To the Graduate Council:

I am submitting herewith a thesis written by Tanya Ola Thomason entitled "Perception of Register Break." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Arts, with a major in Speech Pathology.

Mary Louise Erickson, Major Professor

We have read this thesis and
recommend its acceptance:

Accepted for the Council:

Interim Vice Provost and
Dean of The Graduate School

Perception of Register Break

A Thesis

Presented for the

Master of Arts Degree

The University of Tennessee, Knoxville

Tanya Ola Thomason

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ABSTRACT

This study investigated the perception of the upper register break in classically trained mezzo-soprano and soprano singers. Many researchers have investigated the lower register break, but little is known regarding the perception of the upper register break. In this study three questions were investigated: (1) can the upper register break be perceived? (2) is it perceived in the same location by singer, their voice teacher, and listeners? and (3) are mezzo-sopranos perceived to have a register break at lower pitch intervals than sopranos?

Three mezzo-sopranos and three sopranos were recorded singing the vowel /ɑ/ on eight pitches, C5-G5. These sung vowels were used as stimuli in three perceptual tasks. In the first task, listeners were presented with 126 stimuli consisting of two half-step pairs. Listeners were asked to choose the most dissimilar pair. In the second task, listeners were presented with 42 half-step pairs and 36 whole-step pairs. Listeners indicated whether there was a register break within the pair by marking "yes" or "no". In the third and final task, the listeners heard six chromatic scales (C5-G5), one for each singer, and indicated where they heard the register break.

Overall, the listeners perceived a difference in quality in the same locations that they perceived a register break. Singers and listeners were in the greatest agreement for location of register break. Singers and voice teachers, on the other hand, were not in agreement. Mezzo-sopranos were perceived to have an upper register break at lower pitch intervals than were sopranos.

TABLE OF CONTENTS

CHAPTER PAGE

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

OVERVIEW OF STUDY

REVIEW OF THE LITERATURE

Registers

Definitions

Manuel Garcia, inventor of the laryngoscope, wrote the most quoted definition of a register. His definition focused on defining registers as a total laryngeal event. His definition is:

> By the word register we mean a series of succeeding sounds of equal quality on a scale from low to high produced by the application of the same mechanical principle, the nature of which differs basically from another series of succeeding sounds of equal quality produced by another mechanical principle (as cited in Large, 1972, p. 18).

Harry Hollien (1974) also subscribes to the opinion that it is a total laryngeal event. His definition is:

> A register is a total laryngeal event; it consists of a series or range of consecutive voice frequencies which can be produced with nearly identical phonatory quality; that there will be little overlap in fundamental frequency between adjacent registers, and that the operational definition of a register must depend on supporting perceptual, acoustic, physiologic and aerodynamic evidence (p. 125).

These definitions are still accepted in the fields of speech science, vocal performance, and speech-language pathology. Vennard (1967) refers to registration as an

adjustment of the larynx resulting in tones of a particular quality. Titze (1994) considers registers to consist of perceptually distinctive regions of vocal quality.

Number of Registers and Terminology

Today, vocal pedagogues and voice scientists differ concerning the number of registers produced by the human voice. The number of vocal registers differs for men and women, but generally, vocal experts have postulated as few as one register to as many as seven (Large, 1972). As Vennard (1967) mentions, the ideal singing voice seems like one register, with little perceptual difference noted across the range of the voice. Vocal pedagogues admit that much training is needed to achieve such a voice. Given this, most vocal professionals adopt the concept of two or three registers, or voices.

The concept of two or three registers began as early as the 13th century. According to Large (1972), both John of Garland (c.1193-c.1270) and Jerome of Moravia (c.1250) wrote about three vocal registers: chest, throat voice, and head. These early voice scientists noticed perceptual quality differences for these three registers and focused their vocal training to smoothly blend these three registers.

Harry Hollien (1974) describes the main singing and speaking register with one label, modal, because it includes the range of fundamental frequencies that are normally used in speaking and singing. His label of modal is often subdivided into two or three separate registers. Vennard (1967) divides the main singing range into two different registers, or voices, that apply mainly to the singing voice: light mechanism and heavy mechanism.

While most voice scientists of today agree that the voice consists of three registers, there is less of agreement in terms of nomenclature. As Large (1972) points out, European voice scientists and pedagogues typically use a nomenclature based on singer's perceptual feedback: chest, middle, and head. On the other hand, there is controversy among American singing voice scientists and American speech voice scientists. The singing scientists refer to the three main registers as chest, middle or medium, and head; and the speech scientists refer to the registers as vocal fry, modal or normal, and falsetto or upper. Many voice teachers and singers refer to the main registers as normal or chest, head and falsetto in the male voice, and chest, middle or mixed and head in the female voice (Vennard, 1967).

Register Boundaries/Breaks

Because a register is generally defined as a series of pitches with a similar quality, a shift from one register to another register should be perceivable. Titze (1994) states that if a voice is noticeably registered, a stair-step change in quality can be observed. This change in registration is sometimes accompanied by an audible "break" or "crack". Register changes may occur voluntarily or involuntarily, and may be more easily perceived in some voices than in other voices.

Involuntary register changes have been found to occur at specific ranges of fundamental frequency. Titze (1994) states that an involuntary transition, or register break, occurs in both sexes between D4 (294 Hz) and F4 (349 Hz). This register break is called the *primo passaggio* for females and the *secondo passaggio* for males. In females,

a second involuntary register break has been observed between D5 (587 Hz) and F5 (698 Hz) (Miller, 1986).

Researchers have posited two competing physiologic hypotheses in an attempt to explain the invariance of involuntary register breaks. The first hypothesis, originally proposed by Van den Berg (1960) and investigated by Titze (1983, 1988) and Austin (1992), suggests that subglottal resonances may interfere with vocal fold vibration at specific frequencies. According to perturbation theory (Fant, 1970), a longer trachea would yield lower subglottal formant frequencies. Thus we would expect individuals with longer tracheae to have subglottal formants at lower frequencies than individuals with shorter tracheae. The second hypothesis, proposed by Titze (1994), explains the upper passaggio in men and women in terms of maximum thyroarytenoid muscle stress. According to this hypothesis, the upper register break occurs because the thyroarytenoid muscle, which contracts in opposition to the cricothyroid muscle, reaches a point of maximum stress beyond which it cannot sustain contraction. Upon disengaging this muscle, a noticeable change in registration occurs.

Regardless of physiological cause, voice scientists and, more importantly, vocal pedagogues believe that register breaks occur at frequencies that in part correlate to voice category (i.e., bass, tenor, alto, mezzo soprano, soprano). As described by Large (1972), Preissler (1939) performed a study of register limits within the singing voice. The following conclusions were drawn: (1) when voice classification becomes lighter, register transition points are higher, and (2) male transitions are an octave lower than the

female transitions. This trend can also be noted in the data reported by Tarneaud (1961) and Miller (1986).

Registers/ Timbre

Given that most authorities believe a register is a series of pitches with similar quality, a true understanding of register breaks requires a full understanding of what constitutes quality. Unfortunately, scientists have not developed an adequate definition of quality. The closest perceptual term to quality that has that has been defined by scientists is timbre.

Musical sound possesses three distinct properties: frequency, amplitude, and timbre or quality (Doscher, 1988). Timbre is the most difficult to define, because it is defined by what it is not. Two tones are judged to be of different timbre if they are dissimilar and yet have the same loudness and pitch (American National Standards Institute, 1973). Timbre is what allows the distinction between an oboe and a flute when they are playing the same note at the same loudness level. To define timbre in the human voice, an extra component to the definition is needed. In addition to identical frequency and amplitude, the same vowel must be produced. Therefore, a singer would have a different timbre for each pitch-vowel-loudness combination.

The technical definition of timbre implies that a singer's voice is characterized, not by one timbre, but by a set of related timbres, which are determined by physical properties of that singer's vocal mechanism. This is in contrast to typical notion of timbre voiced by musicians and singers. As Cleveland (1977) states, each singer has a unique timbre resulting from laryngeal source and vocal tract resonances. As a result,

singers with similar timbre share the same voice category or classification. Other authorities such as Titze (1994) believe that a register is a series of pitches with similar quality, or timbre.

Early research has provided evidence against the one voice/instrument, one timbre hypothesis. Helmholtz (1877/1954tr) made a significant discovery when he concluded that with sine tones, the simplest type of sound wave, timbre perception changes as a function of pitch. More recently, research by Erickson and colleagues (Erickson, 1999, June; Handel and Erickson, in revision; Erickson, Perry & Handel, in revision) suggests that a uniform timbre is not perceived across pitch in instruments or in singers. Erickson, Perry and Handel postulate that individual voices are not characterized by a single invariant timbre, but by a systematic and predictable timbre transformation that is invariant for each singer.

Perception of Register Break

The most comprehensive study regarding the perception of register break to date was conducted by Keidar, Hurtig, and Titze (1987). This study focused on the transition between chest and falsetto registers, which is the *primo passaggio* for females and the *secondo passaggio* for males. Two singers were used in this study, one female and one male. The voice classification of the two singers was not given. "Fifteen target tones, ranging from G#3 to A#4, were sung by [the singers] in the context of ascending and descending sequences on the vowels /ɑ/ and /i/ (Keidar et al., 1987, p. 223)." Ten trained listeners were presented the data in four perceptual tasks.

In the first task of Keidar et al.'s (1987) study, the listeners were asked to indicate the shift between chest and falsetto registers when presented with ascending and descending sequences, each consisting of 15 stimuli. In the second task, the listeners were presented with a single tone and were asked to indicate "yes" if the tone sounded like the chest register. The third task consisted of pairs of adjacent tones in ascending and descending order. Listeners indicated whether the pair of pitches belonged to the same register or different registers. In the fourth and final task, listeners were presented with all possible pairs of the 15 stimuli. The listeners assigned a number from one to ten to reflect the degree of similarity or dissimilarity in register, with one being the most similar.

Results from the first task, register shift-point identification, were nearly identical to the results from the third task, register discrimination. For both tasks, Keidar et al. (1987) concluded that the listeners perceived either a register shift and/or a different register for the pitch range of 349-392 Hz (F4-G4) for the female singer, and a pitch range of 294-349 Hz (D4-F4) for the male singer.

Results for the female singer, based on the second task (chest register identification), showed that listeners perceived pitches below 349 Hz (F4) to belong to the chest register and pitches above 392 Hz (G4) to belong to the falsetto register. For the male singer, the listeners perceived pitches below 294 Hz (D4) to belong to the chest register and pitches above 349 Hz (F4) to belong to the falsetto register.

Multidimensional scaling in two dimensions of the dissimilarity judgments for both singers revealed register to be the primary dimension. The second dimension

strongly correlated with pitch. Cluster analysis resulted in two primary clusters: one consisting of stimuli judged as chest in the other perceptual tasks, and another consisting as those judged as falsetto in other perceptual tasks.

In summary, Keidar et al. (1987) concluded that in the identification and discrimination tasks, tasks one through three, the chest and falsetto registers were perceived as distinct entities. The main register break for the male singer was perceived at 320 Hz (~D#4) and the main register break for the female singer was perceived at 353 Hz (~F#4). From the results of task four, the dissimilarity task, they concluded that the "representation of pitch differences was reflected only in the internal ordering of the stimuli within registers, but did not affect the perceptual discontinuity between registers (Keidar et al., 1987, p. 223)." Keidar et al. further concluded that quality was regarded in a binary fashion and pitch was regarded in a continuous fashion, but only within each register. However, in this task, the listeners were not asked to judge dissimilarity of quality, but rather dissimilarity of register. Thus, the results support the idea that perception of the lower register break may be binary, but not that perception of voice quality is binary.

Summary of the Literature Review

Registers are generally believed to be perceptually distinctive regions of voice quality. Most pedagogues agree that perceptual differences between registers can be minimized through vocal training, but the ideal of "one register" is unlikely to be achieved. Involuntary register breaks appear to occur at specific frequency ranges, but

within those ranges it is believed that these breaks occur at lower frequencies for heavier voices such as mezzo-sopranos and at higher pitches for lighter voices such as sopranos.

Research regarding the perception of register break by Keidar et al. (1987) has suggested that perception of the lower register break in females and the upper register break in males is a categorical judgment based largely on the perception of quality. However, their research did not address how quality is perceived within a register. Recent research by Erickson and colleagues (in revision) suggests that timbre perception varies with pitch, suggesting that while quality differences may be associated with perception of voice categories, it may not be true that within a given register, quality is perceived to be similar across all pitches.

PURPOSE

The purpose of this study was to determine whether trained singers could perceive the upper passaggio, register break, in classically trained mezzo-soprano and soprano singers. Additionally, this study sought to determine whether perceived register breaks correlated with vocal category. Following are the questions that were asked in this study:

1. Can vocally trained listeners perceive an upper register break in classically trained female voices?

   It is hypothesized that listeners can perceive a quality change associated with the upper register break. Consistent with the findings of Erickson (1999, June) and Erickson, Perry, and Handel (in revision), it is also hypothesized that singers exhibit individual patterns of timbre transformation as a function of pitch. In this study, it is hypothesized that register breaks are perceived when discontinuities in this timbre

transform occur. This is in contrast to the theories of Titze (1994) and Keidar et al. (1987) who suggest that registers are comprised of a series of pitches of similar quality.

2. Is the upper register break perceived in the same location by the singer, their teacher, and the listener?

    It is hypothesized that singers and teachers will tend to agree on the location of the upper register break. This hypothesis is based on the amount of emphasis placed on smoothing over the register break during voice study. It is hypothesized that listeners will perceive a quality change associated with a register break in close approximation to the singer/teacher identification.

3. Is the register break perceived in different locations for mezzo-sopranos and sopranos?

    It is hypothesized that upper register breaks will be perceived at a lower pitch interval in mezzo-sopranos than in sopranos. This hypothesis is based on the findings of Miller (1986).

CHAPTER TWO

METHODS

SUBJECTS

Description of Subjects

In this study, three groups of subjects were recruited. The first group consisted of six female, classically trained singers. These singers provided stimuli for the experiment. The second group consisted of voice teachers. These subjects were asked to identify the passaggio, or voice break, for any subject in the group of singers, who were currently studying voice with them. The third group consisted of experienced vocalists. These vocalists acted as experienced listeners in all perceptual experiments.

Singers

This group consisted of 6 female singers, three mezzo-sopranos and three sopranos. These subjects were recruited from the University of Tennessee Department of Music. Each singer met the following criteria:

1. Three years of classical voice study;
2. No voice disorder at the time of the experiment as judged perceptually by a certified speech-language pathologist;
3. Voice classification by teacher unchanged for at least two years;
4. Non-smoker for two years.

Voice Teachers

This group consisted of professional voice teachers. Specifically, this group was comprised of the teachers with whom each subject in the group of singers was currently studying. Because some subjects in the group of singers studied with the same teacher, the exact number of subjects in this group was four. The subjects in this group met the requirement of bilateral hearing within normal limits as determined by a 30 dB HL hearing screening at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz.

Experienced Listeners

This group consisted of fourteen persons trained in voice or vocal arts. These subjects were recruited from the Knoxville Opera Chorus, First Presbyterian Church of Knoxville, and Church Street United Methodist Church of Knoxville. Subjects in the group of experienced listeners met the following criteria:

1. Bilateral hearing within normal limits as determined by a 25 dB HL hearing screening at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz and 8000 Hz.
2. Bachelor's degree or higher in a vocal arts related discipline (e.g., pedagogy, performance, or choral conducting) or 5 years experience in a vocal arts discipline.

PROCEDURES

Singers

Tasks

Each singer participated individually in one session. Sessions took place in room 427-1 South Stadium Hall at the University of Tennessee. At the beginning of each

subject's recording, they were asked to state their subject number, voice classification, and number of years that they have studied voice. Each subject was audio recorded while singing 3 five-note scales on the vowel /ɑ/:

1. C5, D5, E5, F5 and G5
2. C#5, D#5, E#5, F#5 and G#5
3. D5, E5, F#5, G5 and A5

Each singer was also asked to sing a chromatic scale from C5 to A5. They were presented with one pitch of the chromatic scale at a time. They were then asked to immediately sing the pitch that was presented for approximately five seconds. An electric keyboard was used to present the pitches.

After recording, each singer was presented with the following chromatic scale on a piece of paper:

C5 C#5 D5 D#5 E5 F5 F#5 G5 G#5 A5.

The singer was asked to mark a slash at their passaggio (register break). A summary of tasks for each subject group is presented in Table 1.

Equipment

Each subject was recorded while standing in an Acoustic System RE-144 single-walled sound-treated booth with a mounted Sennheiser MD441-U microphone adjusted to singer's height and positioned 6 inches from the lips at a ninety-degree angle. Acoustic data were recorded on digital audiotapes (DAT) using a SONY PCMR500 DAT recorder.

Table 1

Summary of Identification and/or Perceptual Tasks Completed by Each Subject Group.

	Identification of Register Break on paper	Paired-pair task	Single-pair task	Chromatic scale task
Singers	X			
Voice Teachers	X			X
Experienced Listeners		X	X	X

Voice Teachers

Tasks

Each voice teacher was asked to complete the following task for only those subjects in the group of singers who were currently studying voice with them. They were given the following chromatic scale on a sheet of paper:

C5 C#5 D5 D#5 E F F#5 G G#5 A5.

They were asked to mark a slash where they felt their student's passaggio, or register break, was located. They also indicated the voice classification of their student. In addition, the voice teachers completed the chromatic scale task. In this task, subjects listened to six chromatic scales, one for each singer, (C5-A5) and indicated where they heard the passaggio (register break). A summary of tasks for each subject group is presented in Table 1.

Equipment

Voice teachers completed the listening task seated in an Acoustic System RE-144 single-walled sound treated booth. Stimuli were delivered over Sennheiser HD-545 headphones. Subjects indicated their responses using a video monitor and mouse.

Experienced Listeners

Tasks

The experienced listeners completed three perceptual tasks: a paired-pair task, a single-pair task, and the chromatic scale task. A summary of tasks for each subject group is presented in Table 1.

Paired-pair task. From each singer, the following 7 pairs, a semi-tone apart, were constructed:

C5&C#5, C#5&D5, D5&D#5, D#5&E5, E5&F5, F5&F#5, F#5&G5

This resulted in 21-paired pairs for each subject. For each singer, every pair of pitches was combined with every other pair. Since there were six singers, the total number of stimuli was 126 (21 x 6). Order of pairing was random. The experienced listeners were presented with the randomly ordered-paired pair stimuli and were asked to choose the pair that was the most dissimilar.

Single-pair task. The experienced listeners were also asked to listen to 42 half-step pairs (six singers times 7 half-step pairs from C5 to G5) and 36 whole step pairs (six singers times 6 whole step pairs from C5 to G5) and indicated if there was a register break between the two notes by marking yes or no.

Chromatic scale task. Finally, the subjects in the group of experienced listeners

listened to six chromatic scales, one for each singer, (C5-A5) and indicated where they heard the passaggio (register break).

Equipment

The experienced listeners completed the listening task seated in an Acoustic System RE-144 single-walled sound treated booth. Stimuli were delivered over Sennheiser HD-545 headphones. Subjects indicated their responses using a video monitor and mouse.

CHAPTER THREE

RESULTS

EXPLANATION OF THE DATA

The first two voice teachers and the first five experienced listeners completed their tasks with the data presented monaurally. A 60-cycle hum was also present. For the remaining subjects, this noise was filtered out and the data were presented binaurally. After close examination of the data, no systematic differences were noted between the first group of subjects with the errors and the second group without the errors. Therefore, the data were combined for analysis.

Paired-Pair Task

Paired-pair comparison data were analyzed by the method of paired comparisons as explained by Torgerson (1963). For each singer and each paired-pair, proportions were calculated based on the percentage of time each member of the pair was chosen as most dissimilar. A 7 X 7 matrix of proportions was constructed, from which a matrix of z-scores was derived. Scale values for each pair were calculated by obtaining mean z-scores for each column in the matrix. The final result was a set of 7 relative perceived distance scores for each singer, one for each pair: C-C#, C#-D, D-D#, D#-E, E-F, F#-G. Within each singer, all relative perceived distance scores were scaled so that the smallest perceived distance was equal to one.

Single-Pair Task

For each subject, the number of times a half-step or whole-step pair was judged as containing a register break was tallied and converted to percentage of times chosen. Data for the whole-step task was discarded due the experienced listeners' tendency to perceive a register break with nearly every pair. This was not the case with the half-step pairs, where the experienced listeners were more selective in choosing which pair they perceived as containing a register break.

Chromatic Scale Task

As in the single pair task, the number of times a half-step pair was chosen as containing a register break was tallied and converted to percentage of times chosen. Unlike the single pair task, each listener was only allowed to chose one location for the register break.

PERCEPTION OF REGISTER BREAK – QUESTION 1

The first question that was postulated in this study was "Can vocally trained listeners perceive an upper register break in classically trained female voices?" To answer this question three perceptual tasks, as described above, were analyzed.

Mezzo-Soprano 1

Responses to the three perceptual tasks for mezzo-soprano 1 are depicted graphically in Figure 1. This figure combines the results of the paired-pair, single-pair, and chromatic scale tasks. The left y-axis provides a scale for interpretation of the

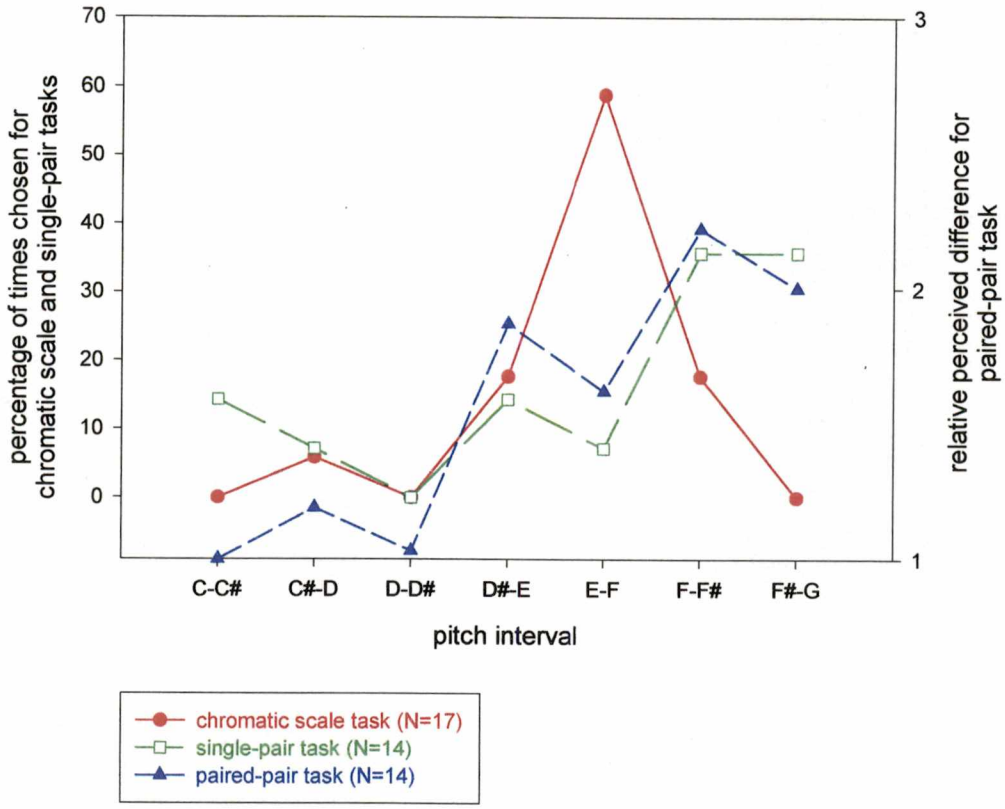

Figure 1: Mezzo-soprano 1— chromatic scale task, single-pair task, and paired-paired task.

chromatic scale and single-pair judgments. The right y-axis provides a scale for interpretation of the paired-pair judgments.

Paired-pair task

The graphic representation of relative perceived differences as a function of pitch for mezzo-soprano 1 resulted in an increasing stair-step pattern. The relative perceived differences between the intervals C5-C#5, C#5-D5, and D5-D#5 were small (< 1.2). A large increase in perceived dissimilarity was seen for the intervals D#5-E5 and E5-F5, each obtaining relative perceived difference scores between 1.5 and 2.0. A final increase in perceived dissimilarity was seen for the intervals E5-F5 and F#5-G5, which obtained relative perceived difference scores above 2.0. The interval which was perceived as being most dissimilar was F5-F#5 with a perceived difference score of 2.2.

Single-pair task

As with the paired-pair task, graphic representation of the percentage of time each pitch interval was selected as a register break for mezzo-soprano 1 resulted in a mostly increasing stair-step pattern. The lowest interval C5-C#5 was perceived as a register break by 14.29% of the experienced listeners. The intervals C#5-D5 and D#5-E5 were perceived as a register break less often than C5-C#5. For interval D#5-E5, the percentage of experienced listeners perceiving a register break increased to 14.29%. The intervals F5-F#5 and F#5-G5 were perceived most often as being a register break (35.71 % for each).

Chromatic scale task

In this forced-choice task, few listeners perceived a register break between the lowest three intervals C5-C#5, C#5-D5, and D5-D#5 (< 5%). The percentage of listeners perceiving a register break increased for the next two pitch intervals, obtaining the highest percentage for E5-F5 (58.82%). This was followed by a steady decrease in perception of register break over the next two pitch intervals, with no experienced listeners perceiving a register break for the interval F#5-G5.

Summary

For mezzo-soprano 1, the paired-pair task and the single-pair task resulted in a similar stair-step pattern for relative perceived difference and perceived register break. Abrupt increases in perception of relative perceived difference and/or register break were noted at D#5-E5 and F5-F#5, with the intervals F5-F#5 and F#5-G5 being perceived to have the largest relative perceived difference in the paired-pair task and also being chosen as a register break most often in the single-pair task. However, in the forced-choice chromatic scale task, listeners perceived the register break most often at E5-F5, one-half step below the interval perceived as most dissimilar in the paired-pair task and the interval most often chosen as a register break in the single-pair task.

Mezzo-Soprano 2

Responses to the three perceptual tasks for mezzo-soprano 2 are depicted graphically in Figure 2. This figure combines the results of the paired-pair, single-pair, and

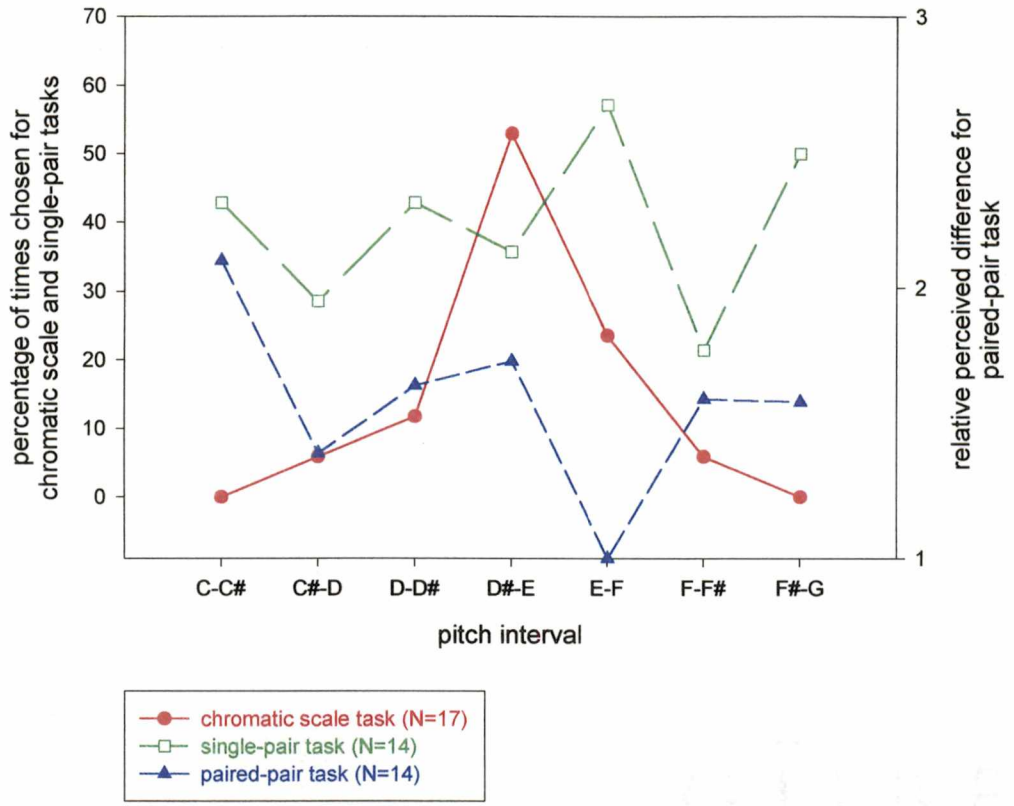

Figure 2: Mezzo-soprano 2— chromatic scale task, single-pair task, and paired-paired task.

chromatic scale tasks. The left y-axis provides a scale for interpretation of the chromatic scale and single-pair judgments. The right y-axis provides a scale for interpretation of the paired-pair judgments.

Paired-pair task

Relative perceived difference was the greatest for the interval C5-C#5 (2.1). This was followed by a decrease in relative perceived difference for the interval C#5-D5 (1.39). Relative perceived difference increased for the next two intervals, peaking at the interval D#5-E5 (1.73). A second decrease in relative perceived difference occurred for the pitch interval E5-F5 (1.0), which was followed by an increase that resulted in a plateau of relative perceived difference for the intervals F5-F#5 (1.6) and F#5-G5 (1.58).

Single-pair task

The perception of register break for mezzo-soprano 2 resulted in an alternating increasing and decreasing pattern. For the first four pitch intervals, C5-C#5, C#5-D5, D5-D#5, and D#5-E5, the percentage of listeners perceiving a register break ranged between 25% and 45%. The interval E5-F5 was heard by the largest percentage of listeners as being a register break (57.14%). The interval F5-F#5 was chosen by only 21.43% listeners as a register break. The highest interval F#5-G5 was chosen by 50% of listeners as being a register break.

Chromatic scale task

In this forced choice task, no listener perceived a register break at the lowest interval, C5-C#5. The percentage of listeners perceiving a register break increased monotonically over the next three intervals, reaching a peak of 52.94% for the interval

D#5-E5. This was immediately followed by a monotonic decline in perception of register break, with no listeners perceiving a register break at the interval F#5-G5.

Summary

For mezzo-soprano 2, the greatest percentage of listeners perceived a register break between D#5-E5. Relative perceived difference in the paired-pair task was the second highest for this interval and was at a maximum when compared to the relative perceived differences of neighboring intervals. In the single-pair task, the greatest percentage of listeners perceived a register break one half-step higher, at E5-F5. Relative perceived difference scores and percentage of times chosen were also high in the paired-pair and single-pair tasks for the interval F#5-G5.

Mezzo-Soprano 3

Responses to the three perceptual tasks for mezzo-soprano 3 are depicted graphically in Figure 3. This figure combines the results of the paired-pair, single-pair, and chromatic scale tasks. The left y-axis provides a scale for interpretation of the chromatic scale and single-pair judgments. The right y-axis provides a scale for interpretation of the paired-pair judgments.

Paired-pair task

Graphical representation of relative perceived difference scores for mezzo-soprano 1 reveals a general increase in perceived difference from the interval C5-C#5 to the interval of D#5-E5, where relative perceived difference peaks at 3.06. For intervals above D#5-E5, relative perceived difference drops monotonically.

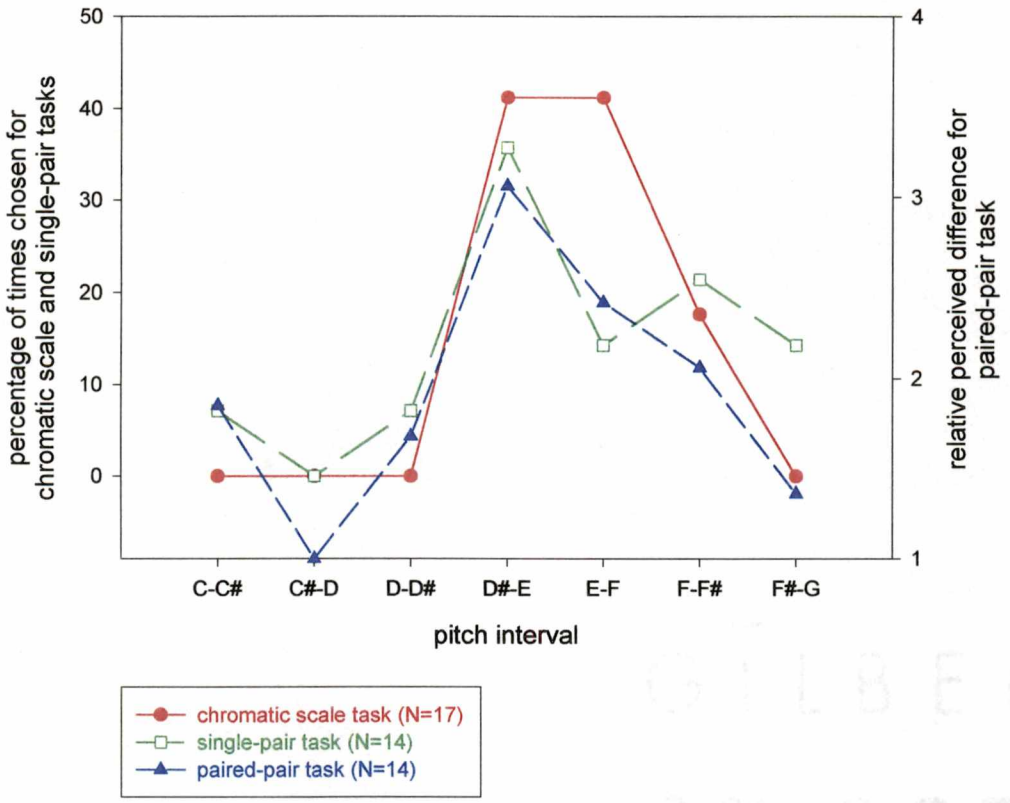

Figure 3: Mezzo-soprano 3— chromatic scale task, single-pair task, and paired-paired task.

Single-pair task

In general, the graphic representation of the results of the single-pair task greatly resemble those of the paired-pair task. Few listeners perceived a register break at the intervals C5-C#, C#5-D5, or D5-D#5 (< 10%). The interval D#5-E5 was perceived by the largest percentage of listeners as a register break (35.71%). The intervals E5-F5, F5-F#5, and F#5-G5 were perceived as a register break less often than was D#5-E5 (14%-22%).

Chromatic scale task

The first three pitch intervals were not perceived by listeners as being a register break. In large contrast, 40% of listeners perceived a register break between the intervals D#5-E5 and E5-F5. For higher intervals above E5-F5, perception of register break declined monotonically.

Summary

For mezzo-soprano 3, all three tasks suggested an increase in perceived difference or in perception of register break between D#5-E5.

Soprano 1

Responses to the three perceptual tasks for soprano 1 are depicted graphically in Figure 4. This figure combines the results of the paired-pair, single-pair, and chromatic scale tasks. The left y-axis provides a scale for interpretation of the chromatic scale and single-pair judgments. The right y-axis provides a scale for interpretation of the paired-pair judgments.

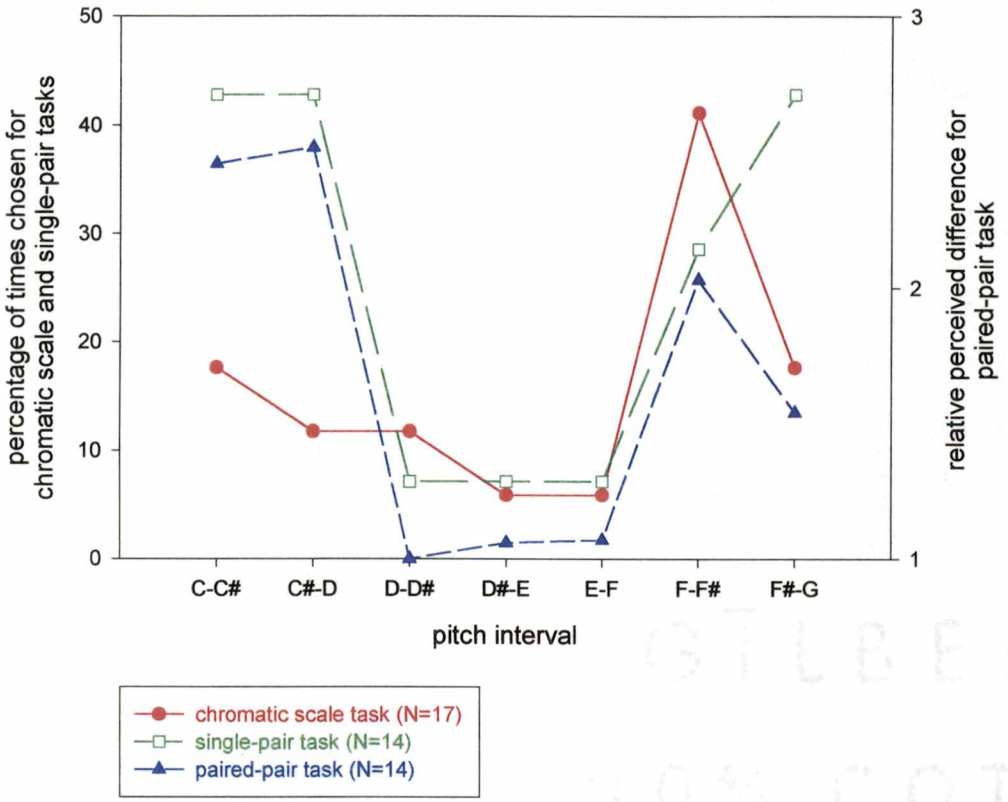

Figure 4: Soprano 1 — chromatic scale task, single-pair task, and paired-paired task.

Paired-pair task

Listeners perceived the greatest difference between the intervals C5-C#5 (2.46) and C#5-D5 (2.52). They heard dramatically less difference between the intervals D5-D#5, D#5-E5 and E5-F5 (< average of 1.1). A second peak in perceived difference occurred at F5-F#5 (2.03) followed by a decrease for the interval F#5-G5 (1.54).

Single-pair task

Graphical representation of the results of the single-pair task yielded a pattern very similar to that observed in the paired-pair task. The intervals C5-C#5 and C#5-D5 were perceived as register breaks by the largest percentage of listeners (42.86%). On the other hand, few listeners perceived a register break at the intervals D5-D#5, D#5-E5, and E5-F5 (< 10%). A steady increase in perceived register break began at F5-F#5 (28.57%) and ended at F#5-G5 (42.86%).

Chromatic scale task

A steady decrease in the percentage of listeners perceiving a register break occurred from C5-C#5 (17.65%) to E5-F5 (5.88%). A dramatically greater percentage of listeners perceived a register at the interval F5-F#5 (41.18%). The following pair, F#5-G5 (17.65%), was less frequently perceived to contain a register break.

Summary

For soprano 1, both the paired-pair task and the single-pair task resulted in similar visual representations, with primary peaks in perceptual judgments occurring at the intervals C5-C#5 and C#5-D5, followed by reduced judgments for the next three

intervals, followed by increasing judgments for the intervals F5-F#5 and F#5-G5. In the chromatic scale task, the register break was perceived most often between F5 and F#5.

Soprano 2

Responses to the three perceptual tasks for soprano 2 are depicted graphically in Figure 5. This figure combines the results of the paired-pair, single-pair, and chromatic scale tasks. The left y-axis provides a scale for interpretation of the chromatic scale and single-pair judgments. The right y-axis provides a scale for interpretation of the paired-pair judgments.

Paired-pair task

The relative perceived difference between intervals steadily decreased from 1.62 at C5-C#5 to 1.0 at D#5-E5. A dramatic increase in perceived difference occurred at E5-F5 (2.0), followed by a slight decrease in perceived difference for the interval F5-F#5 (1.56). Perceived difference increased again for the interval F#5-G5 to 1.83.

Single-pair task

Soprano 2 was perceived to have a register break between C5-C#5 by 14.29% of the experienced listeners. The perception of register break generally increased with pitch, peaking at the intervals D#5-E5 and E5-F5 (35.71%). A second slight decrease in perception of register break occurred for the interval F5-F#5 (28.57%). This was followed by a notable increase in perception of register break for the interval F#5-G5 (50%).

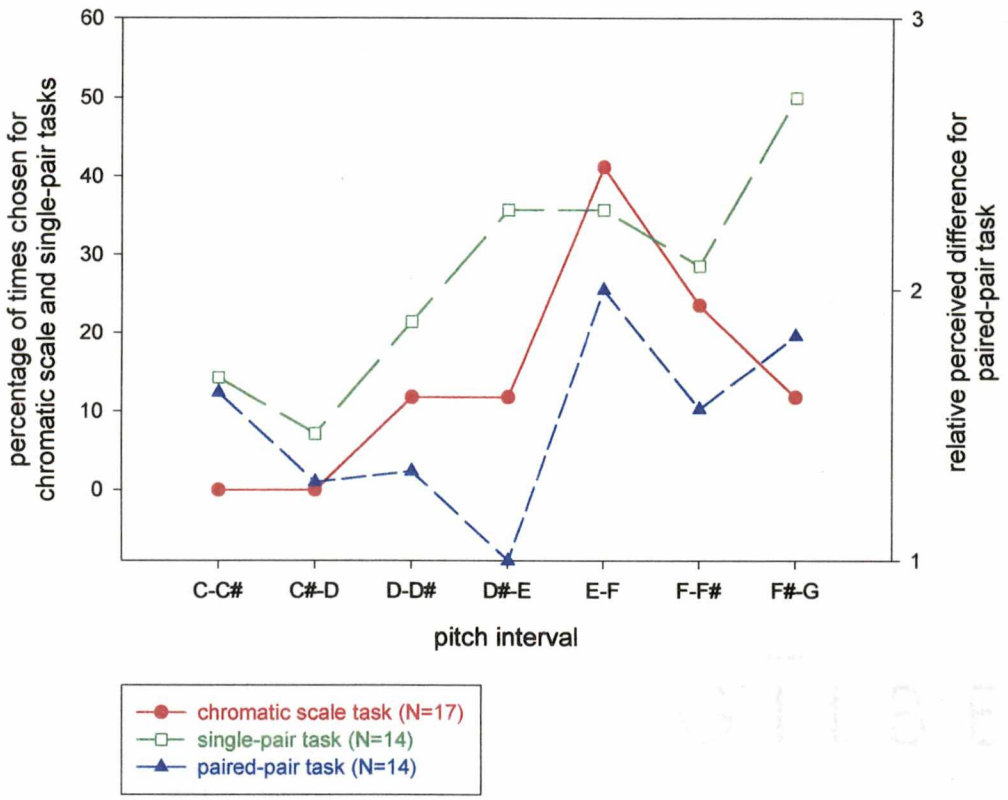

Figure 5: Soprano 2 — chromatic scale task, single-pair task, and paired-paired task.

Chromatic scale task

No listener perceived a register break for the lowest two intervals, C5-C#5 and C#5-D5. Perception of register break increased monotonically, peaking at the interval E5-F5, where 41.18% of listeners perceived a register break. Perception of register break above this interval decreased monotonically to 11.76% for the interval F#5-G5.

Summary

For soprano 2, both the paired-pair and chromatic scale tasks yielded peak relative differences or peak perception of register break, respectively, for the interval E5-F5. In the single-pair task, the greatest percentage of listeners perceived a register break at the interval F#5-G5; however, a large percentage of listeners also heard a register break at the interval D#5-E5 and also at the interval E5-F5.

Soprano 3

Responses to the three perceptual tasks for soprano 3 are depicted graphically in Figure 6. This figure combines the results of the paired-pair, single-pair, and chromatic scale tasks. The left y-axis provides a scale for interpretation of the chromatic scale and single-pair judgments. The right y-axis provides a scale for interpretation of the paired-pair judgments.

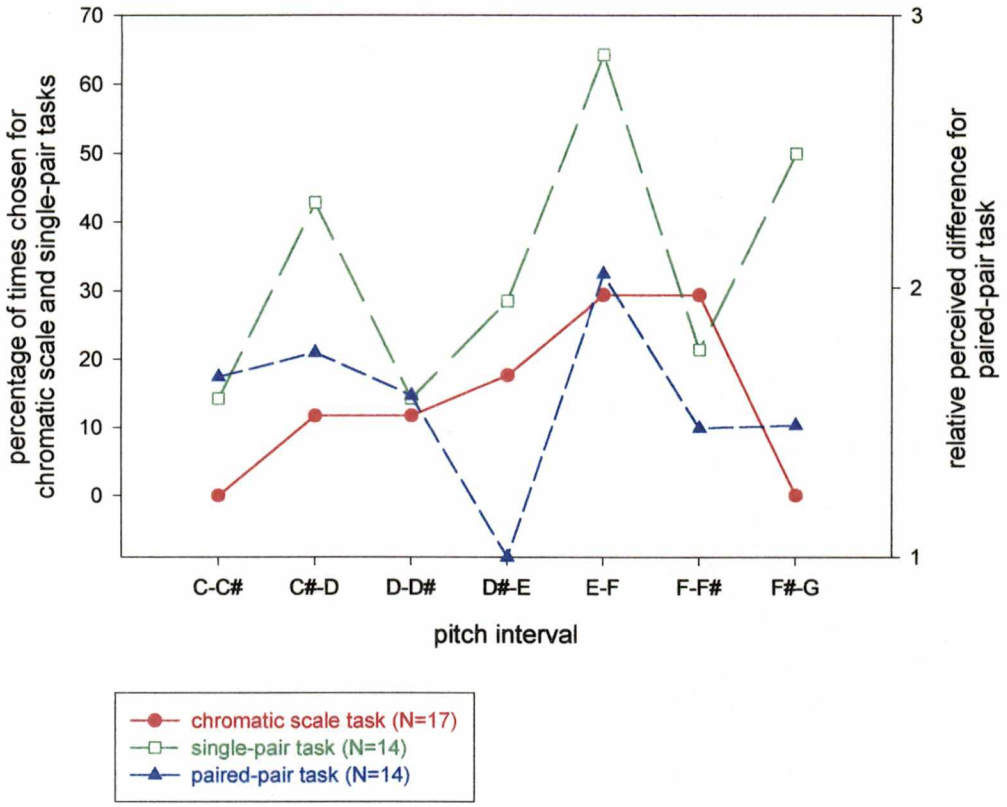

Figure 6: Soprano 3 — chromatic scale task, single-pair task, and paired-paired task.

Paired-pair task

Listeners generally perceived the intervals C5-C#5, C#5-D5 and D5-D#5 to be similarly dissimilar with relative perceived difference scores ranging from 1.67 to 1.6. A sharp decrease in relative perceived difference occurred between D#5 and E5 (1.0), followed by a dramatic increase in relative perceived difference to a peak between E5 and F5 (2.05). This was followed by a decrease in perceived difference for the intervals F5-F#5 (1.48) and F#5-G5 (1.48).

Single-pair task

Only 14.29% of listeners perceived a register break between C5 and C#5. Perception of register break increased for the interval C#5-D5 to 42.86%. Listener perception of register break dropped for the interval D5-D#5 (14.29%), then began to increase until reaching a peak at E5-F5 (64.29%). This was then followed by a decrease in perception of register break for the interval F5-F#5 (21.43%) and another increase in perception of register break to 50% at the interval F#5-G5.

Single-pair task

Perception of register break increased monotonically with pitch from a low of 0% for C5-C#5 to a peak of 29.41% at the intervals E5-F5 and F5-F#5. No listeners perceived a register break between F#5 and G5.

Summary

For soprano 3, all three tasks elicited a peak in perceived difference in perception of register break for the interval E5-F5. In the chromatic scale, a peak in the perception

of register break was also noted one-half step above E5-F5. In the single-pair task, a large percentage of listeners also perceived a register break at F#5-G5.

Summary of Question 1

In summary, the answer to the question, "Can vocally trained listeners perceive an upper register break in classically trained female voices?" appears to be yes. For four out of the six singers (mezzo-soprano 3 and sopranos 1-3), both the paired-pair and the single-pair tasks displayed localized increases in relative perceived difference and perception of register break, respectively, which coincided with the pitch interval most often selected as the register break in the chromatic scale task.

IDENTIFICATION OF REGISTER BREAK – QUESTION 2

The second question in this study was "Is the upper register break perceived in the same location by the singer, their teacher, and the listener?" To answer this question, three comparisons were conducted: voice teachers versus singers, experienced listeners versus singers, and experienced listeners versus teachers.

Voice Teachers versus Singers

Table 2 presents a comparison of voice teacher and singer identifications of register break. Please note that mezzo-soprano 2 indicated two register breaks, one between E5-F5 and another between F#5-G5.

In no case was there agreement between voice teacher and singer regarding location of register break. Voice teachers identified their student's register break at a lower pitch interval than did the singers for two of the three mezzo-sopranos and two of

Table 2

Voice Teachers' Perception of Register Break versus the Singer's Perception of Register Break.

Teacher / Singer	C-C#	C#-D	D-D#	D#-E	E-F	F-F#	F#-G	G-G#
C-C#								
C#-D								
D-D#								
D#-E			M1			M3		
E-F		M2		S1			S2	
F-F#								
F#-G		M2						
G-G#				S3				

the three sopranos. Voice teachers identified the singer's register break one-half step lower than did the singer for two singers, mezzo-soprano 1 and soprano 1. For two singers, mezzo-soprano 3 and soprano 2, the voice teacher placed their register breaks one whole step higher than did the singer. Two singers, mezzo-soprano 1 and soprano 3, were rated by their teacher as having a register break over one whole step lower than identified by the singer.

Listeners versus Singers

Table 3 presents a comparison of listener and singer identifications of register break. Due to its forced-choice nature, the chromatic scale task was used to determine where listeners perceived register breaks. For each singer, the pitch interval chosen most often as a register break by the listeners was determined to be the register break. In cases where two pitch intervals were chosen equally as often, both were considered to be the register break. This was the case for mezzo-soprano 3, who was equally perceived as having a register break at D#5-E5 and E5-F5, and for soprano 3, who was equally perceived as having a register break at E5-F5 and F5-F#5. Also, please note that mezzo-soprano 2 indicated two register breaks, one between E5-F5 and another between F#5-G5.

Listeners' perception of register break was in agreement with the singer's identification of register break for two singers, mezzo-soprano 3 and soprano 2. Three singers, mezzo-soprano 1, mezzo-soprano 2, and soprano 1, were perceived by listeners to have a register break within one-half step of a break identified by the singer. Agreement was poorest for soprano 3, who indicated her register break was over

Table 3

Listeners' Perception of Register Break, Based on the Chromatic Scale Task, versus the Singers' Perception of Register Break.

Chromatic Singer	C-C#	C#-D	D-D#	D#-E	E-F	F-F#	F#-G	G-G#
C-C#								
C#-D								
D-D#								
D#-E				M3	M3 & M1			
E-F				M2	S2	S1		
F-F#								
F#-G				M2				
G-G#					S3	S3		

one-whole step higher than perceived by listeners.

Listeners versus Voice Teachers

Table 4 presents a comparison of listener and voice teacher identifications of register break. For all singers but mezzo-soprano 3 and soprano 2, listeners perceived a register break at higher pitches than indicated by the singer's teacher. Mezzo-soprano 1 and mezzo-soprano 2 were perceived by listeners to have register breaks a whole step higher than indicated by their teachers. On the other hand, mezzo-soprano 3 and soprano 2 were perceived by listeners to have register breaks one whole step below that indicated by their teachers.

Summary of Question 2

In general, the answer to the second question "Is the upper register break perceived in the same location by the singer, their teacher, and the listener?" is no. For the majority of the singers, the voice teachers indicated that their student's register break occurred at a lower pitch interval than did the singers and the experienced listeners. The greatest agreement on location of register break was between the singers and the listeners, based on the chromatic scale task. For mezzo-soprano 3 and soprano 2 the singers and the experienced listeners were in agreement on the location of register break.

VOICE CATEGORY EFFECTS – QUESTION 3

The third research question asked "Is the register break perceived in different locations for mezzo-sopranos and sopranos?" Because of its forced-choice nature, the task that best answered this question was the chromatic scale task. Percentage of

Table 4

Listeners' Perception of Register Break, Based on the Chromatic Scale Task, versus the Teachers' Perception of Register Break.

Chromatic Teacher	C-C#	C#-D	D-D#	D#-E	E-F	F-F#	F#-G	G-G#
C-C#								
C#-D				**M2**				
D-D#					**M1**			
D#-E					**S3**	**S1 & S3**		
E-F								
F-F#				**M3**	**M3**			
F#-G					**S2**			
G-G#								

times chosen for each pitch interval was averaged for the three mezzo-sopranos and the three sopranos. Mean percentage of times chosen and standard errors are depicted graphically in Figure 7.

Mezzo-sopranos

For the mezzo-sopranos, only two pitch intervals were chosen as breaks at above chance levels: D#5-E5 with a mean percentage of time chosen of 37.25% and E5-F5 with a mean percentage of time chosen of 41.18%.

Sopranos

For the sopranos, the only two pitch intervals chosen as register breaks at above chance levels were E5-F5 with a mean percentage of time chosen of 25.49% and F5-F#5 with a mean percentage of time chosen of 31.37%.

Summary of Question 3

The answer to the question, "Is the register break perceived in different locations for mezzo-sopranos and sopranos?" appears to be yes. The greatest mean number of times chosen as register break for mezzo-sopranos occurred between E5-F5, while the greatest mean number of times chosen as register break for sopranos occurred one-half step higher between F-F#. Thus it appears that in this study, mezzo-sopranos were perceived to have a register break one-half step lower than sopranos.

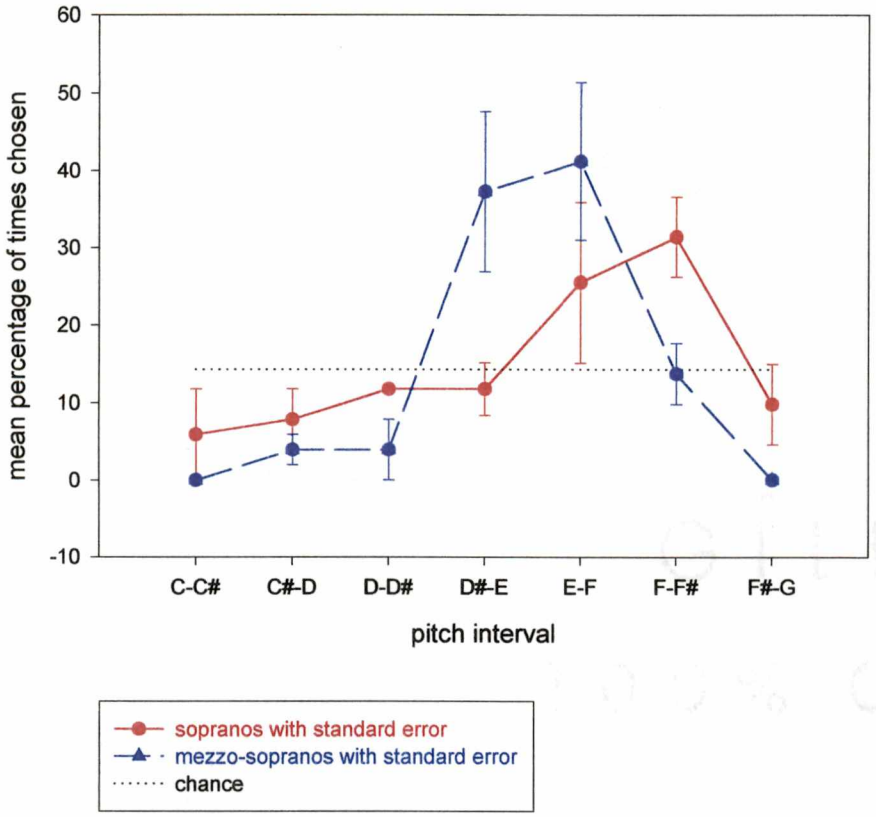

Figure 7: Mean mezzo-soprano and soprano data for the chromatic scale task.

CHAPTER FOUR

DISCUSSION

The purpose of this study was to determine whether classically trained singers could perceive the upper register break in classically trained mezzo-sopranos and sopranos. Additionally this study sought to determine whether perceived register breaks would correlate with vocal category.

Overall, all three tasks resulted in agreement among the listeners for either relative perceived difference and/or perception of register break. For five out of the six singers, the register break as perceived in the chromatic scale occurred at a pitch interval which also corresponded to a peak perceived difference in the paired-pair task. The hypothesis that the singers, their voice teachers, and experienced listeners would hear the register break in approximately the same location was not supported. Based on the chromatic scale task, listeners and singers were in the greatest agreement on location of the register break. The hypothesis that the mezzo-sopranos would be perceived to have a register break at a lower pitch interval than the sopranos was supported, based on the chromatic scale task.

TESTS OF HYPOTHESES

Perception of Register Break

The first experimental question was, "Can vocally trained listeners perceive an upper register break in classically trained mezzo-soprano and soprano singers?" The working hypothesis was that the listeners could perceive a quality change associated with

the upper register break. Each singer would have a predictable timbre transformation as a function of pitch and that the register break would be perceived as a discontinuity in this transform.

Quality Change

In order to determine whether a register break was associated with a perceived quality difference, it is necessary to compare perceived quality differences between successive pitch intervals and perceived register breaks. The first task, the paired-pair task, was designed to elicit information about the former; while the second and the third tasks, single-pair and chromatic scale tasks, were designed to elicit information about the latter.

In the paired-pair task the experienced listeners indicated which pair of adjacent semi-tones was the most dissimilar in quality. Because the pitch intervals were not labeled for the listener, and because the listeners were not asked to indicate a perception of register break, it is likely that the listeners were making judgments of dissimilarity based on quality differences.

In the single-pair task, the listener was presented a single half-step interval and responded "yes" or "no" to the question "Is it a register break?" Here, the issue of quality was not addressed. Instead, the focus was perception of register. As with the paired-pair task, pitch intervals were not labeled for the listener, reducing the likelihood of a bias in response. That is, listeners were less likely to use their preconceived ideas about the location of register breaks in singing to influence their choices. Additionally,

because more than one pitch interval could be chosen as a break, the task allowed for the possibility of multiple register breaks within a singer.

In the chromatic scale task, the listeners were forced to chose one pitch interval for the register break. The advantage of this task was that it allowed listeners to hear all the pitches and it forced listeners to chose the pitch interval that they believed was most likely to be the register break. The data obtained from this task were the most consistent data of the study. However, the results from the chromatic task cannot be viewed in isolation because this task was the most susceptible to listener bias. Pitch intervals were labeled as they were presented to the listeners, increasing the likelihood of listeners choosing a register break based on preconceived notions regarding singing voice or even perceived voice category.

The strongest evidence for a perceived register break would be agreement in peak pitch intervals for all three tasks. However, listener performance on the single-pair task was highly variable so that such a requirement cannot be met for all singers. Nearly as compelling, though, would be a perfect correspondence between a peak in the chromatic scale task and a peak in the paired-paired task. This would provide some evidence that listeners were not basing their judgments solely on preconceived ideas concerning the likely location of a singer's register break and would also suggest a link between the perception of register break and perceived difference in quality. In fact, for five of the six singers, the interval chosen most as the register break in the chromatic scale task coincided with a peak in the paired-pair task, suggesting the following: (1) listeners were not simply responding to the chromatic scale task using preconceived ideas about the

location of register break and (2) a perceived change in quality was associated with a perceived register break.

Perception of Quality within Registers

It was hypothesized that quality would not be perceived as similar within a register, but that register breaks would be marked by a discontinuity in timbre transform. This hypothesis is not in agreement with Titze (1994) and Keidar et al. (1987), who state that registers are perceived in a stair-step fashion with similar quality within each register. Because both the current hypothesis and that proposed by Titze and Keidar et al. consider the perception of register break to be a quality judgment, only the results from the paired-pair task will be discussed.

Theoretical and ideal results that would be in agreement with Titze (1994) and Keidar et al.(1987) are presented in Figure 8. Here, pitch intervals preceding and following the perceived register break are heard to be minimally different in quality, whereas the pitch interval associated with the register break is perceived to be maximally different in quality.

Only mezzo-soprano 3 was perceived by listeners in a manner consistent with Titze (1994) and Keidar et al.'s (1987) theory of register break. Based on the paired-pair task, there was an increase in relative perceived difference for the pitch interval of D#5-E5. Pitch intervals above and below this increase were generally perceived to be minimally different. Such a pattern of responses would be predicted if timbre is relatively constant within in each register.

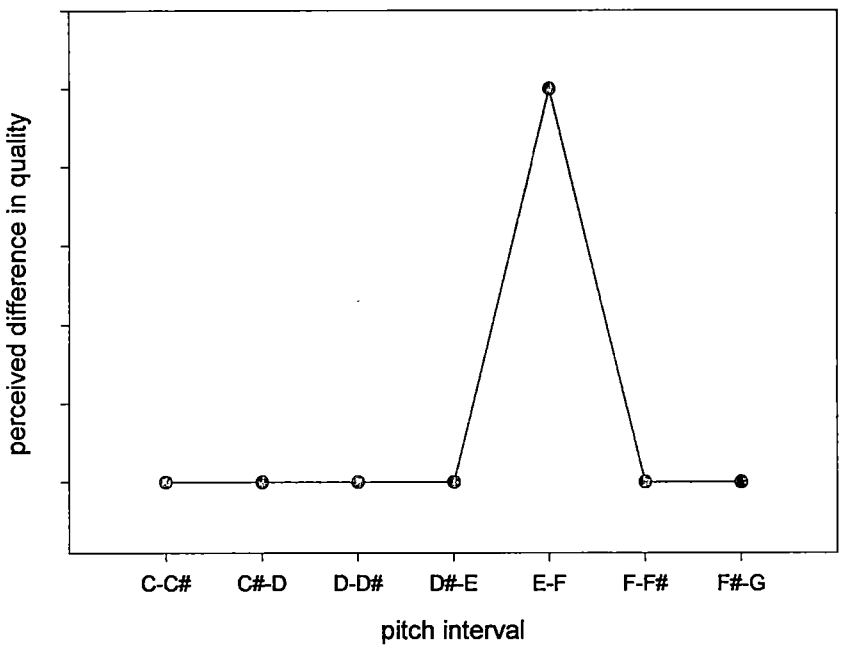

Figure 8: A theoretical and ideal representation of the similar quality theory of registration (Titze, 1994; Keidar et al., 1987), based on the paired-pair task.

Identification of Register Break

For the second question, "Is the upper register break perceived in the same location by the singer, their teacher, and the listener?" the hypothesis was that the singers and teachers would tend to agree on the location of the register break and that the listeners would be in close approximation to the singer/teacher's identification. Based on the results from this study the hypothesis was not supported. Overall, voice teachers indicated that that their student's register break occurred at a lower pitch interval than did the singers and the listeners. The greatest agreement on location of register break was between the singers and the listeners, based on the chromatic scale task.

Prior to completing the chromatic scale perceptual task, each teacher was asked to identify the location of his or her student's register break. The majority of the teachers indicated that their student's register break occurred at a lower pitch interval than did the singer or the experienced listeners. For five out of the six singers, voice teachers also completed the chromatic scale task. Four of these five singers were perceived by their teachers as having a register break at a higher pitch interval on the chromatic scale than they previously indicated verbally. For two singers, the teachers were in agreement with the singer and for two singers the teachers were only a half-step removed from the singer's identification of the register break. This improved agreement in the chromatic scale task suggests that teachers responses in the verbal identification task might have been biased towards stereotypical locations based on the singer's voice classification (i.e., mezzo-soprano/soprano).

Voice Category Effects

The third question asked, "Is the upper register break perceived in different locations for mezzo-sopranos and sopranos?" It was hypothesized that mezzo-sopranos would be perceived to have a register break at lower pitch intervals than sopranos.

Based on results of the chromatic scale task, the register break for mezzo-sopranos were perceived most often at lower pitch intervals (E5-F5) than for the sopranos (F5-F#5). This is in agreement with Miller (1986), who stated that a mezzo-soprano's upper register break typically occurs around E5 and the soprano's upper register break typically occurs around F#5. The finding from this study are also in agreement with Preissler (1939), who stated that as the voice classification becomes lighter, the register transition points become higher.

METHODOLOGICAL CONSIDERATIONS

Strengths of the Study

This study was strengthened by the use of three perceptual tasks, one designed to test perception of difference in quality and two designed to test perception of register break. The first task that was presented to the listeners, the paired-pair task, did not indicate that the research was focusing on the perception of register break. The listeners were asked to judge the stimuli based on quality differences. Because this task yielded results that were often very similar to the two tasks that tested listeners' perception of register break, it was possible to conclude that quality perception might be an important cue to the perception of register break. Previous studies (Keidar et al., 1987), used tasks

that were all framed in terms of registers. These studies shed little light on relationship between perception of quality and perception of register.

Another strength of this study was the fact that voice teachers not only indicated their student's upper register breaks verbally, but also evaluated their own student in a less transparent chromatic scale task. The differences between the results for these two tasks suggest a bias by the teachers to identify register break based on preconceived notions regarding voice classification.

The number of singers providing stimuli strengthened this study. With six female singers, three mezzo-sopranos and three sopranos, the results from the present study may be generalized to a greater degree than those obtained by Keidar et al. (1987) who used only one female singer.

Limitations of the Study

One limitation of this study was the limited range of stimulus pitches, C5-G5. While such a range likely encompasses most female singers' register breaks, it did not provide sufficient detail in the paired-pair task to interpret large relative perceived difference values when they occurred at either pitch extreme in absence of a correlation with perceived register break on the chromatic scale task.

For example, several singers obtained relative perceived difference scores at the pitch intervals C5-C#5 and C#5-D5, but were not perceived to have a register break at these intervals. There are at least two possible explanations for this. First, the observed increase at the lowest pitch intervals could simply be the result of the fact that lower pitches tend to be perceived as being more different than are higher pitches (Erickson,

1999, June). Second, the increased perception of relative difference could indicate a true second register break that was not indicated in the chromatic scale tasks due to its forced choice nature. If the first explanation is true, relative perceived difference scores should increase as pitch intervals decrease below C5-C#5. If the second explanation is true, relative perceived difference scores should decrease as pitch interval decrease from C5-C#5.

The addition of pitch intervals above F#5-G5 would have allowed the examination of relative perceived difference scores for extremely high-pitched intervals necessary to truly understand how timbre and register are perceived in these singers. The addition of the higher pitches would have indicated whether the perception of register break and/or relative perceived difference would decrease after the pitch interval of F#5-G5 as predicted by Erickson (1999, June) or if it would have continued to increase and peak at a higher pitch interval. This addition was strongly needed for soprano 3, who indicated that her register break occurred between G5 and G#5.

Another limitation of this study was the lack of a continuous chromatic scale performed all on one breath. This would have added acoustical information for the listener, such as onsets and offsets, that may have enabled the listener to more accurately perceive the register break.

Finally, the use of natural stimuli, while necessary, limited the study by preventing control for loudness contours, vibrato rate, and vibrato extent, which the listeners may have used as criteria in their perception of register break and/or relative perceived difference.

IMPLICATIONS FOR FUTURE RESEARCH

Future research should examine the perception of register break throughout a larger pitch range for reasons previously discussed. Additionally, a multi-dimensional scaling task examining the perceived differences between all possible pairs of pitches should be conducted so that a mapping of quality perception can be achieved. Finally, the relationship between the perception of quality and register break should be compared to acoustic and aerodynamic data to better understand the acoustics and physiology of both quality and registration.

CHAPTER FIVE

SUMMARY AND CONCLUSIONS

SUMMARY

The first hypothesis stated the listeners would be able to perceive a quality change associated with the upper register break. It was also hypothesized that singers would exhibit predictable patterns of timbre transformation as a function of pitch and that register breaks would be perceived when discontinuities in this timbre transform occur. For five of the six singers, the register break chosen most often in the chromatic scale task corresponded to a pitch interval with a peak relative percent difference score in the paired-pair task, suggesting that listeners were able to perceive an upper register break and that this perception was associated with a perceived change in vocal quality. In the paired-pair task, four of the six singers demonstrated a pattern of decreasing relative perceived difference as a function of pitch followed by a sharp increase in relative perceived difference corresponding with the register break as perceived in the chromatic scale task. From these results, it appears that listeners can perceive a difference in quality associated with a register break. The results also appear to support the idea that register perception occurs when a discontinuity in timbre transform occurs; however, more research concerning this hypothesis is necessary.

The second hypothesis stated that voice teachers would agree with their students on the location of the student's register break and that listeners would perceive a quality change associated with a register break in close approximation to the singer/teacher

identification. Overall, the teachers indicated that their student's register break occurred at lower pitch intervals than did the singers. Likewise, voice teachers did not agree with listeners concerning the location of singers' register breaks. Listeners and singers were in the greatest agreement for location of the upper register break. Based on these results, this hypothesis was partially supported.

The final hypothesis was that mezzo-sopranos would be perceived to have register breaks at lower pitch intervals than the sopranos. Mezzo-sopranos were perceived to have register breaks one-half step lower than were sopranos, based on the chromatic scale task. Thus, this hypothesis was supported.

CONCLUSIONS

This study represents a first attempt at understanding the perception of vocal quality in female singers and how perception of quality relates to perception of register break. The results of this study are not conclusive; however it appears that generally differences in perceived quality are associated with the perception of register break.

REFERENCES

REFERENCES

American National Standards Institute (1973). Psychoacoustical Terminology. S3.20. New York: American National Standards Institute.

Austin, S. (1992). "Subglottal resonance and voice registers." Unpublished thesis, University of Iowa, Iowa City.

Cleveland, T. (1977). Acoustic properties of voice timbre types and their influence on voice classification. Journal of the Acoustical Society of America, 61,1, 1622-1629.

Doscher, B. (1988). The functional unity of the singing voice. Lanham, MD: The Scarecrow Press, Inc.

Erickson, M. L. (1999, June). Dissimilarity and the classification of singing voices. Paper presented at The Voice Foundation's 28th Annual Symposium: Care of the Professional Voice, Philadelphia, PA.

Erickson, M. L., Perry, S., & Handel, S. (in revision). Discrimination functions: can they be used to classify singing voices?

Fant, G. (1970). Acoustic theory of speech production with calculations based on x-ray studies of Russian articulations. Paris: The Hague.

García, M. (1840). Ecole de García: Traité complet de l'art du chant. Paris: Tropenas.

Handel, S., & Erickson, M. L. (in revision). A rule of thumb: the bandwidth for timbre invariance is one octave.

Helmholtz, H. von (1877/1954tr). On the sensations of tone. Dover, New York.

Hollien, H. (1974). On vocal registers. Journal of Phonetics, 2, 125-143.

Keidar, A., Hurtig, R., & Titze, I. (1987). The perceptual nature of vocal register change. Journal of Voice, 1,3, 223-233.

Large, J. W. (1972). Towards an integrated physiologic-acoustic theory of vocal registers. NATS Bulletin, 30, 18-25.

Miller, R. (1986). The structure of singing. New York: Schirmer.

Preissler, W. (1939). Stimmumfänge und gattungen der menschlichen stimme. Arch. Sprach- u. Stimmheilk, 3, 65-85.

Tarneaud, J. (1961). Traité pratique de phonologie et de phoniatrie. Paris: Maloine.

Titze, I. (1983). The importance of vocal tract loading in maintaining vocal fold oscillation. Proceedings from the Stockholm Musical Acoustics Conference, Royal Swedish Academy of Music, SMAC83 (Vol. I), 46, 61-72.

Titze, I. (1988). A framework for the study of vocal registers. Journal of Voice, 2, 183-194.

Titze, I. (1994). Principles of voice production. Englewood Cliffs, NJ: Prentice-Hall, Inc.

Torgerson, W. (1963). Theory and methods of scaling. New York, NY: John Wiley and Sons, Inc.

Van den Berg, J. W. (1960). An electrical analogue of the trachea, lungs, and tissues. Acta Physiologica Pharmacologica Neerlandica, 9, 1-24.

Vennard, W. (1967). Singing: The mechanism and the technique. New York: Carl Fischer.

VITA

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While in college Ms. Thomason performed with the Knoxville Opera Chorus, University of Tennessee Opera, First Presbyterian Church Choir, and a few other choral ensembles. She also worked as a radio announcer for WUOT, Knoxville's public radio station.