that the names of all people in the study will remain anonymous.

I understand that I do not have to take part in this study, and that this will not affect my course grade or my relationship with Portland State University.

I have read and understand the above information and agree to take part in this study.

Date: ________________ Signature: ___________________________

If you have concerns or questions about this study, please contact the Chair of the Human Subjects Research Review Committee, Office of Research and Sponsored Projects, 105 Neuberger Hall, Portland State University, 503/725-3417.

APPENDIX E

VOICE RESEARCH SCREENING FORM

VOICE RESEARCH SCREENING FORM

(Conducted in person, by the researcher)

All of the following information will be kept in the strictest confidence. Please answer the following questions.

1. What is your age?
2. What year of school are you currently in?
3. a. For actress subjects:

   Are you currently enrolled in voice training or have you completed two quarters of voice training? Y/N

   Have you had at least three years of acting experience? Y/N

   b. For vocally untrained normal subjects:

   Have you ever had any speaking or singing voice training? Y/N
4. Are you now, or have you ever been diagnosed with a voice disorder such as vocal nodules, polyps, or cysts? Y/N
5. Do you have any chronic voice problems such as sore throats, persistent dryness, or laryngitis? Y/N
6. Do you have any chronic respiratory tract difficulties such as asthma or severe allergies? Y/N
7. Have you smoked cigarettes or used any other inhalants in the last year? Y/N
8. Are you currently less than 5 days premenstrual? Y/N

APPENDIX F

PROTOCOL FOR VOICE RESEARCH

PROTOCOL FOR VOICE RESEARCH

Subject's Name:____________________________ DOB: __________

Subject # _____ Age: ___________

Date: ____________

I. Introduction

____ Review of Project

____ Complete Questionnaire

____ Complete Hearing Screening

____ Complete Informed Consent Form

II. Pretesting

Record 1000 hz reference tone

Make sure microphone 5 inches from mouth.

I will now ask you to do the tasks we have discussed. I will point at you before each task to cue you to begin and hold my hand up to stop you (demo.)

Recorder on:

Subject reads sign 1 - "Subject Number __"

Subject reads sign 2 - Pretask Vowel

Recorder off

____ Produce the vowel |a| at your normal, comfortable speaking pitch and hold on to it as long as you can, like this, we'll repeat 3 x. (demo). **Turn on recorder. GO**

Repeat x 3. Recorder off

Recorder on

Subject reads sign 3 - Pretask Paragraph

Recorder Off

____ Now read this passage at your normal, comfortable speaking pitch, do not try to dramatize it, but do not read it in a monotone voice. Read as you normally would.

Turn on recorder. GO. Recorder off.

Recorder on

Subject reads sign 4 - Pretask Range High

Recorder Off

____ Now I will ask you to demonstrate your entire range of pitch. First you will need to slide up the scale from a note near the middle of your range to the highest note you can make. Really go for the top of your range by squeaking up into falsetto like this (demo). We'll repeat 3x.

Turn on recorder. GO Repeat x 3

Recorder off

Recorder on

Subject reads sign 5 - Pretask Range Low

___ Now you will need to slide down the scale from a note near the middle of your range to the lowest note you can make not including glottal fry which sounds like this (demo). So it should be like this (demo). We'll repeat 3 x.

Turn on recorder. Repeat x 3 Turn recorder off.

____ Now I will ask you to read this paragraph again. First read as softly as you can without whispering like this (demo). Repeat only if they might have been softer.

_______dB Imin

____ Now read as loudly as you can without shouting, like this (demo). Repeat only if they could have been louder.

_______dB. Imax

____ Calculate 80% of intensity range:

______ + { (______ - _______) x .8] = ________

i min. i max i min.

III. Reading

You will now need to read for one hour. I will watch this sound level meter which I will keep here, 12 inches from your mouth. When your reading level becomes too soft or too loud I will cue you saying "louder" or "softer" depending on how I need you to change it. I will give you an ok sign when you are back on target. It is important that you stay within 5 decibels of this number. Please continue to read through the entire hour unless you truly feel you cannot continue. At the 30 minute point I will give you a one minute break from reading, during which you must not talk or make any other noise. If you need to communicate something to me write it down. When the hour is up I will stop you, at that time do not speak or make any other noise. Do you have any questions? I will cue you to begin by pointing at you.

Set sound level meter. Cue subject. Start Stopwatch.

At 30 minutes give a break of one minute. Remind not to talk. Pause Stopwatch

Please begin to read again when I point at you.

Cue Subject, restart stopwatch

At one hour Stop.

IV. Post-Task Testing

Make sure microphone 5 inches from mouth.

Now I will ask you to repeat the tasks you did before you read. I will point at you before each task to cue you to begin

Recorder on:

Subject reads sign 1 - "Subject Number __"

Subject reads sign 6 - Post-task Vowel

Recorder off

____ Produce the vowel |a| at your normal, comfortable speaking pitch and hold on to it as long as you can, like this, we'll repeat 3 x. (demo). **Turn on recorder. GO**

Repeat x 3. Recorder off

Recorder on

Subject reads sign 7 - Post-task Paragraph

Recorder Off

____ Now read this passage at your normal, comfortable speaking pitch, do not try to dramatize it, but do not read it in a monotone voice. Read as you normally would.

Turn on recorder. GO. Recorder off.

Recorder on

Subject reads sign 8 - Post-task Range High

Recorder Off

____ Now I will ask you to demonstrate your entire range of pitch. First you will need to slide up the scale from a note near the middle of your range to the highest note you can make. Really go for the top of your range by squeaking up into falsetto like this (demo). We'll repeat 3x.

Turn on recorder. GO Repeat x 3

Recorder off

Recorder on

Subject reads sign 9 - Post-task Range Low

Recorder off

___ Now you will need to slide down the scale from a note near the middle of your range to the lowest note you can make not including glottal fry which sounds like this (demo). So it should be like this (demo). We'll repeat 3 x.

Turn on recorder. Repeat x 3 Turn recorder off.

V. Finish

On a scale of 1 to 9, 1 being worst your voice/throat has ever felt and 9 being the best it has ever felt how would you rate it now?

What words would you use to describe how your voice feels now?

Thanks. Suggest water and vocal rest

Payment check # __________

Record 1000 hz reference tone

turn off sound level meter

APPENDIX G

THE RAINBOW PASSAGE

THE RAINBOW PASSAGE
(the first paragraph)

When the sunlight strikes raindrops in the air, they act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arch, with its path high above, and its ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friends say he is looking for a pot of gold at the end of the rainbow.