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The Acoustic Interaction of Voices in Ensemble:

An Inquiry into the Phenomenon of Voice Matching and the Perception of Unaltered Vocal Process

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A Document APPROVED FOR THE
SCHOOL OF MUSIC

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ABSTRACT

It was the purpose of this study to examine and quantify the acoustic interaction of voices in ensemble, with specific consideration to the differences between placement (how voices respond to adjacent voices) and spacing (how voices respond to differences in the space between adjacent voices). This study, further, investigated whether there was any discernible acoustic phenomenon that delineated or defined when a vocal match was made, or if a vocal match was merely a matter of conductor preference. The acoustic data, further, were to be compared with the blend preferences of choral directors and voice teachers, and the preferences of the individual singers used. Information was collected concerning the acoustic appearance of choral blend. A reductionist approach regarding the variables for the study permitted detailed, quantifiable data pertinent to these aims.

Two groups of three male singers were formed. Both groups were recorded in each possible solo, duet, and trio formation. The results were acoustically analyzed, anonymously considered by choral directors and voice teachers, and considered by the individual singers; the combination of acoustic analysis, auditor preference, and singer preference revealed specific trends with regard to both blend and vocal function.

For Group 1, the combination of placement and lateral spacing provided the best alliance of acoustic analysis and auditor/singer preference, at a rate of 54% for placement/lateral spacing and 46% for placement/close spacing. Attention to acoustic placement alone was shown to be superior to spacing alone,

and the combination of acoustic placement and spacing was only slightly more successful than placement alone.

For Group 2, acoustic placement alone provided the best alliance of acoustic analysis and auditor/singer preference, at a rate of 50% each for close and lateral spacing. Attention to acoustic placement alone was shown to be superior to spacing alone, and the combination of acoustic placement and close spacing was shown to be equal to the combination of acoustic placement and lateral spacing.

The findings demonstrate that, when no attention is given to voice matching, lateral spacing may reduce the amount of individual vocal change and contribute to ensemble blend. Should no vocal match be discovered, the combination of acoustic placement and spacing reduces the amount of individual vocal change within ensemble blend. When a vocal match is discovered, specific attention to voice matching contributes to the reduction of vocal change and the overall effect of blend, and may be equally effective in close or lateral spacing.

Proponents of voice matching procedures advocate using them as a primary tenet of ensemble auditions. Confirmation of the variable nature and availability of spacing necessitates a more consistent blending procedure, such as voice matching, for the customary settings of choral ensembles. The acoustic corroboration that voice matching reduces the requisite individual vocal change for singers in ensemble, provides the possibility to begin to reduce any requisite tensions between choral directors and teachers of singing with regard to differences of vocal practice.

Chapter I: Current Concepts

A. Introduction

> What happens to the sound of a voice when it is joined by another, or by many others, and then also by reflections from the room? . . . This special character is usually called the ensemble effect or chorus effect. [T]he sensation of this extraordinary phenomenon, strongly perceived inside the choir, is one of the attractions of choir singing. (Ternström and Sundberg, Formant 10)

Throughout the past century a substantial divergence of opinion has existed between teachers of singing and choral directors, each believing the other to be inflexible, each misunderstanding the vital contribution the other offers to the development of the individual singer. "We are all aware of the controversy among singing teachers and choral directors which has prevailed since the rebirth of choral music back in the 1920's." (Christiansen, Solo 16) This controversy has stemmed, in part, from the notion that efficient singing technique differs between choral and solo genres. Rossing, Sundberg, and Ternström cite,

> Choir singing and solo singing are two distinctly different modes of musical performance, making different demands on the singers. Many singing teachers are reluctant to let their students practice choir singing, because they believe that choir singing requires a voice usage quite different from that used in solo singing. (Voice 1)

Eckholm elucidates the issue further.

> Voice teachers' comments revealed that their primary concern in evaluating vocal production was freedom of phonation. Terms such as "forced," "tight," "pressed," and "restrained," which denote a lack of vocal freedom, were widely used. According to the frequency of such comments, there appeared to be a tendency for singers to inhibit their freedom of phonation when singing in a choral setting, and that this tendency was greater when trying to blend than when singing soloistically. (1999 101)

Singers reported that "... blended singing created a greater degree of tension in the vocal apparatus than soloistic singing." (Eckholm, 1999 45) When surveyed concerning vocal and choral expectations, students responded that there was "... conflict sometimes if not frequently, between what they are taught to do in the voice studio and is expected of them in choir." (Slusher 2) Ternström and Sundberg contend, "The smooth and homogeneous blending of voices is one important criterion of a good choral sound. To avoid standing out from the ensemble, a choir singer must continually match his or her loudness, pitch and voice timbre to the group average." (Formant 10) The conflict, then, is due to the perception of variant demands in solo and choral genres, coupled with the notion that the singing techniques of the two mediums must be essentially dissimilar in process and function.

The individual vocal techniques used by those in choral ensembles may not necessarily be healthy. Not all of those who sing have received adequate private vocal instruction, and these singers may be required to alter individual vocal process in order to contribute to the ensemble. In some respects, although individual attention is limited, the choral rehearsal can serve as a group voice class. In this instance, the choral conductor serves to heighten the awareness of the individual singer to the sensations associated with efficient vocal production.

Efficient vocal technique, thanks to the developments of voice science (Vennard, Appelman, Sundberg, Miller), can be quantified, and while loudness and pitch relationship must be continually considered among the members of the ensemble, timbre (although intrinsic to the genetic makeup of the singer) is, in many cases, a function of the level of vocal proficiency and freedom an individual has acquired. Admittedly, the sources cited above describe twentieth-century permutations of nineteenth-century Italian *bel canto* principles, which have become the norm for Western vocal teaching. These permutations have become invested in the consciousness of current studio practice and training, often finding themselves in conflict with the demand for homogeneous choral timbre.

Goodwin found that,

> [A]lterations made in the individual voice during the blending process were recorded on audio tape and then compared spectrographically to the same individual's vocal production as a soloist. The findings show convincing evidence of the vocal process of blending by alteration of an individual sound. *The long-argued claim that blending was achieved through alteration of an individual vocal characteristic had become more than a claim. It had blossomed onto* [sic] *a genuine vocal concern.* (emphasis added) (qtd. in Giardiniere 19-20)

One issue related to the debate is the relative inability of the novice voice student to create and healthily sustain certain sounds during the process of vocal development. "Student singers do not always have the requisite skills needed to produce vocally what is requested by the director." (Slusher 3) "Students are not always sophisticated enough in their knowledge of vocal pedagogy to know what is best for their vocal health and development." (Slusher 154) This inability has less to do with the impropriety of the sounds and more to do with the lack of full maturation and technical development on the part of the singer, and may apply to the choral rehearsal, the private studio, and the practice room.

The results of this study will, in part, attempt to nullify this issue, as placement of the individual singer within the ensemble can be changed to accommodate newly acquired or mastered techniques while maintaining choral blend. It is not the intention of this study to cite and address issues related to pre-Romantic or non-Italian vocal practices and their substantial influences on the writing of choral and solo music; several fine studies describe historical vocalism. (Fields, 1947; Duey, 1951; Ulrich, 1973; Miller, 1977; White, 1989) Rather, this study will explore acoustic evidence supporting the process of voice matching.

B. Purpose of the Study

To date, studies considering the various issues related to, and procedures associated with, the concept of blend have been highly subjective, based solely on qualitative data. The purpose of this study is to objectively record and report quantifiable data that serve to corroborate or nullify the host of opinions regarding choral blend.

The underlying assumption of this study is the desirability/necessity of choral blend, and more specifically, an inquiry into quantifying the achievement of that effect without sacrificing the integrity of individual vocal technique. The system of voice matching employed by Weston Noble and others purports to achieve this objective. "Voice positioning techniques seek a homogeneity of choral sound that, ideally, does not compromise the vocal production of individual singers. Vocalists are positioned to benefit acoustically from other adjacent voices as the collective sound is constructed." (Giardiniere 23) Eckholm observes that, "The singers in this study were all trained and experienced in both solo and choral singing. Nevertheless, they had trouble maintaining freedom of phonation, intonation accuracy, vibrancy, and resonance in the choral setting, especially when they were asked to blend. (1999 122)

The purpose of this study is to discover whether there is any discernible acoustic phenomenon that delineates or defines when a vocal match has been made, or if a vocal match is merely a matter of conductor preference with regard to timbre, vibrato, intonation, and balance. "Conglomerate choral sound is affected by placement of individual singers qualitatively (Lambson, 1959) and quantitatively (Backus, 1969)." (Giardiniere 23) To this point, no study has empirically addressed the issue of identifying replicable acoustic data to support the aural identification of choral blend. In an e-mail message, choral acoustician Sten Ternström relayed the following information to me:

> I don't know of any formal studies that concern such a delineation, [acoustic identification of choral blend] and they would be very hard to do. *The major problem is that our sense of hearing is much better at parsing complex sounds than is any current instrumentation.* I think the way to study this would be to make syntheses of an ensemble of singers and then tweak a few of them to see when listeners perceive a lack of blend. But there are many acoustic parameters that conceivably could make a voice stand out (most notably "singer's formant" and vibrato, but also timing discrepancies and sheer loudness, for example), so you would have to focus on the most salient ones. (emphasis added) (2002)

With respect to Noble's voice matching process: "The most important factor, however, is that this system avoids any mechanism change on the individual's part." (Meilenz 13) What has yet to be carefully examined is the acoustic analysis of choral blend at the level of adjacent singers, specifically, using the placement of individual singers within the ensemble to ensure the effect of blend without sacrificing the core integrity of the vocal technique. This study further seeks to discover whether or not voice matching eliminates the necessity for alteration of vocal technique to accommodate the blending process.

> Subjugating the individual sounds of any number of singers involves that number of alterations, e.g., if there are 50 singers, then there are 50 compromises. Even subjugating a singer to the blending requirements of a single section (soprano with soprani) involves the number of compromises of that number of soprani. The desired one-ness of the choral sound is the final generation of sound produced by the ensemble. The sounds produced by individuals may be described as the first or initial generation. Voice matching discloses an intermediary generation of sounds produced by the ensemble; a section sound. Placement and acoustical reinforcement can produce a homogeneous section sound, and this section sound greatly reduces the factors melding together to produce the total choral sound. (Giardiniere 23-24)

The supposition is that the effect of blend through voice matching is plausible for various combinations of voices, producing blend at the level of the singers using unaltered vocal process. Singers in voice matched formations should be able to hear others around them (reference), as well as themselves (feedback).

C. Need for the Study

The need for this study is based on the following series of observations:

1) Blend is a desired aspect of choral sound.

2) A wide variety of opinions exist as to the practice of achieving choral blend.

3) A widely held method to achieve choral blend is to require the subjugation of an individual's vocal sound, either to a predetermined tonal ideal or to some ambiguous notion of each singer "matching the sounds" that surround him or her.

4) The desire to achieve blend through altered vocal process has created substantial conflict between teachers of singing and choral conductors.

5) Not all singers have the requisite knowledge and skill level to adequately produce the vocal sounds that are required to achieve choral blend.

6) Methods exist that both achieve blend and purport to nullify the need of singers to modify normative vocal process. These methods include formation and spacing.

7) Recent studies dealing with the spacing of voices have cast doubts upon the applicability of formation (acoustic placement) practices.

8) Spacing is a relevant component of choral formation, yet not all choral performance venues allow sufficient space to solve blend issues.

9) All choirs must stand in some formation. Space is simply a component of formation.

10) Studies considering the effects of both formation and spacing, citing auditor preferences and conclusions, make use of pieces that require both rehearsal and a conductor. The acoustic properties of blend may be distorted by rehearsal procedure and conducting gesture.

11) Specific formation-determining processes, including voice matching, have been carefully delineated. The results of these studies and practices have been assessed as successful by the participants, observers, and selected auditors of the various studies.

12) None of the existing formation research quantifies the acoustic phenomenon that occurs when a vocal match is made.

13) None of the existing formation research quantifies whether blend through formation is achievable without the alteration of primary individual vocal characteristics and process.

14) There is no need to reevaluate acoustic formation procedures, only to identify/clarify the acoustic and physical phenomena that occur as a result of the vocal match.

Many studies concerning choral practices refer to the writings of Howard Swan as foundational for the studies from which they emanate. (Ford, Daugherty, Giardiniere, Tocheff, Goodwin)

> Choral music in America finds itself at the end of a century that has witnessed considerable development and evolution concerning tone quality . . . [A]ccording to Howard Swan, out of this activity, six discernible schools of choral music performance evolved. (Ford 1)

Swan's "schools" delineated conventions endemic in choral singing during the early part of the twentieth century and described the specific practices of listed choral conductors. Various amalgams of these concepts continue to influence current choral practice, including the principles identified with blend.

> [C]horal professionals in America still struggle with the basic tenants represented in these six choral schools. Most choral conductors today can trace their tonal concepts back to one of more of these influences. (Ford 4)

While proponents of certain blending practices may trace their origin to one of these schools, Swan's attention was given to the differences between general categories of practice rather than providing any specific analysis or value judgment of the sounds produced. Knutson's study (1987) indicates a trend away from the historical practice of subordinating or altering the vocal quality of the individual singer in order to achieve blend. Contemporary choral conductors in his study leaned toward a rehearsal style that strove to achieve an acceptable level of uniformity without sacrificing healthy vocal technique. This trend was based on a belief that restricting the vocal development of the individual singer is unhealthy and detrimental to choral sound.

Eckholm's study records individual singers in an ensemble setting. Voice teachers were asked to appraise the relative amount of individual vocal restriction when singers were specifically instructed both to blend and to sing soloistically. "The results suggest that singers modify their solo production in a choral setting, even when asked not to do so." (1999 103) Her original research question was, "Is it possible to achieve an acceptable level of choral blend without modifying solo vocal production?" While there is no acoustic data to support her conclusions, Eckholm revises this question, based on her findings, to read, "Can an acceptable level of choral blend be achieved when singers try to use their normal solo production?" (1999 103) Acoustic placement studies (Tocheff, Giardiniere) already support an affirmative response to this question.

D. Research Questions

Studied voice matching practices assert that it is feasible to place an individual voice within a choral texture in such a way that it becomes generally indistinguishable from the surrounding voices without fundamentally altering individual vocal process. "Blend means to mix and combine. Not to delete individual color." (Wyatt 22)

Consequently, this study seeks to address the following questions:

1) Can an individual singer blend with other singers without alteration of the basic vocal process of any of the singers? "Is choir singing different from other kinds of singing?" (Ternström and Sundberg, Formant 5)

2) What are the acoustic differences between close and lateral spacing of voices?

3) Is there an acoustic phenomenon that delineates, points to, or allows a vocal match?

E. Procedures

A procedure has been developed to 1) acoustically analyze each individual voice in an objective, quantitative manner; 2) determine the most "blended" sound placement for the group of adjacent voices; and 3) acoustically analyze the individual voices within the blended placement. Observations have been made as to the similarities and distinctions between the acoustic analyses.

Vocal matches have been determined by selected auditors, some of whom were choral conductors, some of whom were teachers of singing. Surveys and digital recordings of the groups of singers were mailed to potential auditors. The survey, completed by certain auditors, collected information regarding the personal qualifications of the auditors as well as their preferences regarding the best recorded examples of blend. These preferences were compared to the acoustic data in order to reach quantifiable conclusions that were not simply the opinion of this researcher. Giardiniere asserts,

> It is not surprising that, in any vocal setting with a series of differing partners or positions centered around one voice, some positions would emerge as being preferred by a panel of experts . . . in performances of the choral witnesses, and strength of agreement to what is heard, one is led to what is: specifically, a phenomenon that, when recognized, may be plain that it surmounts preference or opinion. (106)

Appendices A, B, and C include the letter of invitation sent to the auditors, a copy of the survey auditors were asked to complete, and a compilation of the results of the survey.

Empirical data include audio recordings of the procedure along with acoustic analyses of the recordings. Selected choral conductors and private voice teachers analyzed the recorded data according to a provided series of survey questions. Other evidence includes surveys of the individual singers, charting individual reactions to their placement.

The procedure for the study was as follows:

1) Two groups of male singers were established, each group comprised of three singers. Both groups were comprised of singers possessing variant ability and training. No attempt was made to pre-select the specific participants in either group.
    a) Male singers from the same university campus were invited to participate in this study.

b) Only the first six singers to arrive at the recording site were used for the purposes of this study. Group 1 was comprised of the first three singers and Group 2 was comprised of the next three singers.

2) The musical excerpt used in the evaluation process was "My country, 'tis of thee, sweet land of liberty, of thee I sing."
   a) This text uses primary vowel colors, excluding [o] and [u].

   b) The familiarity of this song for the singers negated the need for both prior rehearsal and conducting gesture, save an initial breath and tempo.

3) The key of *Ab major* was used for all individual and aggregate recordings.

4) Each subject sang the excerpt individually. The recordings were acoustically analyzed.

5) Each subject within the groups sang the excerpt in each possible duet placement.
   a) Pairs sang in both close and lateral spacing. Close spacing was defined as adjacent singers standing shoulder-to-shoulder. Lateral spacing was defined as a twenty-four inch separation between adjacent singers, according to Daugherty's (1996) specifications.

   b) Both the aggregate sound and the individual sounds were recorded. The recordings were acoustically analyzed.

6) Each subject within the groups sang the excerpt in each possible trio placement and spacing.
   a) Trios sang in both close and lateral spacing.

   b) Both the aggregate sound and the individual sounds were recorded. The recordings were acoustically analyzed.

7) Both groups sang in the same sequence of takes. Different formations were utilized for each take, so as to prevent any specific sense of getting used to singing together that may naturally occur as the same voices continue to sing together for extended periods of time. The order of recordings, along with the correlation of placement and spacing, is listed in Appendix D.

8) All singers completed a survey describing their choral/vocal experience and their expectations and preferences within the recording process. A copy of the survey and the results compiled from the responses can be found in Appendices E and F.

9) Selected auditors analyzed each group. Auditors were asked to select the most blended sound from among recorded samples. The criterion for blend was set as: groupings of voices in which the combined individual sounds are the least distinguishable from one another. A copy of the survey and the results compiled from the responses can be found in Appendices A, B, and C.

10) The recordings for each group were compared separately, according to the acoustic analyses.
    a) Observations were reported regarding the acoustic properties that differentiate between unblended sounds and vocal matches.

    b) Observations were reported with respect to the amount of individual acoustic spectrum change in a group setting, as an indicator of the retention of individual vocal process.

11) The acoustic findings for the vocal matched groupings from each group were compared corporately. Vocal matches were selected by the auditors from among the recorded duets and trios.
    a) Observations were reported regarding the acoustic similarities and dissimilarities between the groups.

    b) Observations were reported with respect to the amount of individual acoustic spectrum change in a group setting, as an indicator of the retention of individual vocal process.

This study controlled the time and fatigue on the part of both singers and auditors, eliminating these issues as variables from the analysis. The total time of recording, including lead and follow time for clean recording, was twenty minutes. Within a ten-minute period of time, each singer sang for a total of six minutes and twenty seconds, with each excerpt averaging twelve seconds each, plus lead/follow time. Thus, there was no requisite allowance for singer fatigue.

The musical excerpt was selected for its use of varied primary vowel colors. The selection was deemed to be familiar enough with singers raised in the United States, such that neither rehearsal nor conducting, save for initial breath and tempo, was required.

The Independent Auditor Survey required an average of twenty minutes to complete. None of the individual solo excerpts were included, and the lead/follow time for each recording was shortened. The length required to complete the survey alleviated the issue of aural fatigue on the part of the auditors. The survey was structured so that the auditors did not have to choose from a large number of sounds simultaneously. Auditors did not have either the bias of visual orientation of the singers or any reference to what placement or spacing changes may have occurred between selected tracks. For each example, auditors were asked to choose between two recordings of opposite singer placement. Auditors were also asked to choose the best example between alternating examples, each of which had already been heard. At the end of each series, auditors were asked to choose from among the three recordings previously chosen as best examples.

The responsibility of the auditors was not to determine whether or not acoustic placement or spacing had the most effect, nor was any visual or placement reference provided to prejudice the results. Since both acoustic placement studies and spacing studies have already been done, the variables under investigation were the acoustic effect present when blend occurs, to quantify whether or not significant alteration of vocal process occurs in the example identified as "best blend," and to examine the differences on both the acoustic effect and the amount of alteration accomplished by placement and spacing.

The comparison sequence of the Independent Auditor Survey investigated whether or not discernible preference between various placements could be measured. The comparison sequence, further, offered auditors the opportunity to choose between the best example of placement and the best example of spacing as the best example of blend. This reductionist approach to the study sought to provide detailed, quantitative data collection.

F. Preparation of Recordings

All data were professionally recorded on Monday, 20 May 2002. The site used for the recordings was the Kresge Auditorium in the Larsen Fine Arts Center on the campus of Olivet Nazarene University, Bourbonnais, IL. The seating capacity for the auditorium is five hundred and forty occupants. The auditorium is routinely used for both choral rehearsals and performances, and is not constructed as an anechoic (sound dampening) studio setting. The recordings were conducted in front of the proscenium opening. The stage dimensions are seventeen feet high and fifty-three feet wide.

Both groups of singers were recorded in various placements and spacings related to this study. The order of recordings, with reference to the placement and spacing used in each recording, is listed in Appendix D.

Four AKG 414 microphones were used to ensure consistent recording quality. Each microphone was rolled off at 75 Hz. Each microphone was outfitted with a windscreen. A microphone set in a cardioid ("v" shaped) pattern was placed one foot in front of each singer. The cardioid pattern reduced room noise for the solo recordings. In other words, sensitivity to sound coming directly from in front of the microphones was heightened, while sensitivity to sound reflected from the walls, ceiling, and floor to the sides and behind the microphones was attenuated.

Vocal microphones were placed just below the individual mouth height of each singer. This was done in an attempt both to preserve the integrity of the individual track and to lessen the impedance of the source sound to the area microphone. The primary investigator (NWW) adjusted the height of each microphone as necessary. The area microphone, set in an omni-directional pattern, was placed at a height of six feet, center stage, and ten feet in front of the singers. This approximates a common positioning of the conductor in relation to the singers in this auditorium.

The mixer used was a Yamaha MC-2404 Mark 2. All equalization levels were run flat, and effects processing was neither included through the mixer nor any additional effects processing unit. All vocals were recorded on a Tascam DA-88 eight-track digital recorder. Four tracks were used to separate the sounds from the four microphones. The tape used was an 8mm TDK DAT cassette.

The recordings were processed on a Macintosh G4 computer using ProTools LE. Compact discs were formatted through Adaptec Toast 4.0. The sound technician for the entire project was Dale Owen, owner of Owen Sound, Bourbonnais, IL. The recorded audio and wave files were acoustically examined using SoundSwell Signal Workstation 4.0; Hitech Development, 2002. The primary investigator positioned each singer during the recording process. The pitch Ab (207.65 Hz) was given on a Baldwin nine-foot grand piano prior to starting the recording equipment. The primary investigator gave the singers a tempo and starting gesture for each recording.

G. Expected Outcomes

This study evaluated and identified the acoustic phenomenon that occurred when paired voices match, presupposing a consistent acoustic variance between the pairs of analyses. Recent studies concerning the spacing of voices in choral ensembles have suggested that acoustic placement is unnecessary to the development of optimized blend. Consequently, identifying such an acoustic phenomenon serves to quantify the viability of the voice matching process as a practical means to achieve choral blend.

This study sought to affirm that blend may exist apart from the requirement that individual singers subjugate vocal function either to a preconceived tonal assumption or to an imprecise notion of blending *with those around him or her*. While some conductors may prefer a particular tone quality or may assume a tonal sense for period pieces, voice matching allows the individual vocal process to remain basically intact, while yet contributing to an overall blended ensemble sound.

> Once the optimal arrangement is found, no singer will need to feel unproductive or that he should hold back because of the character of his voice.
>
> Each singer must be free to use the full range of his tonal color and resonating capacity if the choir is going to preserve its flexibility, be capable of performing different styles, and stay in tune. A voice will not add to the quality of the choir if it is in conflict with other voices or if it is swallowed by more dominating sounds. The conductor should treat each singer as an individual with special talents whose placement in the ensemble is of critical importance to the sound of the choir. (Johnson, Influence 14)

With these data, the conflict between teachers of singing and choral conductors, specifically with regard to consistent vocal practices, should be lessened.

H. Delimitations

This study was limited to a comparison of the acoustic responses of two groups of male voices. The number of voices used constituted neither a section nor a choir as subject of the study. Therefore, the results imply, but do not wholly prove, the full application for choral sections and choirs. Non-acoustic studies of voice matching using full choirs and reputable auditors have already been conducted. While the specific placement of individual voices may vary with an increased number of singers, this reductionist approach permitted detailed, quantitative data collection that can be expanded to full choral ensembles in future studies.

The scope of this study was limited to the use of unison male voices and, therefore, does not address the issue of voice matched females nor mixed-gender formations. Neither does it speak to the issue of like gender and alternate voice parts. While similar acoustic phenomena may be readily identifiable in alternate settings, no attempt was made to quantify that assumption.

Subject placement was limited to close (shoulder-to-shoulder) and lateral (twenty-four inches between singers) positioning. Most choirs use a depth of several rows, which may affect both the perception of a vocal match and the conscious or unconscious alteration of individual vocal process. No attempt was made to study the possible affect of front-to-back voice matching.

Microphone placement was consistent relative to the singer's individual heights. No attention was given to the possible affect of individual height on voice matching. Since placement was empirically found to play a significant role in the perception of blend, it warrants further inquiry into the effect of hearing variances by the singers, relative to the individual singer's right and left ear apprehension of sounds.

The subjects used for the recording were university students, both music majors and non-music majors. The results broadly imply use for singers of a younger age and less experience, and for choral groups comprised of singers of professional quality.

The selection of "My Country, 'tis of Thee" provided a basic series of vowels; however, not all of the basic vowels are represented, so the effect of voice matching on the omitted vowels is not known. The acoustic analyses examined the aggregate effect of voice matching rather than on individual vowels. This study examined the effect of voice matching on English vowels rather than the many other standard languages of vocal/choral singing.

The key selected required all subjects to negotiate one registration event (Bb for baritones, C for tenors). No attempt was made to examine the differences in blend between registers, nor was any attention given to tessitura.

This study examined vocal matches and choral blend as nouns, i.e., as defined, fixed entities, rather than as an ongoing attempt by the individual members of an ensemble to match the vocal qualities surrounding them. The alternate placements used during the recording process allowed only for examination of the immediate result of a vocal match between adjacent voices and did not consider the long-term implications of such placements.

Certain studies describe micro-placement procedures according to sight-reading ability. The selection used for this study was familiar to all participants and did not address the effect voice matching may have on group sight-reading ability.

Auditor responses reflect the perceptions and preferences of the particular array of listeners, under the stated parameters. While Giardinere asserts that a discernible trend in the blending preferences of experts is predictable, there may be different preferences for the tone color of the specific group of voices that is blending. (116) This also raises the possibility that the different colors applicable to different genres and style periods may be attainable through alternate acoustic placements, however, no attention was given to that assumption.

Despite the ease of acquiring various technologies, choirs may not have ready access to acoustic analysis equipment. While vocal matches were acoustically observed and identified in this setting, the individual conductor perception will normally serve as the arbiter of vocal matches in choral settings. This correlates with the above statement by Ternström that, ". . . our sense of hearing is much better at parsing complex sounds than is any current instrumentation."

Recording studio technology facilitates the separation of individual sound. This study recorded singers in a setting common to choral performance. One variable may have been to what degree the recording equipment was able to localize the individual sounds from one another. To minimize the impact of this variable, the microphones used to record the individual voices were set in a cardioid pattern. This reduced the possibility of both recording direct signals from adjacent singers and the sonic reflections from the auditorium.

The microphone recording the aggregate ensemble sound was placed at a single distance from the singers. The supposition was that once blend is achieved at the level of adjacent singers its effect continues throughout the duration and distance of the sound.

No specific control over audio playback equipment could be exerted; however, each of the independent auditors was sent a digitally produced compact disc containing the recorded excerpts.

I. Definition of Terms

Definitions for the terms employed in this study were determined by their general use in the reviewed literature.

Anechoic: material used to reduce sonic signal and reflection/reverberation, used in recording studios, as in: an anechoic chamber.

Blend: the process and effect of combining multiple voices, with no constituent voice essentially distinguishable from any other. Blend is achieved/occurs when, under normal circumstances and hearing, multiple sounds of like quality (e.g., voices, violins, trombones) are aurally processed as a single sonic event.

Factors influencing blend: uniformity of vowels, diction, tone quality, intonation, vibrato, balance, rhythm, dynamics, grading of tone in crescendo and decrescendo, number of available voices, method of vocal production, vocal maturity, seating arrangement, choice of literature, and age and experience of voices. Although many of the concepts of diction, tone quality, rhythm, dynamics, and vibrato may be correct in the context of solo performance, *one may be required to alter these elements in order to achieve choral blend.* (emphasis added to highlight premise) (Knutson 6)

Blend may also refer to the practice of common textual accentuation and pronunciation. In imitative textures it may refer to common concepts of timbre or phrase shape. Homophonic or treble-dominant textures may suggest an alternate ideal, calling for a particular voice to lead or predominate the overall texture within the proportions of the piece itself; the predominate part may even be distributed between voices. It is not the intention of this study to consider the specific implications of choral texture, that is, issues of melodic or harmonic prominence.

<u>Bright</u>: vocal color producing overtones at higher Hertz with increased intensity. (Giardiniere 116)

<u>Cardioid</u>: a "v" shaped pattern measured from a fixed point. Microphones set in a cardioid pattern will receive direct sonic signal from a concentrated area, reducing the collection of both the amount of direct signal from alternate sources and the sonic reflections from any sources present.

<u>Choral balance</u>: the relative level of loudness among voice parts.

<u>Choral blend</u>: the resulting choral sound in relationship to the combination of various voice types.

<u>Close Spacing</u>: adjacent singers standing shoulder-to-shoulder.

<u>Dark</u>: vocal color producing overtones at lower Hz with greater intensity. (Giardiniere 116)

<u>Decibel</u>: (abbreviated dB) term used as an absolute indicator of sound power per unit area on a scale from the threshold of human hearing, 0 dB, upward towards the threshold of pain, about 120-140 dB. As examples: the sound level in the average residential home is about 40 dB, average conversation is about 60 dB, typical home music listening levels are about 85 dB, a loud rock band about 110 dB, and a jet engine close up is 150dB.

<u>Feedback</u>: the sound a singer hears of his or her own voice.

<u>Formant</u>: a specific frequency peak within a sonic spectrum.

Hertz: (abbreviated Hz) a unit of frequency (of change in state or cycle in a sound wave, alternating current, or other cyclical waveform) of one cycle per second. It replaces the earlier term of "cycles per second (cps)." In acoustic sound, the range of human hearing is from 0 Hz to roughly 20 KHz. The pitch of Middle C on a piano is tuned to 263 Hz.

Lateral Spacing: adjacent singers standing with 24" between them, as in "windowed" choral formation.

Placement: positioning singers in their best placement in relationship to surrounding voices, where they and neighboring voices function in acoustical congruence.

Reference: the sound a singer hears of the rest of the choir.

Spacing: placing a pre-determined amount of distance between adjacent singers, as in close and lateral, in order to facilitate choral blend. (Daugherty 1996, 10)

Spectral Change: the average acoustic difference (Hz and dB), for the same singer, between the solo setting and an ensemble setting.

Spectral Shift: the average acoustic difference (Hz and dB) for the same singer, between different ensemble placement/spacing.

Vocal Match: when the production of vocal sounds by individuals concurs to form a new conglomerate sound in which individual vocal characteristics are present, but not noticeable. (Giardiniere 111)

Voice Matching: the process of discovering the appropriate placement of individual voices in an ensemble in such a manner that no single voice is distinguishable from any other, and where none of the vocal participants is required to alter normal vocal process.

Chapter II: Literature Review

A. Introduction

> Some conductors want to achieve a blend, and they are willing to compromise other vocal factors to do it, others want a certain kind of blend which will not compromise the voice, and still others do not consider blend to be important enough or desirable enough that they will sacrifice any qualities of expression and tone. (Knight 98)

Within the realm of choral practice vocalists are routinely required to alter their technical process. Blend is practiced as a malleable condition (verb) that must be frequently adjusted by each member of the ensemble, rather than being viewed and practiced as a constant effect (noun), that is the result of acoustic placement of individual singers within the ensemble. A review of the literature pertaining to blend reveals a variety of trends and opinions.

B. Blend as a Noun

> Too often blend is viewed by choral conductors as a group process with little attention to individual vocal technique. Blend can and should be a natural outgrowth of healthy vocal technique. However, it appears that blend in choral music has made a strange transition from noun to verb. In that transition, the individual vocal health of our singers has been affected. (Jordan 84)

There exists a wide diversity of opinion as to a functional definition of blend. Terms and vocal concepts linked with the effect of blend often include intonation, vibrato, vowel shape, and volume. Within the scope of these terms can often be found the attitude that any one of the number of vocal variables can and ought to be adjusted for the sake of achieving choral blend. Many writers have provided notable acoustic case studies in various categories related to blend: intonation (Liemohn, 1958; Mayer, 1964; Wyatt, 1967); vibrato (Wyatt, 1967; Trevor, 1977); and vowel shape (Hammer, 1965; Wyatt, 1967; Oldham, 1994).

Each of these studies relates the topic listed to the larger context of choral blend, suggesting that attention to the specific issue would resolve the difficulties of choral blend. In each instance the resolution includes alteration of individual vocal process. Certain studies presuppose that any change in vocal process a choral director may require would, of necessity, be contrary to the vocal health of the individual singer, and it is this assumption toward changed vocal process in the choral context that contributes significantly to the conflict between teachers of singing and choral conductors.

> When asked if they would try to alter the tone quality and blend of their group in order to achieve a sound which best fits the musical style and interpretation of the composition, all conductors interviewed said yes, they would try. Some feel that they could change the sound to a large extent, while others feel they could change the sound only slightly. The disagreement lies in the area of how they would go about changing the sound and how important adherence to musical style is in relation to tone quality and blend. The majority of conductors would agree . . . that the kind of tone quality they are trying to develop in a certain composition should . . . approximate whatever the conditions were vocally of the composer's music. (Knight 125)

Research concerning blend has centered on a variety of topics. Comparisons of solo and choral singing have been made by: Goodwin (1980); Rossing, Ternström, and Sundberg (1985, 1989); and Eckholm (1999, 2000). In each case the researchers, predisposed to the notion that vocal technique is of necessity altered between solo and choral settings, simply delineate existing differences. Under a similar series of assumptions, the rationale and practice of various conductors and teachers of singing have been explored by Knutson (1987), Slusher (1991), and Moore (1995). These studies outline individual routines, placing them in the continuum of musical practice without specific attention to the general application of idiosyncractic propensities. Further ideas comparing presumed differences include the work of Ekstrom (1959), Sundberg (1980), Ternström and Sundberg (1983), and Ternström (1989). Each study offers a foray into concepts of the individual singer hearing himself or herself within the choral ensemble context. These focus on acoustic surveys of the "self-to-other" ratio, i.e., how clearly a singer hears himself or herself (feedback) in direct proportion to his or her ability to process the sounds of others (reference). The specific applications deal with intonation, the level of individual volume, and spacing. These studies also assume altered vocal technique. Finally, some acoustic surveys concentrate on the acoustics of musical spaces: Sundberg (1982) and Naylor (1987). While the underlying assumption of these studies is altered vocalism, the research core investigates how the acoustic properties of various musical spaces and performing venues weigh in on other issues, such as intonation and blend. Sten Ternström and Johann Sundberg broach the topic of acoustic vocal interaction in a variety of studies. Rossing, Ternström, and Sundberg have explored differences between solo and choral singing (1975-99). Rossing, et al. cite, "Choir singing and solo singing are two distinctly different modes of musical performance, making different demands on the singers. Many singing teachers are reluctant to let their students practice choir singing, because they believe that choir singing requires a voice usage quite different from that used in solo singing." (2)

A common fallacy among researchers and choral practitioners is the assumption that singing technique must be substantively altered in order to successfully navigate the musical demands of each environ. The requirement of constantly altered technique on the part of singers who generally lack the proficiency to do so, elects one "mode" of singing above the other and sacrifices vocal integrity and health for musical effect. Of further concern is that the preponderance of these studies were conducted with recorded examples heard by the subject over headphones, instead of using live examples. This does not offer the subject the ability to interact *acoustically* with other sounds, merely to process and react to the aural presentation of recorded sounds. In effect, this nullifies the assertion that the study can be applied broadly to the choral environment, where numerous individual sounds are simultaneously processed into a single entity.

Sundberg believes in the desirability of knowing that the same type of voice timbre is not sought in choral and solo singing. (Vocal 11) Miller shares this belief and points out major differences between the vocal tone concepts of choral conductors and singing teachers. (Solo 31) This indicates the existence of aesthetic preferences within the larger voice community toward one type of solo or choral singing; in fact, the choice of timbre in singing may be subjective, influenced by the preference of the conductor, composer, or singer. Slusher discusses the varying perspectives of conductors, voice teachers, and students about solo and choral singing. (19) A wide variety of timbral preferences can be found in both the professional and amateur singing ranks, particularly in choral singing. (Swan, qtd. in Decker 7) This study purports that choral tone is the aggregate result of the choral participants, rather than a preconceived entity, and that the blending of individual sounds is feasible without surrendering or manipulating individual vocal process. It is the specific contention of this study that during the voice matching process, a quantifiable acoustic phenomenon coincides with the discovery of vocal matches and, further, that this achieves the effect of choral blend without the exploitation of individual vocal process.

C. Historical Models

> Like it or not, false blend occurs in many of our ensembles at the expense of the vocal health of young singers. (Jordan 26)

Howard Swan describes diverse practices and models of choral tone production and blend associated with specified conductors from the early part of the twentieth century. As previously stated, these schools are specifically related to the conductors credited with their inception; however, the literature routinely cites two of these schools as foundational models, and as such, bear some scrutiny. Several studies (Decker, Knutson, Tocheff, Daugherty) refer to one extreme of choral practice as the "St. Olaf" tradition, and provide fine summaries of its concepts. F. Melius Christiansen, the founder of this choral school, is quoted as having practiced a system of blend in which "every singer . . . has a primary responsibility to subordinate his own ideas concerning tone production . . . to the blended and unified sound made by the total ensemble." (Decker 12) This school purports that singers must manipulate individual technique and tone to achieve a similar color, thus creating blend. (Tocheff 15)

As recently as the May/June 2002 issue of *The Choral Journal*, renowned vocal pedagogue Richard Miller describes the principles of what he labels the "British" and "Scandinavian-Lutheran" choral traditions, where ". . . jaws are hung and back vowels are favored as a means of masking the individual quality of solo voices." (Miller, Imaginative 417)

James Daugherty cites this tonal practice as a "one size fits all" approach to vocal production and voice quality, requiring all singers of a particular voice part to match or imitate the sound of a preconceived ideal voice. (Spacing 40) This technique of blending voices seems particularly suited to the demands of *a cappella* choral literature.

> Christiansen . . . believes that the perfect choir is an organism in which every member loses his identity for the sake of the ensemble. (Bergmann, qtd. in Knutson 18)

> I don't believe in creating blend for blend's sake; I think it must be a result rather than a cause. I think there was a period of time in this country when people went for blend first. Then we heard a false sound and had a very dull situation. (Decker 42)

Eckholm reports that singers ". . . found that blended singing created a greater degree of tension in the vocal apparatus than soloistic singing." (1999 45)

She further conveys that,

> Blending with a choir may be more problematic for higher voices than for lower ones. Sopranos, in particular, indicated vocal discomfort and difficulty reaching notes at the extremes of their range when singing in a blended mode. Tenors may have to switch to falsetto register to reach their higher range comfortably in blended mode. Altos and basses may have fewer problems with choral blend. However, when forced to sing in the lower extreme of their range, basses complained of difficulty focusing the tone in the blended mode and a resultant need to "push" in order to project the tone. (1999 123)

The substantial influence of the St. Olaf blending practice can be seen in many modes of blend procedure. Singers are often instructed to "listen to those around you and match their sound." This instruction offers little clue as to the intention of "matching," whether that be volume, timbre, vowel shape, or pitch. Some procedures begin by placing a "model" voice in a key position within a section, whether that be a timbral model or a singer with a specifically desired trait, such as sight reading ability or overall strength of sound. (Haasemann and Jordan 91) Surrounding singers are instructed to pay particular attention to these key voices. In contrast, Finn says, "It is not so much the quality of color of individual voices that causes problems with the blend in a section, but the increased amplitude of a small number of voices that substitutes the sound of a few for the sound of the whole section." (qtd. in Knutson 45) These concepts will be discussed as part of micro-formation.

The other extreme, the "Westminster" school, follows the practices of John Finley Williamson, who viewed individual vocal timbre as beneficial to the overall choral sound. "The conductor needed to be concerned with improving the vocal production of each singer. Each rehearsal was to be treated as a voice class where the conductor worked to develop full, sonorous, vitalized tone." (Williamson, qtd. in Knutson 28) Decker states that, "To a considerable degree the director is concerned with the growth of the individual . . . and gives somewhat less attention to the needs of the group." (12) Speaking of this school, Tocheff maintains, "Individual vocal differences are assets to blend. Good choral blend is the resulting sound of a properly combined group of individuals singing freely and naturally with good technique." (14)

The primary tenet of the Westminster practice was the development of individual vocal function. Singers were encouraged to use the full weight and color of the voice as an expressionary tool within the choral ensemble. The pervasive opinion of this practice was perhaps formed as the specific result of this choir's interaction with large symphonic orchestras, requiring a more full-bodied vocalism to project through the orchestral texture. Blend was achieved as the aggregate sounds converged with the orchestral sounds, ultimately as they reached the audience. This practice seemed particularly suited to the needs of Romantic choral/orchestral literature.

Concerning this school, Tocheff observes, ". . . too often the basic ingredient of true choral singing, a well-blended texture of choral sound, is lacking. A choral group cannot actually be referred to as such unless it projects an integrated effect. Until that occurs the group is merely a collection of individual voices unified only thorough physical and mechanical means." (12)

Other conductors constructed a philosophy of blend within this school of thought, depending on the venue in which each choir regularly performed. Referring to radio broadcasts, Fred Waring's practice was that, "The placement of each singer within the choir was determined by the voice quality. The heavier voices and the voices which projected the most were placed furthest from the microphone in order to avoid the dominance of any one individual voice." (Knutson 35)

Waring is also noted for his use of "tone syllables," or the specific rhythmic placement of various sung sounds, as a means to blend. "In order for one to achieve a blended sound according to the Waring school of choral singing every singer must learn to voice every syllable at exactly the same time as the other members of the group." (Knutson 37)

Robert Shaw once said: "The greatest choral sound is made up of the greatest solo voices. The only reasons that it might be difficult to form a chorus out of the greatest solo voices have nothing to do with their sound, but have everything to do with their musicianship, i.e., the individual singer's ability to sing in tune and at the right time." (Knutson 68)

Margaret Hillis writes, "This chorus [Chicago Symphony Chorus] does not have a 'choral tone.' To impose such inflexibility on a score is musically dishonest, even if superficially successful. Instead, we strive for a musical sonority appropriate to the expressive content of the particular composition to which we are committed." (5)

Joseph Jennings says, "A blended sound results when there is a balance between the volume of sound produced by individual voices within a section or large ensemble. [A] well produced voice will result in a healthy quality which will color the section rather than 'stick out.'" (Knutson 73)

Within these permutations of the Westminster blending practice, individuals producing the singer's formant are likely to be found within the ensemble. Research by Ternström and Sundberg (1982, 1983, 1989, etc.) acoustically shows that the singer's formant is reduced to a significant degree by singers attempting to blend. Their research, further, asserts that

> It would be inappropriate for a singer to sing with a singer's formant in an amateur choir. Doing so, this singer would fail to blend with the ensemble sound (c.f. Sundberg, 1977). On the other hand, if all members sing with a singer's formant, the blending should not be affected. This might be the case in some opera choirs, consisting of more soloistically trained singers. In any event, the degree to which a singer's formant is present in a choral sound must be relevant to the timbre of the choral sound. (Ternström and Sundberg, qtd. in Neufeld 43)

Ternström and Sundberg suggest that in order to successfully achieve choral blend, either each singer within a given ensemble must create the singer's formant or none of the singers should produce this acoustic effect. However, Sundberg's research on the singer's formant (Acoustic) suggests that the creation of the singer's formant is the most efficient method of singing.

Bolster also discusses the implication of vowel formants to the choral blend process.

> Every musical instrument, including the voice, has fixed pitches by which sympathetic resonance augments whatever partials of the fundamental are in tune with it. These bands of exaggerated partials are known as formants. Each vowel and consonant has its own characteristic pattern of overtones associated with a specific shape of the human resonating cavity. Each vowel is distinguished by the first two formants. These formants (bands of energy) occur at the same frequencies for any given vowel regardless of the fundamental, therefore, vowels, in this sense, have pitch. Bolster asserts that often in the female's upper range, the sung pitch is higher than the formant of certain vowels. She must, then, modify the vowel by raising the lowest formant frequency to match the fundamental. Concerning the singer's formant, Bolster states that the voice works more efficiently with its presence, and that fatigue is caused when it is intentionally removed (e.g. continually asked for softer dynamics). Rather than asking for its removal, Bolster contends that this formant should be developed in all singers. (Tocheff 19)

Bolster's findings, that the most efficient use of the vocal mechanism includes the singer's formant, have specific implications for choral blend. Goodwin delineates specific differences in the vocal process of solo singers and singers attempting to blend. (127) While the choral "instrument" is the aggregate sound of the combined voices, great care should be exercised to avoid impeding the ability of the individual singer. Yet, blend as a desirable choral characteristic, implies that no single voice is distinguishable from any other within the choral texture.

Heffernan says,

> By no means do I advocate training a choir to sing always with the same tone. In spite of those well-known groups who are revered for their light or dark tone, the one-color approach is essentially wrong in that, unless the choir sings from a limited period of music literature, the one chosen color will be inappropriate for at least half the repertoire being performed. (86)

Similarly, Swan queries,

> Are there choruses who can change their tone at will to correspond with the interpretive demands of the composition? Perhaps a group of professional singers can do this. Most of us must continue to make choices - not only of repertoire and of the music which we like best (and which we usually conduct best) but of the kind of tone which we enjoy hearing from our chorus. We will conduct more effectively if we accept the premise that there will be a strong relationship between the tone used by our singers and the kind of music which we like best to hear them sing. (13)

Swan tacitly implies that the most complex task a choir may face is the deliberate alteration of choral tone. Yet, "Voices can openly clash, creating harsh, unpleasant sound combinations. Conflicts can occur even between two fine voices." (Knight 50) Therefore, a method of blending should be employed that does not require manipulation of individual vocal process. Research to date includes two possibilities: blend through spacing and blend through formation.

D. Comparisons of Choral and Solo Singing

> A primary aesthetic concern of choir singing is that individual voices should not be discernible as such. Choir singers are required to achieve a blend of their own voice with the sound of the rest of the choir. In a general sense, this means that each singer, in addition to performing the music, should strive to make the sound of his or her own voice similar in character to that which is prevalent in the group. (Ternström and Sundberg, Acoustical 517)

> Choral singing and solo singing are two distinctly different modes of musical performance, making different demands on the singers. (Rossing, Voice 1; Acoustic 1975)

As mentioned previously, the fundamental assumption that choral and solo singing must of necessity make different demands on the singing voice has sparked many debates between teachers of singing and choral conductors. This conflict has been further exacerbated by the demand to manipulate individual vocal production to match an arbitrary aggregate choral tonal ideal, such as the St. Olaf tradition. While practices of dynamics and tempo are subject to the demands and interpretation of the conductor, choral ensembles can employ blending practices that do not require the individual singer to substantively alter basic vocal function. Most of the acoustic research into choral singing has adopted the above premise, without regard to the possibility that significant alteration of basic individual voice function is unnecessary. As such, a summary of these findings is provided.

> Goodwin's findings show convincing evidence of the vocal process of blending by alteration of an individual sound. The long-argued claim that blending was achieved through alteration of an individual vocal character had become more than a claim. It had blossomed onto a genuine vocal concern. (Giardiniere 20)
>
> Goodwin (1980), in an article derived from his dissertation (1977) on individual voices in choral blend, emphasized, "when choral singers are placed so that each singer can hear himself and the rest of the choir, individual singers tended not to 'oversing . . .' A singer monitors his or her sound by what she or he hears of it. If a singer 'is placed in a situation where he cannot hear himself adequately (e.g., crowded together on risers), the singer will <u>unconsciously</u> and <u>intuitively</u> sing louder" (pg.6). In other words, if surrounding choristers were too close and singing in a way which made it difficult for an individual to obtain adequate feedback form her or his own voice, the individual compensated by singing louder. (Daugherty, Spacing 61)

Daugherty somehow fails to apprehend the significance of his own summary of Goodwin; i.e., "... singing in a way which made it difficult for an individual to obtain adequate feedback ..." has direct implications for the importance of voice matching.

Goodwin's data were obtained from trained singers. Most choirs include both trained and untrained singers, but it is unclear to what extent relative amounts of training influenced the results. In addition, Goodwin's study of blended sounds requires the individual singer to interact with recorded sound replayed through headphones. This study leaves some questions unanswered: What level of vocal training is necessary to acquire the ability to healthily and consciously alter individual sound?; Do all singers unconsciously alter vocal process as a function of blend?; and, How might the results change when studying the interaction of live rather recorded subjects?

> In a similar vein, Ternström and Sundberg (1984) made an acoustic comparison of voice use in solo and choir singing. Rossing, Sundberg and Ternström (1986) found a difference in voice timbre between solo singing and choral singing among male bass and baritone singers. Rossing, Sundberg, and Ternström (1987) found that female singers tended to produce more energy as soloists than as choristers. (Daugherty, Spacing 69)

Moreover, the change in vocal production, "... appears to be accomplished through adjustments in both articulation (adjustment of formant frequencies) and phonation (change in glottal waveform)." (Daugherty, Choir 5) These studies also record the interaction of subjects with recorded sounds and do not resolve the questions left unanswered by Goodwin.

Of some concern is that,

> [O]nly Ternström (1989) studied choral singing in a genuine choral environment. Rossing, Sundberg, and Ternström presented evidence of differences between solo and choral singing. (Neufeld 45)

> In a pure sense, these studies did not deal with choral singing in real terms; rather, they simulated a choral environment with the aid of technology. Informal comparisons by the investigator of personal singing experiences in a recording studio with the headphones and microphones to a concert or rehearsal hall surrounded by live singers revealed a marked difference in singing quality, aural feedback, and attitude. The singer in a studio, no matter what aural feedback is present, tends to function as an isolated individual. Choral singing in its purest form does not create this sense of isolation, instead fostering a sense of being part of the entire ensemble. The techniques used to produce commercial choral recordings seem to support this assertion. Microphones are placed in front of the ensemble, not in front of each individual. It appears that there are acoustic differences between the sound of an ensemble and that of a group of individuals. (Neufeld 44)

More recent studies address the issue of live subjects.

> Ford (1999) found significant preference for non-resonant choral tone among undergraduate students, including those with choral training, those with instrumental training, and persons with no training in either choral or instrumental music. Most subjects clearly preferred non-resonant (i.e., without singer's formant) choral tone. Moreover, choral training appears to increase such preference. (Daugherty, Rethinking 5)

Ford's study also fails to address these questions, merely citing preferences for the use of the singer's formant in choral tone. This study only serves to reinforce the conflicting choral/vocal stereotypes.

Eckholm asserts:

> Choral singing appears to involve some compromise in vocal technique for trained singers. There is clearly a difference between the vocal techniques used in solo singing and in choral singing. This is partly due to opposing aesthetic requirements of the two modes: the requirement that the solo voice be differentiated from the background sound versus the need for the choral voice to blend in with the surrounding sound.
> (2000 124)

She further states:

> Differences in vocal production were readily perceived by expert voice teachers who listened to individual singers in solo and choral settings. Moreover, the difference between solo and choral singing was greater when choristers were asked to blend their voices with those of singers around them than when they tried to maintain their normal solo vocal technique in the choral setting. (2000 122)

Eckholm's conclusions are empirically suspect, as they rely solely on the preferences of auditors and do not include the backing of acoustic data. Moreover, microphones of different construction and sensitivity were use to record the individual sounds appraised by the auditors. Her study does serve to underscore the division of opinion among choral/vocal practitioners. She further reports that singers ". . . found that blended singing created a greater degree of tension in the vocal apparatus than soloistic singing." (45) Her conclusions allege that singers inevitably alter normal vocal production in the choral setting, but do not clarify the extent to which this occurs. (44)

The underlying assumption of these studies is that the individual singing in both choral and solo contexts will of necessity alter vocal sound. Their mode of discovery was either to identify isolated traits of the assumed alterations or to survey preferences for the use of the divergent sounds. These studies comprise the body of research into the acoustic interaction of voices in choral settings, yet none address the needs of the individual singer, nor do the studies acknowledge the possibility that unaltered vocal sounds may interact in complimentary fashion.

E. Blend Through Spacing of Voices

One approach to blend which purports to eliminate a great part of the need for individual vocal change is placing sufficient space between voices. The main tenet for this practice is that the acoustics of most conflicting voices will eventually come to a point of resolution given an appropriate distance between the two conflicting sources.

Dale Warland attempts to demonstrate this effect in a commercial video using the Dale Warland Singers. Warland says that the voice needs space around it to realize its full potential. He further asserts that space between singers reduces the influence of voices to the right and left of the individual singer. He attempts to demonstrate this spatial effect by instructing the ensemble to sing the same musical excerpt in close and lateral spacing. This demonstration of spacing placed onto a video sound track may be more influenced by the visual effect of spacing, rather than specific aural transformation. Warland cites absorption of sound by surrounding bodies as one of the reasons spacing is effective. (Warland) His demonstration of this is by crossing his arms in front of his face. Whether this muffles the sound of his voice or simply alters the response of his lapel microphone is unclear. Regardless, it is evident that Warland regards spacing as crucial to the overall choral sound strata.

A crucial part of ensemble singing is the ability to hear oneself (feedback) and surrounding singers (reference).

> This [feedback to reference ratio] would lead to a tendency for the entire choir to change its reference pitch during the performance of a piece. The effect should then be possible to reduce by changing the amplitude of the individual singer's external reference, i.e., by spacing the singers more, by bringing them closer together, or by changing the acoustic properties of the room. (Ternström, How Loudly 24)

The principles of spacing seem to increase the possibility of successfully achieving the requisite proportion of feedback to reference. However, certain voices may negate the ability to hear feedback, due to acoustic conflicts between the singers' voices. Certain voices will not blend in adjacent position regardless of the amount of space between them, and space resources are often limited by stage dimensions and riser placement.

James Daugherty, like Warland, proposes that the key to blend is spacing between voices. Daugherty cites Ternström's research that asserts the most important relationship in choral singing is how well an individual can hear his or her own sound in proportion to his or her ability to hear the sounds of other ensemble members. "The choir singer's perceptual task of parsing a composite sound, such that the sound of one's own voice may be discriminated from that of a number of other similar voices, would seem to present an unusual challenge to the auditory system." (Ternström, Hearing 300)

"A singer's section colleagues sing the same notes and the same text, and are therefore the most efficient maskers of his or her feedback." (Ternström, Hearing 11) It is according to this research that Daugherty finds close spacing (no space between adjacent singers) problematic. "The reference may mask the feedback when the choir is crowded onto a small podium and/or in especially reverberant rooms." (Ternström, Hearing 11) While acknowledging lack of space as a potential issue, Daugherty (Spacing 1996) fails to address the needs of the average choir director who routinely works with space limitations. He also fails to consider that the nature of spacing practices depends upon intimate knowledge of singers and the room in which they are singing. "There would . . . be little point in separating the singers by more than the reverberation distance of the room."

(Ternström, Hearing 11) This presents practical difficulties for festival and touring situations. It is in a later work that Daugherty (2001) begins to present alternate concepts of spacing, not specifically to address confinement issues, but rather issues of balance. Ternström's research, further, implies that too much space between singers can be problematic as well. Neither Daugherty nor Ternström consider the possibility that the issue of masking, that is, when individual feedback is "drowned-out" by the reference, may be resolved by the process of acoustic voice matching.

Daugherty's initial attempt to describe the process of spacing is limited to risers of an eight-inch elevation and twelve to eighteen inches in depth. (Spacing 1996 82) Williams, cited in Tocheff, advocates a riser elevation of twelve to fourteen inches. (Tocheff 24) Daugherty studies the effects of using close, lateral, and circumambient spacings (close spacing refers to a shoulder-to-shoulder relationship of adjacent singers; lateral spacing refers to a specified amount of spacing between adjacent singers; circumambient spacing adds to lateral spacing additional space between parallel rows of singers). Although he touts circumambient spacing as optimum, he also acknowledges that amateur singers prefer close spacing. Circumambient spacing, then, fails to address the issues of choirs with singers of mixed or amateur ability. Most choirs are not comprised of singers of professional quality and need a different solution to blend. Daugherty furthermore fails to address the issues of contest and tour performances, when space may be severely limited, and circumstances when time in an unfamiliar venue does not allow for the necessary experimentation with spacing.

Daugherty's premise seems to be that any two voices, given sufficient space between them, will produce a blended sound. Although he sets basic spatial parameters for his study, he never addresses the question of exactly how much space might be necessary to blend two voices; it may be inferred that the space used for his study is to be emulated in practice. It is, however, conceivable that two voices may conflict so much that not only would the space used in his study not be sufficient, but the space required to "blend" would actually result in the receiving ear processing them as two different source sounds. This concurs with Ternström's assertion concerning the reverberance of the room restricting the available spacing. Furthermore, he seems in later studies to withdraw from his early spacings, citing that different situations will require different spacing and implying that spacing is no longer a definitive process, but is instead malleable to the particular set of singers and circumstances.

In various studies Daugherty reviews the various surveys of voice placement as a means to blend, asserting that the studies were flawed and merit little practical value for use; he further states that formation processes are idiosyncratic to particular conductors and are not replicable. The cited flaws center on their lack of empirical data and the lack of standardized procedure between them. Daugherty's assertion is that voice matching procedure is successful largely due to the spacing apart of singers with incompatible vocal production characteristics.

Daugherty consistently cites that his studies show a marked preference among auditors and singers for spacing over formation. However, after declaring that his study is empirical and that none of the formation studies, for want of empirical evidence, bears scrutiny, his comparison of spacing and formation is baseless. The only credible conclusion Daugherty can assert is that his analytical process was more empirical than the formation studies he cites. In fact, the formations used in Daugherty's study were randomly generated macro-formations that placed singers in sections and mixed formation without regard to individual vocal placement.

Eckholm finds that, "Choristers . . . expressed a significant preference for the acoustic seating arrangement over the random seating arrangement for both vocal comfort and aesthetic quality." (1999 44) Daugherty contends that flaws exist in Eckholm's findings, but fails to delineate the flaws. (Choir Acoustics 12) Instead of comparing random formation and acoustic placement as does Eckholm, Daugherty consistently makes use of random placement.

Other criticisms of formation studies by Daugherty are that the processes are idiosyncratic to particular conductors, are not readily replicable, and require a great deal of trial and error to be useful. Daugherty's study in 1996 carefully delineates a particular spacing for choral groups. Yet, Daugherty himself declares, "Some experimentation is likely needed to determine optimal spacing conditions for particular choirs and particular singers in particular venues." (Choir Spacing 80) No longer do we find spacing as standardized procedure, but only as a concept that can be manipulated as necessary for multiple applications. However, throughout his writing, Daugherty continues to require formation studies to meet the primary criterion of standardization.

> Such experimentation, though, is perhaps in itself of pedagogical value. Allowing singers to assist in the process of experimenting with spacing by soliciting their evaluations and preferences from one spacing formation to another focuses their attention on nuances of choral sound and permits them more ownership in the sound of the choir as a whole. (Daugherty, Choir Spacing 80)

Daugherty admits that, "It may not be a good idea . . . to initiate circumambient spacing as a fixed protocol with a beginning choir the moment the first rehearsal begins." (Choir Spacing 80) Despite his assertions concerning the superiority of space, however, choirs *always* exist in some type of formation.

A final assertion of Daugherty's is that no formation studies have evaluated large, intact choirs. In so saying, he fails to acknowledge the full choir studies of Tocheff and Giardiniere.

Daugherty cites that his studies are done empirically, with replicable standards of spatial dimension. Yet, the spacing of his pilot study is not always used in his subsequent writings. Daugherty goes on to encourage experimentation with various concepts and spatial dimensions. He offers alternate spacing illustrations that don't match his initial premise and dimension. Rather than describing an empirical, replicable spacing procedure, Daugherty is, in fact, only describing general spatial principles. Therefore, the studies of Tocheff and Giardiniare describing the principles of voice matching are equally empirical, under Daugherty's own practice, despite his stated standard of measurement.

In the body of his initial study Daugherty acknowledges that voice matching may have value once it is defined more clearly. (Daugherty, Spacing 1996 171) In fact, the summary of Daugherty's initial study, as well as his subsequent articles and publications, clearly contends that spacing is more successful than formation and (by implication) voice matching. "Results clearly suggested that choir spacing made a greater contribution to choral sound preferences of both auditors and choristers than choral formation." (Daugherty, Choir Spacing 79) Yet, the random placement of singers in his study does not afford him the luxury of empirical comparison with voice matching. The value of this assessment is speculative, at best.

To the contrary, Eckholm states that,

> Vocal production was judged to be better in the acoustic seating arrangement than in the random seating arrangement. This result implies that positioning choristers so that adjacent voices are acoustically matched gave them a greater impression of blending naturally. Thus they felt less need to restrain their voices in order to achieve an acceptable degree of homogeneity. (101)

Daugherty's initial study begins by outlining alternate spacings to be used within traditional concepts of choral formation. His various writings through 2001 highlight a number of possibilities with regard to the spatial placement of choral forces, according to particular ensemble and venue requirements. Daugherty continually asserts that his research is distinctive from the concepts of choral formation. Careful scrutiny of his literature reveals a predilection for the inclusion of formation practices as an essential component of overall choral sound. More exactly, spacing should be regarded as a component of formation study.

> Thereafter, *nuances* in choral landscape can be achieved by: choir spacing; conducting gesture; **choir formation**; **voice compatibility matching**; proactive rehearsing. (emphasis added) (Daugherty, Rethinking 14)

> Once the optimal arrangement is found, no singer will need to feel unproductive or that he should hold back because of the character of his voice. Each singer must be free to use the full range of his tonal color and resonating capacity if the choir is going to preserve its flexibility, be capable of performing different styles, and stay in tune. A voice will not add to the quality of the choir if it is in conflict with other voices or if it is swallowed by more dominating sounds. The conductor should treat each singer as an individual with special talents whose placement in the ensemble is of critical importance to the sound of the choir. (Johnson, Choral 13)

While acknowledging the potential value in formation practice, specifically voice matching, Daugherty reveals his essential misapprehension of the intention of voice matching by identifying voice matching as a "non-confrontational way to place unusual voices or behavior problems within the choir in a position of least influence." (Rethinking 9) The premise of voice matching is not to mask individual vocal quality, but to offer placement within the ensemble where each voice may comfortably contribute to the total sound of the ensemble, without eclipsing the aggregate sound texture. What is yet required is to cite the acoustic principles that delineate when blend occurs, whether by a vocal match or by spacing.

F. Blend Through Singing Formations

> Most choral conductors would agree that the primary goal of their efforts is to produce a choral sound that is balanced, homogeneous, and blended. There is some disagreement, however, as to the best approach for producing such a sound. Two basic problems face most conductors: that of fitting varying degrees of student expertise, maturity, and talent into an ensemble mold and that of managing voices in the choir that "stick out"- that are larger, more resonant and more powerful than other voices in the group. The key to the solution of these problems lies, to a considerable extent, in the way singers are positioned in the ensemble, and the degree to which the conductor will allow himself to experiment with different sounds produced by different arrangements of personnel. (Johnson, Choral 12)

> Differences of quality do not usually mar the blend of any choral line. On the contrary, they tend to enhance its musical value. (Knutson 46)

Numerous studies and articles explore the possibility that a viable solution to the issue of choral blend without substantially sacrificing individual vocal integrity is found in the acoustical placement or formation of voices. By the term "acoustical," Tocheff (1990) describes the application of a voice matching process to yield sectional and mixed arrangements, that is, positioning individual singers in relationship to surrounding voices in such a manner that individual vocal characteristics were no longer noticeable. "The important concept to learn is that changing the seating position of your choir is a possible solution to various musical problems, and each arrangement will create an entirely different sound." (Brinson 49)

> Twentieth century choral methods literature reflects considerable opinion and preference with regard to placement of singers in choral formation. Generally, such perspective may be grouped into two major areas of focus: a) macro-arrangement concerns; and b) micro-arrangement concerns. Macro-arrangement refers to positioning the choir and each of its voices [sic] sections as a whole. Micro-arrangement refers to the positioning of individual singers within the choir or voice section. (Daugherty, Spacing 1996 21)

1. Macro-arrangements

> Many conductors endure needless frustration trying to remedy "blend" and pitch problems that are caused by inappropriate positioning of singers; most pitch difficulties and many blend challenges can be corrected through a simple alteration of seating. (Hassemann and Jordan 46)

Macro-arrangement generally refers to positioning members of an ensemble based on voice part rather than individual vocal character. This includes formations based on lateral or horizontal section blocks and mixed formations, either by design or random placement.

Certain writers cite various rationales concerning the use of sectional formations. These include: improved intonation (Webb, 1993), more effective part cueing (Hammar, 1984), more efficient learning of music (Wilson, 1959; Alderson, 1979; Gordon, 1989), and formant concerns (Hammar, 1984). Further discussions center on the positioning of voice sections within the ensemble. (Brewer, 1991; Brinson, 1996; Kohut and Grant, 1990; Busch, 1984) Some writers cite possible disadvantages to sectional order, such as: faulty intonation, dependence of weak upon strong singers, and the possibility of one strong voice influencing the entire section adversely. (Diercks, 1961; Stocker, 1975; Busch, 1984) Other writers prefer mixed formations, citing improved intonation. (Brinson, 1996; Hammar, 1984; Hassemann and Jordan, 1991) Webb (1993) clarifies the intention of mixed formation by suggesting that it may offer the "whole architecture of a chord . . . to all singers, presumably aiding choral intonation."

Some of the major figures in twentieth-century choral conducting have modeled the use of mixed formations. Stocker asserts that the use of mixed formation by these well-known ensembles contributed to the popularization of such arrangements in the United States.

> According to Stocker (1975), the Robert Shaw Chorale (1947-1965) normally employed a mixed formation, as did the Norman Luboff Choir. Robinson and Winold (1976) reported that the Roger Wagner Chorale used a mixed arrangement for music other than Renaissance polyphony. Kortkamp (1969) reported that Fred Waring preferred the mixed arrangement for his Pennsylvanians. (Daugherty, Spacing 1996 28)

Other macro-arrangements are discussed, such as "scrambled," that is, mixing voices without regard to the symmetry or specific balance among voice part distribution. (Boyd, 1977; Lamb, 1988; Webb, 1993) Still another category is the modified arrangement, which variously combines the principles of lateral and horizontal sections and mixed formations. (Lamb, 1988; Gordon, 1989; Hassemann and Jordan, 1991; Webb, 1993) The variety of macro-formations corresponds to the wide array of issues that may be encountered in choral settings, such as unequal section members, either in number or volume.

2. Micro-arrangements

The choral formation chosen should promote both vocal independence (Garretson 245) and corporate responsibility. (Pfautsch, qtd. in Decker and Herford, 1973) Micro-arrangement involves the placement of individual singers according to the pairing of specific, graded characteristics, such as: loud vs. soft volume; mature vs. immature tone quality; and faster vs. slower sight-reading ability.

Various placements based on the above criterion exist, each with specific rationale. Suggestions include: placing strong singers behind or between weak singers (Roe, 1983; Gordon, 1989); placing the strongest singers at the core of the ensemble (Mielenz, 1966; Busch, 1984; Swears, 1985); the alternation of strong and weak singers (Hoffer, 1983; Kohut and Grant, 1990); and the alternation of singers with excellent and mediocre tone quality. (Lamb, 1988)

Some authors recommend the positioning of singers according to the intrinsic characteristics of the individual voices. A variety of opinion exists with regard to the mixture of like and opposite vocal traits. Certain practitioners believe that blend is best discovered when opposite voice types are paired. (Diercks, 1960; Busch, 1984; Lamb, 1988; Pfautsch, in Decker and Herford, 1988; Haasemann and Jordan, 1991; Noble, in Giardiniere, 1991; Johnson, 1997)

Certain authors suggest micro-formation based on labeling each voice using contrasting instrumental timbral designations such as flute, reed, and string. (Krone, 1945; Ehret, 1959; Busch, 1984) Others contrast vocal timbre using descriptors such as light, airy, medium, and heavy, full, and dark. (Decker, qtd. in Knutson, 1987; Haasseman and Jordan, 1991)

Still others contend that the pairing of like voice types offers the optimum quality. (Molnar, 1962; Johnson, 1978; Roe, 1983; F. Melius Christiansen, in Knutson, 1987) Some conductors will use a modified procedure of grouping like voices, i.e., a progression of dark-to-light tone quality. Aitken attributes to Rodney Eichenberger the process of placing the ". . . heaviest textured, more-resonant voice in the center of the ensemble and then plac[ing] the 'not-so's' next until the end of each soprano, alto, tenor and bass line had the lighter, thinner-textured voices." (17) However, later in the description, Aitken asks these questions of his singers as part of the blending process: "Do they blend? What about balance? Intonation? Someone may be asked to change their sound. Can they sing a lighter sound? A more resonant sound?" (17) Aitken also points toward voice matching, which in some way negates the need for his earlier questions. "We may substitute a different person who has a different sound until the desired small group blend and balance is obtained." (17)

Regardless of the rationale, it seems clear that "The balance, blend, and even the tone of a choir will likely change as different placements are used," (Lamb, 1988), and that conductors ought to ". . . be aware that considerable variance in sound will occur according to the placement of the singers within the section." (Heffernan, 1982)

3. Voice Matching

> Chorus effect: occurs when many voices and their reflections create a quasi-random sound of such complexity that the normal mechanisms of auditory localization and fusion are disrupted. In a cognitive sense, the chorus effect can magically dissociate the sound from its sources and endow it with an independent, almost ethereal existence of its own. (Ternström, qtd. in Daugherty, Rethinking 20)

"The original practice of voice matching and experimentation with placement of individuals in a choral ensemble can largely be traced to the tenure of one man as a conductor and founder of the St. Olaf Choir: F. Melius Christiansen." (Bergman, qtd. in Giardinere 16) Christiansen, however, eschewed blend as the key to beautiful ensemble sound, using a system of individual vocal subordination rather than individual acoustic placement. Swan remarks that, "No single approach to choral sound has sparked the level of discourse, often extremely emotional, as has Christiansen's, nor has his method existed without harsh criticism as well as overwhelming success." (Swan, 1973 and AATS, 1964, qtd. in Giardiniere 17)

Giardiniere continues,

> A great outcry immediately emerged in the form of symposia, dialectics, and published writing and has continued almost uninterrupted about this practice and its effect on the vocal health of an individual submitted to this form of training. Virtually every director since Christiansen has been forced to deal with this precept, and with the possible effects of blended singing on the individual voice. (17)

Twentieth-century studio training by nature fosters a vocalism designed to permeate its aural climate. Conversely, twentieth-century choral practice demands a vocalism that coalesces with its aural surroundings. This contrast in desired outcome places singers in an amorphous milieu of altered vocal practice. The average singer lacks sufficient training to successfully navigate this variety of demands. Eckholm found that singers had difficulty maintaining freedom of vocal production when asked to alter vocal production in order to blend. (1999 111) Voice matching offers practical resolution to this conflict.

> Having been trained as a voice teacher and having products of at least 8 other voice teachers, as well as untrained voices, in my choral group it was especially desirable to develop ways of producing a choral tone which would not disturb the voice of the studio products and developed the voices and ears of the untrained. (Diercks 45)

> The most important factor . . . is that this system avoids any mechanism change on the individual's part. (Mielenz 13)

> Each singer must be free to use the full range of his tonal color and resonating capacity if the choir is going to preserve its flexibility, be capable of performing different styles, and stay in tune. A voice will not add to the quality of the choir if it is in conflict with other voices or if it is swallowed by more dominating sounds. The conductor should treat each singer as an individual with special talents whose placement in the ensemble is of critical importance to the sound of the choir. (Johnson, Choral 13)

> Experimentation with voice placement . . . leads to an environment in which the acoustical characteristics of neighboring voices work together rather than against each other. The individual singer feels freer and is, therefore, better able to sing in tune and contribute more individual control of blend within his immediate environment. (Johnson, Choral 17)

Various studies have exhibited the properties of voice matching. Tocheff used auditors to assess if acoustical placement of voices was beneficial to the resultant choral sound. (133) These matched formations were assessed in contrast to sectional and mixed formations in which no attention had been paid to individual vocal placement. The question under scrutiny was: "Does careful acoustical placement of voices in choral formation, with respect to surrounding singers, significantly affect the quality of choral sound?" (5) Replication of the process was achieved by using two choirs, each choir singing twice in each formation. (7) No attempt was made to acoustically evaluate either the procedure of voice matching the choirs or the individual choral performances.

Tocheff concludes that:

> The acoustical placement of voices for compatibility of singers benefits every variable of choral sound tested in this study, regardless of whether the singers are placed in sectional or mixed formation. The areas of choral sound that benefit the most from acoustical placement are overall blend, intonation, and rhythmic precision/ensemble/diction. (152)

Giardiniere documents the actual processes of Weston Noble, at Luther College. (Voice Matching) Noble is often cited as the patriarch of voice matching; his process has had such disciples as Rodney Eichenberger and Anton Armstrong. Noble has not published any codification of his process, although he has successfully demonstrated this process in workshops and conventions on numerous occasions. "Others have described his procedures, and many mimic those for use in their own choirs, with great success. However, his practices have never been substantiated quantifiably, and so, fall under the realm of speculation." (Daugherty, Spacing 1996 37) Although the acoustic effect of this blending procedure has never been acoustically surveyed, Noble's more than half a century of successful voice matching can hardly be dismissed as "anecdotal" or as mere "speculation."

> Blended choral sounds . . . result from the phenomenon of blend, rather than the process of blending. (Giardiniere 5)

> The key . . . lies, to a considerable extent, in the way singers are positioned in the ensemble, and the degree to which the conductor is willing to experiment with different sounds produced by various arrangements of personnel. (Johnson, Choral 22)

> Through a milieu of criticism, the technique of voice matching has endured and even benefited. The system developed by Noble . . . treats vocal matches as an outcome-in noun form-rather than an active process. (Giardiniere 20)

> Voice positioning techniques seek a homogeneity of choral sound that, ideally, do not compromise the vocal production of individual singers. Vocalists are positioned to benefit acoustically from other adjacent voices as the collective sound is constructed. (Giardiniere 23)

> Proponents of this method believe that blend is thus enhanced naturally through acoustic phenomena, allowing singers substantial individuality in vocal timbre and freedom in vocal production. (Eckholm 3)

Both Tocheff (1990) and Giardiniere (1991) offer insight into the voice matching procedures of Weston Noble. Daugherty, however, asserts that Tocheff's research "evidenced major flaws," and that Giardiniere's results are "inconclusive." (Rethinking 9) Neither study employs acoustic analyses; instead, each, respectively, charted the reactions of cataloged auditors, and a noted conductor, in his own venue, using his own choir. However, Daugherty's own study (Spacing 1996 172) confirms Tocheff's findings with regard to the surveyed preferences of singers, directors, and auditors. Eckholm concludes that vocal production is better in an acoustic seating arrangement than in a random arrangement, due to the perception of choristers and voice teachers that individual singers had less need to substantively alter vocal production in order to achieve an acceptable degree of blend.

> Vocal production was judged to be better in the acoustic seating arrangement than in the random seating arrangement. This result implies that positioning choristers so that adjacent voices are acoustically matched gave them a greater impression of blending naturally. Thus they felt less need to restrain their voices in order to achieve an acceptable degree of homogeneity. (Eckholm 1999 101)

> [T]he issue of conglomerate sound . . . has not received the same scientific attention as the study of the individual voice . . . [C]horal tone exists as its own entity, separate from, although dependent upon, the production of a single sound. (Giardiniere 26)

> Inquiry into the positioning of individual voices through subjective means (voice matching) revealed the phenomenon of vocal matches. The distinction between voice matching and the vocal match is a significant one, since it identifies the relationship between a process (subjective) and a phenomenon (empirical). (Giardiniere 108)

The premise of Giardiniere's study is to "investigate whether positioning of individual singers affected [the aggregate choral sound] to the extent that experts could discern and identify preferred sounds heard on audio recordings." (2) Giardiniere's study outlines Noble's procedure and probes the question as to whether the perceived vocal matches were simply Noble's preferences or if they were readily discernible by auditors outside the procedure itself. The so-called "inconclusive" results (Daugherty, Rethinking 9) were dictated by statistical analysis of the collected data. In fact, the ". . . agreement of experts with preferences of Weston Noble directed the researcher to a uniformity indigenous to matched sounds." (Giardiniere 7) As stated above, Daugherty's observations concerning spacing more exactly correspond to the component of spatial relationships within choral formation, rather than serving to supplant formation, specifically voice matching, as a procedure for choral blend.

In his thoughts for further research, Giardiniere calls for "An acoustic study of vocal samples." (118)

> Spectrograph, radiograph, or other measurement through technological apparatus would provide further evidence of the existence of vocal matches. Should the findings show a correlation between perceived matches and acoustically defined measurements, research would complete the process of investigation and isolation of the vocal match phenomenon initiated with this study. (Giardiniere 118)

Tocheff and Giardiniere elucidate that voice matching is a viable method to achieve choral blend. Moreover, it is the tacit assertion that this procedure addresses the desire for blend without requiring individual singers to alter vocal process.

> The difficulty in assessment of any aspect of voice matching stems from the original premise of choral blend, techniques of vocal positioning, and the capability of the human voice to blend by compromise, either willfully or unwillfully. Although a considerable amount of willful alteration of vocal sound may be minimized, unwillfull compromise of the vocal instrument can never be eliminated and, hence, brings a voice matching investigation under suspicion. However, should a phenomenon known as the "vocal match" exist, independent of the efforts of an individual to compromise on vocal iteration, the 'match' may emerge whether compromises are made or not. (Giardiniere 6)

Eckholm's study confirms that unintentional compromise of vocal process occurs when individuals sing in ensemble. (1999 101) What remained for this study was to ascertain the specific acoustic phenomenon that exists as the direct outcome of voice matching and to confirm that voice matching reduces the amount of requisite alteration of individual vocal process.

G. Summary

> The choral model seems to embody the concept that the sum total of the singers is a single "instrument," a collective voice comprised of many voices. To that end, many choral directors have pursued the concepts of blend, unity, and ensemble. The choral ensemble is comprised of singers having various levels of vocal proficiency, and in many cases the choral conductor is the only voice instructor that choral singers ever encounter. (Anderson 25)

A review of the literature concerning blend reveals certain specific influences and practices. The literature concerning historical choral models divides conductors into several "schools" of practices. Among these is the "St. Olaf" school, founded by F. Melius Christiansen, which is cited as being most effective for the performance of Renaissance music. This practice has resulted in a great deal of criticism and concern, however, due to its requisite subordination of individual vocal process. Another school is the "Westminster" school, following the teachings of John Finley Williamson, which is cited as being most effective for the performance of choral/orchestral literature. This practice encourages a soloistic vocalism, which, in many respects, defeats the desired effect of blend. These historic models, among others, provide a foundation for current choral practices.

Attention has been given to differences in choral and solo singing, based on the underlying assumption that the vocal process required for each mode of musical expression is of necessity different. These widely divergent practices, permutations of the St. Olaf and Westminster schools, have incited conflict among teachers of singing and choral conductors, specifically as regards the vocal health and integrity of the individual singer. As such, a search for blending practice that does not obligate the singer to compromise vocal process has ensued. Current research only serves to fortify the notion that singing technique is, of necessity, malleable.

Some research indicates that employing sufficient space between singers allows the desired vocal independence. James Daugherty purports that spacing is superior in practice to formation, including voice matching, in achieving this effect. However, his conclusions are fallacious, as his study compares spacing concepts only to randomized macro-formations, without attention given to concepts of voice matching. His research, which denigrates formation studies as being non-standardized, actually encourages experimentation with the process of spacing.

Among formation studies, certain trends exist. Some include the survey of macro-formation, or the placement of singers in sectional and mixed formations with regard to voice part. Others study micro-formation procedures, which elicit attention to placement of individual voices based on the idiosyncratic traits of each voice. The voice matching procedures of Weston Noble and others have been examined with regard to their relative success in achieving choral blend. These divergent systems purport to have solved the issues related to the effect of choral blend without the significant concession of individual vocal process. Eckholm concludes that voice matching significantly reduces the requisite amount of individual vocal process alteration.

We could compare individual tonal colors and timbres in the way a painter views a palette of colors - each hue and shade brings to the total picture something unique and fresh as part of the total spectrum of gathered colors. One without the other might not specifically mar the work or image; certainly a skilled artisan could produce magnificent works with fewer colors. Yet, when the color palette is rich and full, the energy of the scene is more vivid and comes to life with greater intensity. It is the combination of these colors that enriches our ability to sense the shapes, textures, and emotions of the scene.

From a survey of Western cultural history we know that certain composers wrote by commission, often for specific performers with their own particular timbre, tone, and nuanced shadings of pitch and rhythm. While we cannot resurrect long-silent singers, the music can nevertheless still live in our realization of melodic lines and harmonic textures. As a requisite component of this realization, most of historical Western corporate singing has called for some sort of homogeneity, particularly as relates to ensemble textures; this effect we now designate as blend.

Music is one of the expressionary modes of social interaction. Voice matching considers differences in vocal tone as assets to choral sound and professes to include the divergent colors of each individual voice included in the ensemble. This inclusion of varied sounds serves to enrich our understanding of shapes, textures, and expressionary ideals inherent in choral music. What remains to be corroborated is acoustic evidence that substantiates the effectiveness of the tool of voice matching as a means to choral blend without significant vocal alteration.

Chapter III: Acoustic Considerations

All tones are comprised of a complex series of frequencies, including fundamental and overtones, and can be measured on a graph called a frequency spectrum. All musical instruments, including the human voice, are characterized by the relative intensity of the various overtones they produce when a note of a particular fundamental frequency is played or sung. Neither the fundamental (pitch) nor the amplitude (volume) of the tone will change the idiomatic character of a given instrument. It is the presence or absence of the harmonic overtones that results in the major difference in the tone quality of string and wind instruments; i.e., a violin and flute may simultaneously play the same fundamental, but the configuration and amplitude of the separate overtones will construct an idiomatic timbral sensation for each instrument.

Sonic signals produced simultaneously will produce a combined frequency spectrum where the characteristic overtones for each signal are present in the new spectrum, but no new frequencies are added. The *contribution* of the separate overtones, however, may be altered by the combination of overtones of similar frequency; i.e., if both the violin and flute are producing an overtone of 600 Hz, the combined frequency spectrum will reflect the aggregate amplitude of the individual overtones. This combining of characteristic overtones produces orchestral color and texture. Composers carefully choose combinations of instruments, and the specific tessitura for each, to reflect the desired aesthetic.

Unrelated frequencies produce noise or "beats" in the processing of the aural spectrum. Beats will be aurally processed when one instrument plays an A, tuned to 440 Hz, and another instrument simultaneously plays an A, tuned to 443 Hz. Instead of the frequency spectra sounding in complimentary fashion, the resulting frequency spectrum will contain conflicting overtones.

Voices produce pitch within a more limited frequency range than instruments. Vocal pitch frequencies characteristically occupy the first formant (frequency peak) position (F1) within the vocal spectrum, with the exception of the highest notes of the soprano voice. Table 1 (on page 66) delineates the pitch frequencies for the musical excerpt used in this study. In contrast to instruments, voices also create a second formant (F2) of nearly equal intensity corresponding to vowel shapes. Table 2 (on page 66) delineates the vowel frequencies for the musical excerpt used in this study. Individual vocal timbre is the result of the relative strength of the various overtones of the frequency spectrum. While timbral differences can be somewhat delineated by examination of the pitch and vowel frequencies, Sundberg (Acoustics) asserted that the chief timbral frequency lies in the region of the singer's formant. A group of individual singers may simultaneously produce the same fundamental pitch, yet each singer retains specific acoustic demarcations that identify the individual voices from one another.

Choral/vocal studies have concentrated on various aspects of choral singing that contribute to the phenomenon of acoustic "beats" in the combined frequency spectrum (vibrato rate; fluctuation of the fundamental in harmony with frequency wave pattern; intonation, affecting fundamental frequency; and vowel shape, affecting various frequencies). As yet, timbral issues have been regarded as largely unimportant in the blend process. The underlying assumption of these studies is that while solo singing strives for a uniform individual vocal production, choral singing is, of necessity, a malleable vocal process. Further, they falsely assume that all methods of private vocal instruction produce equally refined individual sounds. The choral experience often serves as a group voice session, to the benefit of many singers, particularly as related to the production of vocal sounds characteristic of various musical eras. As previously mentioned, however, this study is not a discussion of the vocal needs constituted by music of different eras nor of the requisite differences in a capella and choral/orchestral singing. Rather, it is a study of the timbral frequencies as they relate to the phenomenon of blend, and their relative requisite malleability.

Rossing compares "... five singers who were skilled in both modes. [choral and solo singing] In this case, no systematic differences in F1 or F2 are apparent. We might therefore infer that ... choir singing is much the same as solo singing, with regard to the first two formants." (1978) Since the first two formants show only slight changes between solo and choral singing, it will be necessary for the purposes of this study to examine changes in the area of the singer's formant.

The procedures used in this study address a number of salient issues raised in other studies of choral singing. It is the presumption of virtually all of the studies of choral singing that vocal techniques must, of necessity, be different between choral singing and solo singing. (Rossing, Ford, Ternström) This study investigates the possibility that certain blending processes, namely voice matching and spacing, allow singers to blend without significant alteration of vocal process.

The studies put forth by Sundberg and Ternström (1982-1994) reported on the recording of subjects singing in anechoic (signal/reflection dampening) studio chambers. This study presents subjects singing in an auditorium that is routinely used for choral rehearsal and performance. The Sundberg/Ternström studies recorded the vocal reactions of a single singer responding to recorded sounds heard via headphones. The implications of these findings do not speak to the acoustic interaction of multiple sounds, but rather to the isolated reactions of a single singer. This study considered the interaction of multiple singers, singing simultaneously. The Sundberg/Ternström studies, further, do not take into consideration the fact that singers process the same sound source in different ways depending on which ear receives the sound. This study recorded all the possible positions of the same groups of singers, allowing investigation into how individual vocal process is affected by different sound sources coming in on different lateral sides.

Several studies (Tocheff, 1990; Giardiniere, 1991; Daugherty, 1996; Eckholm, 1999) present auditor reactions to full choir sounds, with neither acoustic data to corroborate the opinions nor any tool for investigating the change of individual vocal processes. This study presents auditor reaction to the sounds of multiple voices, with corroborating acoustic evidence. This study, further, presents data that offers insight into individual vocal process.

Daugherty's (1996-2001) studies concerning spacing as a means to choral blend asserts that studies concerning the formation of individual singers, including voice matching studies, do not bear scrutiny for want of both empirical evidence and replicable procedure. He purports that his studies of spacing between choral singers are, in fact, empirical. He then, however, endeavors to draw substantive comparison of the results of his empirical study and non-empirical formation studies. This study, however, empirically investigates the phenomenon of voice matching. Daugherty's writings subsequent to his initial study display a lack of continuity of the spacing procedures used in alternate settings. In fact, Daugherty specifically endorses the practice of experimenting with spacing as the solution to issues in different settings. His study, therefore, follows the premise of voice matching procedure, which is to test various voices, singing simultaneously, in order to discover the best positioning of the group of voices. Additionally, Daugherty alleges that his study compares the phenomena associated with both spacing and formation. A careful reading of his work, however, exposes the fact that his formation practice did not include any specific attention to voice matching. Instead, his investigation of formation placed singers in random positions. While the current study did not assign permanent positions to the singers, it was conducted under that supposition that appropriate positions were identifiable through the procedure of voice matching. This study also acoustically analyzed the effect of lateral spacing in direct correlation to lateral voice matching. Further, the study took into consideration the combined effects of both practices.

Eckholm's (1999) intention was to study the viability of normal vocal process in the choral setting. She used voice teachers to ascertain if change occurred in the vocal processes of random singers. An ad hoc choral ensemble was recorded singing in "blended" mode and "soloistic" mode, in both voice matched and arbitrary individual placements. Voice teachers aurally determined that change in vocal process occurred in all settings, but that the least amount of change happened in the acoustic-soloistic setting. These findings were established, however, listening to sounds recorded on microphones of different model and sensitivity. The current study acoustically examined the requisite changes in vocal process in each singer, rather than random singers. This study, further, used the same model microphone to record each sound bite. This allowed the relative amount of change in each individual voice to be acoustically compared. No study to date has acoustically examined both aggregate and individual sounds. This study carefully considered the procedures necessary to appraise both sounds.

All of the studies listed above made use of musical examples that required both rehearsal and conductor management. Rehearsal procedure and attention to details of vocal score have direct bearing on the practice and perception of blend for both singers and auditors. The conducting gesture is a systematic vehicle for communicating, not only breathing, tempo, and entrances, but also variables such as dynamics and intensity, balance, vowel shapes, and intonation. Eckholm initially endeavored to contend with this issue by using a videotaped conductor whose intention was to avoid any systematic differences in gestures, expression and posture. (1999 46) The present study utilized a musical excerpt familiar to all of the subjects in the study. This familiarity eliminated the need for both prior rehearsal and conducting gesture, save for the preparatory breath and tempo.

The adult auditory system is capable of processing signals in a frequency range between 20 and 20,000 Hz. The various parts of the ear, however, provide amplification of signals within a much more narrow range: 100-5500 Hz. While the outer ear canal is a passive portion of the auditory system, its shape and dimensions amplify frequencies between 2000 and 5500 Hz by as much as 15-20 dB. The middle ear similarly amplifies frequencies between 100 Hz to 2000-2500 Hz by as much as 30 dB. This combination of amplified frequencies comprises the area of acoustic inquiry for this study. While there may be timbral connotations for frequency changes above 5500 Hz, the most significant issues in the perception of individual timbre remain with changes in this frequency range. For this reason, although the normally functioning adult ear can process sound between 0 and 20,000 Hz, frequencies are not typically examined below 20 Hz and above 5500 Hz. Further, the studies listed above that do examine frequency spectra limit their investigations to frequencies within the range of 100-5500 Hz. The relative amount of frequency and decibel change within this range yields significant transformation in the overall quality of both solo and ensemble voices.

In the solo spectrum of each singer similar significant peaks and dips were chosen for comparison. A sample graph with highlighted peaks and dips, along with the corresponding Hz and dB information can be found in Appendix D. Pitch and vowel frequencies were readily identified in each solo voice and in each ensemble setting of the individual voices. Timbral frequencies were examined from 2500-5500 Hz. Frequency (Hz) and decibel (dB) changes were recorded and compared as indicators of the relative amount of individual vocal change. Table 1 shows the frequencies of the pitch set used in the musical excerpt.

TABLE 1

Pitch Frequencies	
Note Name	Frequency (Hz)
G	196.0
Ab	207.65
Bb	233.08
C	261.63
Db	277.18

The relative amount of pitch change was examined by averaging significant peaks and dips between 196.0 and 277.18 Hz. An individual voice exhibiting a frequency peak at 207.65 Hz when singing a solo and a frequency peak at 199.18 Hz when singing in a particular formation would be judged to have a frequency shift of -8.08 Hz, an indication of the pitch going flat. The normal ear will readily process a frequency shift of +/- 3 Hz.

Several vowel sounds were present in this musical excerpt. The various formants of each vowel sound are identified in Table 2.

TABLE 2

Vowel Frequencies			
IPA	F1	F2	F3
[i]	300	1950	2750
[I]	375	1810	2500
[ə]	500	1500	2500
[a]	550	1200	2500
[æ]	620	1490	2250

The relative amount of vowel change was examined by averaging significant peaks and dips between 300 and 2750 Hz. An individual voice exhibiting a frequency peak at 300 Hz when singing an [i] as a solo and a frequency peak at 310 Hz when singing in a particular formation would be judged to have modified the vowel sound to a somewhat more open quality. The upper formants generally are altered in similar fashion.

All sound sources create a complex series of frequencies. The relative strength and weakness of specific frequencies serve to delineate the individual character of each sound source. While concurrent sounds are aurally processed simultaneously, sources producing unrelated frequencies are readily discernible from each other. The objective of blend in the choral setting is to combine multiple voices, with no constituent voice essentially distinguishable from any other. When concurrently sounding voices produce substantively unrelated frequency peaks and dips the voices will be perceived as "unblended."

Frequencies peaks and dips between 2750 and 5500 Hz were examined as an indicator of the relative amount of timbral change, as illustrated in the following example. Singer 1 exhibited a frequency peak at 2998.50 Hz. In close and lateral combinations with Singer 2 this peak appeared at 3014.65 Hz, 3044.26 Hz, 3044.26 Hz, and 2966.20 Hz. The placement/spacing for these are listed in Appendix E as recordings 1, 4, 5, 6, and 7. This showed that when in combinations with Singer 2, Singer 1 exhibited a frequency peak nearest to the solo spectrum peak or exhibiting the least amount of vocal change, -16.15 Hz, in placement/spacing 12. In combinations with Singer 3, the same peak for Singer 1 appeared at 2952.74 Hz, 2974.27 Hz, 2952.74 Hz, and 2974.27 Hz. The position/spacing for these are listed in Appendix E as recordings 8, 9, 10, and 11. Of interest is that in pairings with Singer 3 the same position exhibited the same amount of change, regardless of spacing. The frequency peak for placement/spacing 13 and 1-3 each appeared at 2952.74 Hz, and the frequency peak for placement/spacing 31 and 3-1 each appeared at 2974.27 Hz. The dB level for the frequency peak in position/spacing 13 and 1-3 only differed by 0.03 dB, while the dB level for position/spacing 31 and 3-1 differed by 1.59 dB. In each placement/spacing the dB level is lower than that of the solo peak. This analysis shows that, in the instance of this single frequency peak, Singer 1 exhibited less overall spectrum change in pairings with Singer 3, specifically in placement/spacing 13 and 1-3, than in any of the pairings with Singer 2. However, if Singer 1 must be paired with Singer 2, the optimum placement changes with different spacing.

Chapter IV: Discussion

1) Can an individual singer blend with other singers without alteration of the basic vocal process of any of the singers?

This study considered whether it was possible for multiple voices to blend without the alteration of vocal process. Eckholm (1999) used voice teachers to consider this question. Her findings suggest that even when instructed to sing in a "solo" manner, singers alter vocal process when singing in an ensemble. Voice teachers from Eckholm's study also found that the least vocal change occurred when individuals singing "soloistically" were placed in voice matched positions. At first blush Eckholm's findings appear to answer the research question. However, concerns with the recording procedure and equipment used in her study suggest further scrutiny of this question. Her study, further, did not make use of any acoustic analysis to verify the opinions of the auditors. The modified question is: Does acoustic analysis support the finding that individual vocal process is changed when singing in an ensemble?

In this study, acoustic comparisons for each singer were made between the musical excerpt sung as a solo and sung in various ensemble placements and spacing. It should be noted that each singer was recorded one time singing the musical excerpt as a solo. Singers were instructed to sing "normally" for each recorded excerpt. Further study could record individual singers on multiple solo occasions in order to determine if the vocal process used by the individual singer is consistent on every solo occasion. Establishment of individual solo vocal consistency could have considerable impact on the findings concerning the requisite amount of vocal process change in ensemble settings.

The acoustic analyses confirmed Eckholm's findings that individual vocal process change does occur between solo and ensemble singing, revealing changes in the vocal process of each singer participating in this study. The recording process attempted to preserve the quality of vocal interaction that occurs in an ensemble setting. No effort was made to separate individual singers using anechoic material. There was, therefore, some initial question as to the degree of separation of individual sounds that was achieved from the individual microphones. The individual ensemble acoustic graphs reveal observable changes from the solo graphs, but also reveal a readily discernible pattern for each singer. The relative consistency of the shapes of the acoustic graphs for each singer, therefore, illustrate that an adequate degree of separation occurred.

If placement played no significant role on either ensemble sound or individual vocal process, as Daugherty asserts, then the frequency spectrum of the same groupings of voices should be virtually identical, regardless of placement. The results, however, clearly reflect that individual vocal change occurred as a product of different placements. This finding supports the notion that the placement of individual voices within the ensemble significantly affects the contribution of the individual voice to the aggregate vocal sound. It is also clear that the frequency spectrum was altered when the spacing between singers using identical placement was changed. This acoustic verification of individual vocal process change necessitated a series of modified research questions. Original research question #2, dealing with the relationship of placement to spacing was dealt with in this part of the discussion.

Modified Question 1A
What impact do placement and spacing make on the amount of individual vocal change?

A. Results

Multiple studies from Goodwin (1980) through Eckholm (1999) indicate that significant individual vocal change occurs as a requisite part of ensemble singing. None of these studies, however, analyzed the acoustic output of multiple individuals singing simultaneously. Consequently, a portion of my study was devoted to documenting the acoustic output and evaluating the changes that occur.

Each individual singer was first recorded singing the musical excerpt as a solo. The subsequent recordings cataloged the individual singers in each possible ensemble placement and spacing. This order is documented in Appendix E. The individual acoustic spectrum from each ensemble setting was compared to the acoustic spectrum from the individual solo recordings. These comparisons are listed in Appendix F.

Group 1 Duets

Individual singers exhibited acoustic changes with both changed placement and spacing. Singer 1, when paired with Singer 2, showed the least overall vocal change with placement/spacing 12, and the corresponding placement/spacing 1-2 also exhibited less vocal change than its opposite placement. There was a marked difference, 19.93 Hz, between placement/spacing 12 and 21. Moreover, changed placement exhibited a change in the direction of the movement of the acoustic spectrum, increasing the average frequency 7.95 Hz for placement/spacing 12 but decreasing the average frequency -11.98 Hz for placement/spacing 21. In addition, both examples of lateral spacing showed elevated rates of change when compared to the examples of close spacing. This set of changes clearly illustrates that the specific placement was crucial for Singer 1 when paired with Singer 2, and that acoustic placement in close spacing shows reduced levels of vocal change compared to lateral spacing.

Singer 2, when paired with Singer 1, showed the least overall vocal change with placement/spacing 12. Placement/spacing 21 exhibited a direction change in the movement of the acoustic spectrum, -3.79 Hz for placement/spacing 12 to 7.28 Hz for placement/spacing 21. Singer 2 also exhibited elevated rates of change when laterally spaced. This set of changes clearly illustrates that the specific placement was crucial for Singer 2 when paired with Singer 1.

Singer 1, when paired with Singer 3, exhibited the least amount of vocal change in placement/spacing 31. The rate of change for placement/spacing 13, 13.59 Hz, was triple the rate of 31, 4.04 Hz. Placement/spacing 3-1, -8.01 Hz, showed twice the amount of change compared to 31, 4.04 Hz, and the change was in the opposite direction. In lateral spacing, placement 3-1 exhibited twice the amount of change of 1-3, 4.69 Hz, and the change was in the opposite direction. This set of changes illustrates that placement was an important element for Singer 1 when paired with Singer 3.

Singer 3, when paired with Singer 1, exhibited the least amount of vocal change in placement/spacing 3-1. Both examples of lateral spacing exhibited less change than either example of close spacing. Although placement/spacing 31, 24.36 Hz, exhibited nearly triple the rate of change compared to 3-1, 8.34 Hz, 31 also exhibited less change than 13, 32.96 Hz. This set of changes illustrates that placement was a necessary element for Singer 3 when paired with Singer 1, but that lateral spacing provided greater reduction of vocal change for Singer 3 in this pair of voices.

Singer 2, when paired with Singer 3, exhibited the least amount of vocal change in placement/spacing 2-3, 12.91 Hz. Placement/spacing 23, 13.76 Hz, also exhibited less change than its opposite placement. In each case the opposite placement exhibited nearly twice the amount of vocal change. This set of changes clearly illustrates the necessity of specific placement in the reduction of vocal change for this pairing of voices.

Singer 3, when paired with Singer 2, exhibited the least amount of vocal change in placement/spacing 3-2, 6.37 Hz; 2-3, 20.74 Hz, exhibited more than three times the amount of change. Although placement/spacing 32, 12.54 Hz, showed twice the amount of change compared to 3-2, 32 also exhibited less change than 23, 17.79 Hz. This set of changes clearly illustrates that specific placement was necessary to reduce vocal change in this pairing of voices.

In Group 1 Duets, lateral spacing exhibited increased vocal change compared to close spacing by 2.21 Hz. Singer 1 exhibited more change in lateral spacing by 1.48 Hz. Singer 2 showed reduced vocal change in lateral spacing by -0.77 Hz. Singer 3 exhibited increased change in lateral spacing by 6.70 Hz.

The same placement/spacing exhibited the least overall change for both Singers 1 and 2, and both in close spacing. It may be noted that, although the spacing was different, Singers 1 and 3 exhibited the least amount of change in the same placement. Singers 2 and 3 exhibited least vocal change in opposite placements from one another, and both in lateral spacing. Of the six examples of least vocal change, three were in close spacing and three were in lateral spacing. Singers 1 and 2 showed least change in close spacing, Singers 1 and 3 in close or lateral spacing, and Singers 2 and 3 in lateral spacing.

The overall rates of change for the combinations of paired voices were marked. An analysis of the results suggests the improbability of a vocal match between these three voices. Taken together, however, the results imply that the best blend would likely occur in a formation that placed Singer 1 between Singers 2 and 3, but that the formation would have equal chance to be in close or lateral spacing. Moreover, the basis for this implication was not merely the separation of the voices least likely to blend, but more specifically the discovery of the positional relationship of Singer 1 to Singers 2 and 3. Placement was clearly shown to be more crucial to the reduction of vocal change than spacing.

Group 1 Trios

When in the first position (stage right), Singer 1 exhibited the least amount of vocal change in placement/spacing 132, -16.66 Hz. Placement/spacing 1-3-2, -17.37 Hz, also showed less change than its opposite placement. It should be noted that the addition of lateral spacing to close placements exhibited elevated levels of vocal change compared to same placement/close spacing. Placement/spacing 1-2-3, 46.33 Hz, showed more than double the rate of change compared to 123, -20.76 Hz, and in the opposite direction. This set of changes clearly illustrates that specific placement was crucial for Singer 1, when in the first position, and that acoustic placement in close spacing showed a reduced level of vocal change compared to lateral spacing.

With Singer 2 in the first position, Singer 1 exhibited the least amount of vocal change in placement/spacing 2-3-1, 1.67 Hz. 231, 2.69 Hz, also showed less change than its opposite placement. The opposite placement showed markedly elevated levels of change, nine times higher, and in the opposite direction. This set of changes clearly illustrates that specific placement was crucial for Singer 1.

With Singer 3 in the first position, Singer 1 exhibited the least amount of vocal change in placement/spacing 3-2-1, -9.04 Hz. While placement/spacing 321, -14.68 Hz, also showed less change than its opposite placement, both examples of lateral spacing showed less change than either example of close spacing. This set of changes illustrates that, although lateral spacing showed less overall change, the specific placement was crucial to the reduction of vocal change for Singer 1.

With Singer 1 in the first position, Singer 2 exhibited the least amount of vocal change in placement/spacing 123, 21.29 Hz. Placement/spacing 1-3-2, 22.08 Hz, showed less change than its opposite placement. This set of changes illustrates that, although placement was shown to reduce the amount of vocal change, placement needed to be changed for different spacings.

When in the first position, Singer 2 exhibited the least amount of vocal change in placement/spacing 2-3-1, 9.83 Hz. Both examples of lateral spacing showed reduced levels compared to either example of close spacing, by nearly five times in one instance. Placement/spacing 213, -18.48 Hz, showed nearly three times less change than its opposite placement, and in the opposite direction. This set of changes illustrates that for this particular placement lateral spacing most reduced the amount of vocal change, and, although placement was shown to reduce the amount of vocal change, placement needed to be changed for different spacings.

With Singer 3 in the first position, Singer 2 exhibited the least amount of vocal change in placement/spacing 312, 7.59 Hz. Placement/spacing 3-1-2, 20.00 Hz, also showed reduced vocal change compared to its opposite placement. Both examples of lateral spacing showed elevated rates of change compared to examples of same placement/close spacing, in one instance increasing vocal change by more than half. This set of changes not only clearly illustrates that specific placement was crucial to the reduction of vocal change, but also that close spacing has the probability to more greatly reduce vocal change than lateral spacing.

With Singer 1 in the first position, Singer 3 exhibited the least amount of vocal change in placement/spacing 1-2-3, 5.51 Hz. Although placement/spacing 1-3-2, -11.42 Hz, showed change in the opposite direction, both examples of lateral spacing showed less vocal change than either example of close spacing. The rate of change for placement/spacing 123, 18.51 Hz, was more than three times that of 1-2-3, and placement/spacing 132, 13.13 Hz, showed less change than 123. In this set of changes, lateral spacing showed decreased levels of change, and placement needed to be changed for different spacings.

With Singer 2 in the first position, Singer 3 exhibited the least amount of vocal change in placement/spacing 2-1-3, -1.12 Hz. Both examples of lateral spacing showed decreased vocal change compared to either example of close spacing. However, 213, -10.57 Hz, also showed one third less change than its opposite placement. In this set of changes, lateral spacing showed decreased levels of change, and, specific placement was shown to be a factor in the reduction of vocal change.

When in the first position, Singer 3 exhibited the least amount of vocal change in placement/spacing 312, -4.07 Hz. 3-1-2, -5.19 Hz, also showed less change than its opposite placement. Moreover, changed placement exhibited a change in the direction of the acoustic shift for both close and lateral spacings. Lateral spacing in placement/spacing 3-2-1, 18.12 Hz, increased vocal change by nearly three times compared to 321, 5.71 Hz.

In Group 1 Trios, lateral spacing decreased the amount of vocal change by 1.83 Hz. Singer 1 exhibited less change in lateral spacing by 4.17 Hz. Singer 2 exhibited less change in lateral spacing by 0.88 Hz. Singer 3 exhibited less change in lateral spacing by 0.44 Hz.

Group 2 Duets

When paired with Singer 5, Singer 4 exhibited the least vocal change in placement/spacing 45. Both examples of close spacing showed less change than either example of lateral spacing. 4-5 also showed less change than its opposite placement. While close spacing reduced vocal change at a greater rate than lateral spacing, the specific placement was crucial to the reduction of vocal change.

When paired with Singer 6, Singer 4 exhibited the least vocal change in placement/spacing 4-6. 46 also showed less change than its opposite placement. Changes in spacing also reversed the direction of the acoustic shift. The specific placement was crucial to the reduction of vocal change.

When paired with Singer 4, Singer 5 exhibited the least vocal change in placement/spacing 45. 4-5 also showed less change than its opposite placement. The addition of lateral space changed the direction of the acoustic shift for both sets of placements. The specific placement was crucial to the reduction of vocal change.

When paired with Singer 6, Singer 5 exhibited the least vocal change in placement/spacing 56. 6-5 showed only 0.06 Hz more vocal change than 56. Pairings with Singer 6 exhibited the least overall change of any pairings in either Group 1 or 2. Placement was crucial to reduced vocal change, but needed to be changed for different spacings.

When paired with Singer 4, Singer 6 exhibited the least vocal change in placement/spacing 4-6. 46 also showed less change than its opposite placement. In these examples changed placement reversed the direction of the acoustic shift. The specific placement was crucial to reduced vocal change.

When paired with Singer 5, Singer 6 exhibited the least vocal change in placement/spacing 6-5, and the acoustic shift showed changed direction with lateral space. 56 showed less change than 65. Placement was a crucial part of reduced vocal change, but needed to be changed for different spacings.

In Group 2 Duets the overall change from close to lateral spacing was -5.81 Hz. Singer 4 showed a reduction in vocal change with lateral spacing by -4.12 Hz. Singer 5 showed a reduction in vocal change with lateral spacing by -1.00 Hz. Singer 6 showed a drastic reduction of vocal change with lateral spacing by -13.13 Hz.

Group 2 Trios

When in the first position, Singer 4 exhibited the least overall vocal change of any singer in this study in placement/spacing 4-5-6 at 0.47 Hz. 456 also showed less change than its opposite placement, and the change in space with this placement exhibited a change in the direction of the acoustic shift. The specific placement reduced the amount of vocal change.

With Singer 5 in the first position, Singer 4 exhibited the least overall change in placement/spacing 564. 5-4-6 showed less change than its opposite placement. Although shifting in different directions, the addition of space changed the direction of the acoustic shift in these examples. Placement was crucial to the reduction of vocal change, but needed to be changed for different spacings.

With Singer 6 in the first position, Singer 4 exhibited the least overall change in placement/spacing 645. 6-5-4 showed less change than its opposite placement. There was a change in direction of the acoustic shift between 654 and 6-5-4. Placement reduced vocal change, but needed to be changed for different spacings.

With Singer 4 in the first position, Singer 5 exhibited the least overall change in placement/spacing 456. 4-6-5 showed less change than its opposite placement. Placement had to be changed for different spacings in order to reduce the amount of vocal change.

When in the first position, Singer 5 exhibited the least overall change in placement/spacing 546. 5-6-4 showed less change than its opposite placement. Both examples of close spacing showed less change than either example of lateral spacing. Placement had to be changed for different spacings in order to reduce the amount of vocal change.

With Singer 6 in the first position, Singer 5 exhibited the least overall change in placement/spacing 6-5-4. 654 also showed less change than its opposite placement. Both examples of lateral spacing showed less change than either example of close spacing. Placement needed to be changed for different spacings.

With Singer 4 in the first position, Singer 6 exhibited the least overall change in placement/spacing 4-5-6. 456 also showed less change than its opposite placement. The change in space also changed the direction of the acoustic shift. The specific placement was crucial to the reduction of acoustic change.

With Singer 5 in the first position, Singer 6 exhibited the least overall change in placement/spacing 564. 5-6-4 also showed less change than its opposite placement. The change in placement changed the direction of the acoustic shift. Both examples of close spacing showed less change than either example of lateral spacing. The specific placement was crucial to the reduction of acoustic change.

When in the first position, Singer 6 showed the least overall change in placement/spacing 645. 6-4-5 also showed less change than its opposite placement. The specific placement was crucial to the reduction of vocal change.

For Group 2 Trios, the overall change between close spacing and lateral spacing was -1.65 Hz. For Singer 4 lateral spacing reduced change by -1.77 Hz. For Singer 5 lateral spacing reduced change by -0.5 Hz. For Singer 6 lateral spacing reduced change by -2.66 Hz.

B. Connotations
Group 1 Duets

In a comparison of the acoustic analyses of Group 1 Duets, Singer 1 exhibited an average spectral change (difference between solo spectrum and ensemble spectra) of 10.06 Hz, 0.44 dB. The examples of least vocal change for Singer 1 were found in Examples 1-4 and 1-9, placement/spacing 12 and 31, both examples of close spacing. In pairings with Singer 2 specific placement was shown to be of fundamental importance to the reduction of vocal change, regardless of the spacing used. In pairings with Singer 3 placement was shown to be of importance, but a different placement was required for different spacing. These results clearly show that attention to acoustic placement has a greater capacity to reduce vocal change for Singer 1 than spacing.

Singer 2 exhibited an average spectral change of 14.74 Hz, 0.88 dB and showed the least overall individual change in pairings with Singer 1. The examples of least vocal change for Singer 2 were found in Examples 2-4 and 2-14, placement/spacing 12 and 2-3. Singer 2 exhibited the least overall amount of spectral change in Example 2-4, placement/spacing 12. In pairings with Singer 1, both examples of close spacing showed less vocal change than either example of lateral spacing; the least change for lateral spacing was placement/spacing 2-1. In pairings with Singer 3 specific placement was shown to be of fundamental importance to the reduction of vocal change, regardless of spacing. Examples 2-12 and 2-14, placement/spacing 23 and 2-3, exhibited a shift of only 0.81 Hz, and only exhibited a change of only one-half that of the opposite placements. These results clearly show that attention to acoustic placement has a greater capacity than spacing to reduce vocal change for Singer 2.

Singer 3 exhibited an average spectrum change of 17.11 Hz, 2.98 dB and showed the least overall individual change in pairings with Singer 2. In addition, Singer 3 exhibited the least amount of spectral change in Example 3-15, placement/spacing 3-2. In pairings with both Singers 1 and 2, the reduction of vocal change was found in examples of lateral spacing but also in direct relationship to the specific placement. In pairings with Singer 1 both examples of lateral spacing showed less change than either example of close spacing. These results show that attention to spacing has a marginally greater capacity to reduce vocal change than acoustic placement.

Taken together, the results from Duet pairings for Group 1 clearly show that attention to acoustic placement sustains a greater probability to reduce vocal change than spacing. Moreover, the combination of placement and lateral spacing are equally likely to produce the least amount of vocal change compared to placement and close spacing. The greatest strategic value for the reduction of vocal change clearly lies with acoustic placement.

Singer 1 showed the least overall individual change in pairings with Singer 3. Singer 1 exhibited the least amount of spectral change in Example 1-9, placement/spacing 31.

The most dramatic example of the effect of placement on vocal function for Singer 1 was between Examples 1-4 and 1-5, placement/spacing 12 and 21. The spectral shift between these placements was 19.93 Hz, 0.44 dB. It may be noted that the spectral shift between Examples 1-6 and 1-7, placement/spacing 1-2 and 2-1, was less dramatic (6.27 Hz, 0.01 dB) than the examples of close spacing.

The most dramatic example of the effect of spacing on vocal function for Singer 1 was between Examples 1-5 and 1-7, placement/spacing 21 and 2-1. The spectral shift between these spacings was 30.31 Hz, 0.25 dB. It should be noted that spectral shift between Examples 1-4 and 1-6, placement/spacing 12 and 1-2, was less dramatic (3.91 Hz, 0.81 dB).

When paired with Singer 2, Singer 1 exhibited least vocal change in placement/spacing 12. It should also be noted that placement 1-2 showed less vocal change than its opposite placement. When paired with Singer 2, specific placement reduced vocal change for Singer 1, regardless of spacing.

When paired with Singer 3, Singer 1 exhibited least vocal change in placement/spacing 31. It should be noted that placement/spacing 1-3 exhibited only slightly more vocal change. When paired with Singer 3, placement reduced vocal change for Singer 1, but needed to be changed with changed spacing.

The most dramatic example of the effect of placement on vocal function for Singer 2 was between Examples 2-14 and 2-15, examples of opposite placement/lateral spacing. The spectral shift between these placements was 11.86 Hz, 0.46 dB.

The most dramatic example of the effect of spacing on vocal function for Singer 2 was between Examples 2-4 and 2-6, examples of same placement/different spacing. The spectral shift between these spacings was 24.04 Hz, 0.58 dB.

When paired with Singer 1, Singer 2 exhibited least vocal change in placement/spacing 12. It should be noted that both close placements showed less vocal change than either example of lateral spacing. When paired with Singer 1, placement reduced vocal change for Singer 2, but needed to be changed with changed spacing.

When paired with Singer 3, Singer 2 exhibited least vocal change in placement/spacing 2-3. It should also be noted that placement 23 showed less vocal change than its opposite placement. When paired with Singer 3, specific placement reduced vocal change for Singer 2, regardless of spacing.

The most dramatic example of the effect of placement on vocal function for Singer 3 was between Examples 3-14 and 3-15, examples of opposite placement/lateral spacing. The spectral shift between these placements was 14.37 Hz, 1.62 dB.

The most dramatic example of the effect of spacing on vocal function for Singer 3 was between Examples 3-8 and 3-10, examples of same placement/different spacing. The spectral shift between these spacings was 28.17 Hz, 1.47 dB.

When paired with Singer 1, Singer 3 exhibited least vocal change in placement/spacing 3-1. It should be noted that placement 31 also showed less vocal change than its opposite placement. It may further be noted than both laterally spaced placements showed greater reduction of vocal change than either closely spaced example. When paired with Singer 1, lateral spacing reduced vocal change for Singer 3, but specific placement also reduced vocal change.

When paired with Singer 2, Singer 3 exhibited least vocal change in placement/spacing 3-2. It should also be noted than placement/spacing 32 also showed less vocal change than its opposite placement. When paired with Singer 2, specific placement reduced vocal change for Singer 3, regardless of spacing.

Singer 1 showed the least average vocal change, irrespective of placement or spacing, 10.06 Hz, 0.44 dB. Singer 3 showed the most average vocal change, irrespective of placement or spacing, 17.11 Hz, 2.98 dB. Singer 2 showed a middle amount of average vocal change, irrespective of placement or spacing, 14.74 Hz, 0.88 dB.

In one case both examples of close spacing showed less overall change than either example of lateral spacing: Examples 2-4 and 2-5.

In one case both examples of lateral spacing showed less overall change than either closely spaced example: Examples 3-10 and 3-11.

Only one example yielded the least amount of vocal change for both singers: Example 1-4/2-4.

Singers 1 and 2 each had one instance where there was a direct correlation between placement and reduced vocal change, regardless of spacing. For Singer 1 it was when paired with Singer 2; for Singer 2 it was when paired with Singer 3.

For Singer 3, pairings with both Singers 1 and 2 showed a direct relationship between placement and reduced vocal change.

For Singer 1 the examples exhibiting the least vocal change were both in close spacing. For Singer 2 the examples exhibiting the least vocal change were split, one close and one lateral. For Singer 3 the examples exhibiting the least vocal change were both in lateral spacing.

In Group 1 Duets, acoustic placement alone produced equal opportunity for reduced vocal change when compared to spacing alone. Further, acoustic placement, in combination with spacing, produced greater opportunity for reduced vocal change when compared to spacing alone. Taken together, I conclude that attention to acoustic placement is superior to random placement, regardless of spacing.

Group 1 Trios

In a comparison of the acoustic analyses of Group 1 Trios, Singer 1 exhibited an average spectral change of -4.28 Hz, 0.76 dB. Singer 1 showed the least overall change with Singer 2 in the first position and the least total amount of spectral change in Example 1-23, placement/spacing 2-3-1, 1.67 Hz, 1.80 dB; placement/spacing 231 exhibited only slightly more change than 2-3-1. When in the first position, Singer 1 showed the least change in placement/spacing 132, -16.66 Hz, -0.47 dB; placement/spacing 1-3-2 showed slightly elevated levels of change. With Singer 3 in the first position, Singer 1 showed the least change in placement/spacing 3-2-1, -9.04 Hz, 1.65 dB, and both examples of lateral spacing showed less change than either example of close spacing. Placement/spacing 321, however, did show less change than its opposite placement. The results clearly show that, although there was a single occurrence of both examples of lateral spacing showing decreased levels of change compared to close spacing, in each set there was a specific correlation of placement to least vocal change for Singer 1, regardless of spacing.

Singer 2 exhibited an average spectral change of 19.50 Hz, 0.68 dB and showed the least overall individual change when in the first position, but the least amount of spectral change in placement/spacing 312, 7.59 Hz, 1.36 dB. With Singer 1 in the first position, placement/spacing 123 and 1-3-2 showed the least amount of change. When in the first position, both examples of lateral spacing showed reduced rates of change compared to either example of close spacing. With Singer 3 in the first position, placement/spacing 312 and 3-1-2 showed reduced vocal change for Singer 2, regardless of spacing. The results show that, in each set, placement showed reduced amounts of vocal change, but needed to be changed with changed spacing.

Singer 3 exhibited an average spectral change of 4.29 Hz, -1.76 dB. Singer 3 showed the least overall individual change when in the first position, but the least amount of spectral change in Example 3-22, placement/spacing 2-1-3, -1.12 Hz, -1.13 dB. With Singer 1 in the first position, placement/spacing 1-2-3 and 1-3-2 showed the least amount of change, and both examples of lateral spacing showed decreased amounts of vocal change compared to either example of close spacing. With Singer 2 in the first position, both examples of lateral spacing showed reduced vocal change compared to either example of close spacing, but there also existed a relationship for placement/spacing 2-1-3 and 213. When in the first position, Singer 3 showed the least amount of vocal change in placement/spacing 312 and 3-1-2. The results show that, while lateral spacing may reduce vocal change, there is a relationship of placement to reduced vocal change.

Taken together, the Trio settings from Group 1 clearly show that attention to acoustic placement sustains the greater probability to reduce vocal change than spacing. Moreover, the combination of placement and lateral spacing reduced vocal change only slightly more often than placement and close spacing. The greatest strategic value for the reduction of vocal change clearly lies with acoustic placement.

The most dramatic example of the effect of placement on vocal function for Singer 1 was between Examples 1-18 and 1-19, placement/spacing 1-2-3 and 1-3-2. The spectral shift between these placements was 63.70 Hz, 0.39 dB. The most dramatic example of the effect of spacing on vocal function for Singer 1 was between Examples 1-16 and 1-18, placement/spacing 123 and 1-2-3. The spectral shift between these spacings was 67.09 Hz, 2.81 dB. When in the first position, Singer 1 exhibited least vocal change in placement/spacing 132. It should be noted that 1-3-2 also exhibited less change than the opposite placement. With Singer 1 in the first position, the specific placement reduced vocal change for Singer 1, regardless of spacing. With Singer 2 in the first position, Singer 1 exhibited least vocal change in placement/spacing 2-3-1. It should be noted that placement/spacing 231 also exhibited less change than the opposite placement.

With Singer 2 in the first position, the specific placement reduced vocal change for Singer 1, regardless of spacing. With Singer 3 in the first position, Singer 1 exhibited least vocal change in placement/spacing 3-2-1. It should be noted that placement/spacing 321 also exhibited less change than the opposite placement. In addition, it may be noted that both examples of lateral spacing showed less change then either example of close spacing. With Singer 3 in the first position, lateral spacing reduced vocal change for Singer 1. There was also, however, a direct relationship of placement to the reduction of vocal change. Taken together, I conclude from the results that attention to specific placement is crucial to the reduction of overall vocal change. With Singer 2 in the first position, both examples of lateral spacing showed less change than either example of close spacing. With either Singer 1 or Singer 2 in the first position, placement reduced vocal change for Singer 2, but needed to be changed for different spacings.

The most dramatic example of the effect of placement on vocal function for Singer 2 was between Examples 2-20 and 2-21, examples of opposite placement/close spacing. The spectral shift between these placements was 66.07 Hz, 0.16 dB. The most dramatic example of the effect of spacing on vocal function for Singer 2 was between Examples 2-21 and 2-23. The spectral shift between these examples was 37.37 Hz, 1.14 dB. When in the first position, Singer 2 exhibited the least vocal change in placement/spacing 2-3-1. It should be noted that both examples of lateral spacing exhibited less vocal change than either example of close spacing. There was, however, a substantial spectral shift between the examples of close spacing. With Singer 2 in the first position, placement reduced vocal change for Singer 2, but needed to be changed with changed spacing. With Singer 1 in the first position, Singer 2 exhibited the least vocal change in placement/spacing 123. It should be noted that in lateral spacing least vocal change was displayed in placement was 1-3-2. With Singer 1 in the first position, placement reduced vocal change for Singer 2, but needed to be changed with changed spacing. With Singer 3 in the first position, Singer 2 exhibited the least vocal change in placement/spacing 312. It should be noted that placement/spacing 3-1-2 also exhibited less vocal change than its opposite placement. With Singer 3 in the first position, the specific placement reduced vocal change for Singer 2, regardless of spacing.

The most dramatic example of the effect of placement on vocal function for Singer 3 was between Examples 3-20 and 3-21. The spectral shift between these placements was 40.38 Hz, 2.52 dB. The most dramatic example of the effect of spacing on vocal function for Singer 3 was between Examples 3-21 and 3-23. The spectral shift between these examples of spacing was 36.60 Hz, 2.48 dB. When in the first position, Singer 3 exhibited the least vocal change in placement/spacing 312. It should be noted that placement/spacing 3-1-2 showed less vocal change than its opposite placement. With Singer 3 in the first position, the specific placement reduced vocal change, regardless of spacing. With Singer 1 in the first position, Singer 3 exhibited the least vocal change in placement/spacing 1-2-3. It may be noted that both examples of lateral spacing showed less vocal change than did either example of close spacing. There was, however, a greater spectral shift between the examples of lateral spacing than the examples of close spacing. With Singer 1 in the first position, placement reduced vocal change, but needed to be changed for different spacings. With Singer 2 in the first position, Singer 3 exhibited the least vocal change in placement/spacing 2-1-3. It should be noted that placement/spacing 213 showed less change than its opposite placement. It may be further noted that both examples of lateral spacing showed less vocal change than did either example of close spacing. With Singer 2 in the first position, lateral spacing reduced vocal change. There was also, however, a direct relationship of placement to reduced vocal change.

Singer 1 showed the least average vocal change, irrespective of placement or spacing, -4.28 Hz, 0.76 dB. Singer 3 showed only slightly more average vocal change, irrespective of placement or spacing, 4.29 Hz, -1.76 dB. Singer 2 showed the highest average vocal change, irrespective of placement or spacing, 19.50 Hz, 0.68 dB.

In four instances, both examples of lateral spacing showed less overall change than either closely spaced example: Examples 1-26 and 1-27; Examples 2-22 and 2-23; Examples 3-18 and 3-19; and Examples 3-22 and 3-23. No single Example exhibited the least amount of vocal change for each of the singers. Example 1-23/2-23 exhibited the least vocal change in a given set for two singers.

For Singer 1, each set contained a direct correlation between specific placement and reduced vocal change, regardless of spacing. For Singer 2, one set contained a direct correlation between specific placement and reduced vocal change, regardless of spacing. For Singer 3, two sets contained a direct correlation between specific placement and reduced vocal change, regardless of spacing.

For Singer 1, two examples exhibiting the least vocal change were lateral spacing and one example was close spacing. For Singer 2, two examples exhibiting the least vocal change were close spacing and one example was lateral spacing. For Singer 3, two examples exhibiting the least vocal change were lateral spacing and one example was close spacing.

Acoustic placement alone and spacing alone produced virtually equal opportunity for reduced vocal change. Acoustic placement in combination with spacing offered greater opportunity for reduced vocal change than spacing alone. Finally, acoustic placement in combination with spacing offered only slightly more opportunity for reduced vocal change than placement alone. Taken together, I conclude from the results that attention to acoustic placement is superior to random placement, regardless of spacing.

Group 1 Summary

In nine of fifteen Sets for Group 1 there was a direct correlation between singer placement and reduced change in vocal function. In only five of the fifteen sets did both laterally spaced examples show less vocal function change than either closely spaced example. Three of these examples, further, presented a direct relationship of placement to the reduction of change in vocal function. In one of the fifteen sets, both examples of close spacing retained less vocal change than either example of lateral spacing.

Eight of the fifteen sets exhibited the least overall amount of vocal change in laterally spaced examples. Seven of the fifteen sets exhibited the least overall amount of vocal change in closely spaced examples.

The results illustrate that both placement and spacing effected vocal change upon the individual singer. Overall in the Group 1 Duets there was slightly more frequency change between changed spacing than changed placement. There was, conversely, slightly more decibel change between changed placement than changed spacing.

Overall in the Group 1 Trios there was slightly more frequency change between changed placement than changed spacing. There was, conversely, slightly more dB change between changed spacing than changed placement.

The results clearly demonstrate that placement retained greater impact on vocal function than did spacing. The results also suggest that the combination of placement and spacing impacted vocal function only slightly more often than placement alone.

The Duet results demonstrate that close spacing, with specific attention to acoustic placement, produced less requisite change in singers whose vocal process was fairly stable. The examples of least vocal change were equally divided between close and lateral spacing. Lateral spacing, combined with specific attention to acoustic placement, produced less requisite change in singers whose vocal process was more malleable. Moreover, while singers with more consistent vocal process were less likely to be dramatically impacted by surrounding singers, singers with less consistent vocal process required acoustic placement in order to reduce the overall amount of vocal process change.

In the Duets from Group 1, the examples of least overall vocal change were equally divided between close and lateral spacing, intimating yet further validation of the use of acoustic placement. In particular, young and amateur singers require an opportunity in ensemble settings to apply consistent vocal process. Although some change in individual vocal process occurs in ensemble settings, acoustic placement offers the prospect of reduced requisite vocal process change.

The Trio results demonstrate that close spacing, with specific attention to acoustic placement, produced less requisite change in singers whose vocal process was less consistent. Lateral spacing, combined with specific attention to acoustic placement, produced less requisite change in singers whose process was fairly consistent. It may be noted that the least amount of average vocal change in each singer was found to occur when the singer was in the first position.

Singer 1 Trios showed elevated rates of change compared to Duets in examples of both placement and spacing. Singer 2 Trios showed markedly increased rates of change compared to Duets in examples of both placement and spacing. Singer 3 Trios showed elevated rates of change compared to duets in examples of spacing, but markedly increased rates in examples of placement.

In Group 1 Trios, when the examples of least overall change in each set was examined, lateral surpassed close spacing by a slim margin of five to four. This result is further evidence that spacing in combination with acoustic placement was only marginally more effective than acoustic placement alone, and that acoustic placement alone was more probable to foster less vocal change than spacing alone.

Only in the case of Singer 3 Duets did spacing exhibit more than marginal dominance in terms of spectral shift over placement. Spacing was superior to placement in the Duets of both Singer 1 and Singer 3; however, in both Singers, placement was superior to spacing in the Trios. For Singer 2, placement was superior to spacing in both Duets and Trios. The scope of this study was limited to two groups of three singers each. The results suggest, however, that a larger numbers of singers would require specific attention to placement.

Group 2 Duets

In a comparison of the acoustic analyses of Group 2 Duets, Singer 4 exhibited an average spectral change of 15.38 Hz, 1.57 dB. The example of least vocal change for Singer 4 was found in placement/spacing 45. Singer 4 showed the least average overall individual changes in pairings with Singer 5. In pairings with Singer 5, both examples of close spacing showed less than half the amount of vocal change of either example of lateral spacing, and the specific placement showed less change than the opposite placement. In pairings with Singer 6, the specific placement was shown to be of fundamental importance to the reduction of vocal change, regardless of the spacing used. These results clearly show that attention to acoustic placement had a greater capacity to reduce vocal change for Singer 4 than spacing.

Singer 5 exhibited an average spectral change of 7.69 Hz, 3.65 dB and showed the least overall individual changes in pairings with Singer 6. Singer 5 exhibited the least amount of spectral change in Example 5-39, placement/spacing 56. Placement spacing 6-5 showed only 0.06 Hz change from 56, and 45 showed only 0.39 Hz change from 56. In pairings with Singer 4, specific placement was shown to be of importance, regardless of spacing. In pairings with Singer 6, placement was shown to be of importance, but a different placement was required for changed spacing. These results clearly show that attention to acoustic placement has a greater capacity to reduce vocal change for Singer 5 than spacing.

Singer 6 exhibited an average spectral change of 8.86 Hz, 2.41 dB and exhibited the least overall individual changes in pairings with Singer 4. In addition, Singer 6 exhibited the least amount of spectral change in Example 6-42, placement/spacing 6-5. In pairings with Singer 4, the specific placement showed between one-half and three times less change than opposite placements. In pairings with Singer 5, placement was shown to be of importance, but needed to be changed for different spacings. These results clearly show that attention to acoustic placement has a greater capacity to reduce vocal change than spacing.

Taken together, the results from Duet pairings for Group 2 clearly show that attention to acoustic placement sustains a greater probability to reduce vocal change than spacing. Moreover, the combination of placement and lateral spacing are equally likely to produce the least amount of vocal change compared to placement and close spacing. The greatest strategic value for the reduction of vocal change clearly lies with acoustic placement.

The most dramatic example of the effect of placement on vocal function for Singer 4 was between Examples 4-36 and 4-37, placement/spacing 4-6 and 6-4. The spectral shift between these placements was 33.18 Hz, 1.23 dB.

The most dramatic example of the effect of spacing on vocal function for Singer 4 was between Examples 4-34 and 4-36, placement/spacing 46 and 4-6. The spectral shift between these spacings was 23.09 Hz, 1.36 db.

When paired with Singer 5, Singer 4 exhibited the least vocal change in placement/spacing 45. It should be noted that placement/spacing 4-5 exhibited less change than the opposite placement. It should further be noted that both close placements showed less vocal change than either lateral placement. When paired with Singer 5, the specific placement reduced vocal change for Singer 4, regardless of spacing.

When paired with Singer 6, Singer 4 exhibited the least vocal change in placement/spacing 4-6. It should be noted that placement/spacing 46 exhibited less change than the opposite placement. When paired with Singer 6, the specific placement reduced vocal change for Singer 4. regardless of spacing.

The most dramatic example of the effect of placement on vocal function for Singer 5 was between Examples 5-33 and 5-34, placement/spacing 4-5 and 5-4. The spectral shift between these placements was 33.14 Hz, 1.36 dB.

The most dramatic example of the effect of spacing on vocal function for Singer 5 was between Examples 5-32 and 5-34, placement/spacing 54 and 5-4. The spectral shift between these spacings 41.80 Hz, 0.33 dB.

When paired with Singer 4, Singer 5 exhibited the least vocal change in placement/spacing 45. It should be noted that placement/spacing 4-5 also showed less change than its opposite placement. It may be further noted that both examples of close spacing exhibited less change than either example of lateral spacing. When paired with Singer 4, the specific placement reduced vocal change for Singer 5, regardless of spacing.

When paired with Singer 6, Singer 5 exhibited the least vocal change in placement/spacing 56. It may be noted that placement/spacing 6-5 produced only slightly elevated levels of change. When paired with Singer 6, placement reduced vocal change for Singer 5, but needed to be changed for different spacings.

The most dramatic example of the effect of placement on vocal function for Singer 6 was between Examples 6-39 and 6-40, placement/spacing 56 and 65. The spectral shift between these placements was 27.27 Hz, 3.39 dB.

The most dramatic example of the effect of spacing on vocal function for Singer 6 was between Examples 6-40 and 6-43, examples of same placement/different spacing. The spectral shift between these spacings was 23.88 Hz, 1.65 dB.

When paired with Singer 4, Singer 6 exhibited the least vocal change when in placement/spacing 4-6. It should be noted that placement/spacing 46 also exhibited less change than its opposite placement. When paired with Singer 4, the specific placement reduced vocal change for Singer 6, regardless of spacing.

When paired with Singer 5, Singer 6 exhibited the least vocal change when in placement/spacing 5-6. It should be noted that placement/spacing 56 also exhibited less change than its opposite placement. When paired with Singer 5, the specific placement reduced vocal change for Singer 6, regardless of spacing.

Singer 5 exhibited the least average vocal change, irrespective of placement or spacing, 7.69 Hz, 3.65 dB. Singer 4 exhibited the most average vocal change, irrespective of placement or spacing, 15.38 Hz, 1.57 dB. Singer 6 exhibited slightly higher average vocal change than Singer 5, irrespective of placement or spacing, 8.86 Hz, 2.41 dB.

In one case both examples of close spacing showed less overall change than either example of lateral spacing: Examples 4-31 and 4-32, placement/spacing 45 and 54. Two examples yielded the least amount of vocal change for both singers: Example 4-31/5-31, placement/spacing 45, and Example 4-37/6-37, placement/spacing 4-6.

Both sets for Singers 4 and 6 exhibited a direct correlation between placement and vocal change, regardless of spacing. Singer 5 had one example containing direct correlation between placement and vocal change: paired with Singer 4.

For Singer 4, one example exhibiting least vocal change was close spacing, one was lateral spacing. For Singer 5, both examples of least vocal change were close spacing. For Singer 6, both examples of least vocal change were lateral spacing.

In Group 2 Duets, acoustic placement alone produced greater opportunity for reduced vocal change when compared to spacing alone, by a margin of five-to-one. Further, acoustic placement, in combination with spacing, produced greater opportunity for reduced vocal change when compared to spacing alone. Taken together, I conclude from the results that attention to acoustic placement is superior to random placement, regardless of spacing. The greatest strategic value for the reduction of vocal change clearly lies with acoustic placement.

Group 2 Trios

In a comparison of the acoustic analyses of Group 2 Trios, Singer 4 exhibited an average spectral change of 3.44 Hz, -1.73 dB. Singer 4 showed the least overall change when in the first position and the least total amount of spectral change in Example 4-45, placement/spacing 4-5-6, 0.47 Hz, -3.45 dB. Singer 4 also showed a specific correlation of placement to least vocal change, regardless of spacing. With Singer 5 in the first position, Singer 4 showed least vocal change in placement/spacing 564, 3.56 Hz, -1.27 dB. Placement was shown to reduce vocal change, but needed to be changed with changed spacing. With Singer 6 in the first position, Singer 4 showed least vocal change in placement/spacing 645, 1.71 Hz, -3.82 dB. Placement was shown to reduce vocal change, but needed to be changed for different spacings. The results show that, although placement needed to be changed for different spacings, placement clearly contributed to the reduction of vocal change. Moreover, in the examples where placement changed for different spacings, the rate of change fell between double and nearly five times the overall rate of change.

Singer 5 exhibited an average spectral change of 13.92 Hz, 2.94 dB. Singer 5 showed the least overall change when in the first position and the least total amount of change in Example 5-46, placement/spacing 546, -2.27 Hz, -3.75 dB; both examples of close spacing showed less change than either example of lateral spacing. It should be noted, however, that the change in placement showed a change in the direction of the spectral change, placement/spacing 564, 3.01 Hz, -3.02 dB. It should also be observed that the rate of vocal change with increased spacing was elevated between four and nine times. With Singer 6 in the first position, Singer 5 showed the least amount of vocal change in placement/spacing 6-5-4, and both examples of lateral spacing showed less vocal change than either example of close spacing. There was, however, a direct relationship of placement to reduced vocal change. The elevation of vocal change with close spacing was double or less the rate compared to lateral spacing. With Singer 4 in the first position, Singer 5 showed least vocal change in placement/spacing 456; placement, however, needed to be changed for different spacings. The results show that close spacing more often produced the least vocal change, consistent with specific placements. In one instance close spacing showed less overall change than lateral spacing, and in one instance lateral spacing showed less overall change than close spacing. Although changed spacing necessitated changed placement, the use of placement showed reduced amounts of vocal change. Moreover, the instance when both examples of lateral spacing showed greater reduction than either example of close spacing, showed markedly elevated rates of change compared to the example when both examples of close spacing showed greater reduction than either example of lateral spacing.

Singer 6 exhibited an average spectral change of 6.67 Hz, -4.43 dB. Singer 6 showed the least overall change with Singer 5 in the first position, but exhibited the least total amount of change in Example 6-45, placement/spacing 4-5-6, 7.78 Hz, -3.73 dB. Placement/spacing 456 also showed less change than its opposite placement. With Singer 5 in the first position, placement/spacing 564 showed least vocal change, -1.46 Hz, -4.91 dB, and both examples of close spacing showed less vocal change than either example of lateral spacing. With Singer 6 in the first position, placement/spacing 645 showed least vocal change, 12.93 Hz, -6.54 dB, and there was a specific relationship of placement to least vocal change. Although one set showed less vocal change in both examples of close spacing, the rate of change doubled with changed placement in close spacing. The results clearly show that, in each set, specific placement showed reduced amounts of vocal change.

The most dramatic example of the effect of placement on vocal function for Singer 4 was between Examples 4-51 and 4-52, placement/spacing 645 and 654. The spectral shift between these placements was 22.69 Hz, 4.20 dB.

The most dramatic example of the effect of spacing on vocal function for Singer 4 was between Examples 4-52 and 4-54, placement/spacing 654 and 6-5-4. The spectral shift between these spacings was 31.02 Hz, 0.41 dB. When in the first position, Singer 4 exhibited least vocal change in placement/spacing 4-5-6. It should be noted that placement/spacing 456 also exhibited less change than its opposite placement. With Singer 4 in the first position, the specific placement reduced vocal change for Singer 4, regardless of spacing. With Singer 5 in the first position, Singer 4 exhibited least vocal change in placement/spacing 564. It may be noted that placement/spacing 5-4-6 showed less change that its opposite placement. With Singer 5 in the first position, placement reduced vocal change for Singer 4, but needed to be changed with changed spacing. With Singer 6 in the first position, Singer 4 exhibited least vocal change in placement/spacing 645. It may be noted that placement/spacing 6-5-4 showed less change that its opposite placement. With Singer 6 in the first position, placement reduced vocal change for Singer 4, but needed to be changed for different spacings.

The most dramatic example of the effect of placement on vocal function for Singer 5 was between Examples 5-43 and 5-44, placement/spacing 456 and 465. The spectral shift between these placements was 10.39 Hz, 2.73 dB. The most dramatic example of the effect of spacing on vocal function for Singer 5 was between Examples 5-47 and 5-49, placement/spacing 546 and 5-4-6. The spectral shift between these spacings was 21.80 Hz, 0.04 dB. With Singer 4 in the first position, Singer 5 exhibited least vocal change in placement/spacing 456. It may be noted that placement/spacing 4-6-5 exhibited less vocal change than its opposite placement. With Singer 4 in the first position, placement reduced vocal change for Singer 5, but needed to be changed for different spacings. When in the first position, Singer 5 exhibited least vocal change in placement/spacing 546. It may be noted that both examples of close spacing showed less vocal change than either example of lateral spacing. When in the first position, placement reduced vocal change for Singer 5, but needed to be changed for different spacings. With Singer 6 in the first position, Singer 5 exhibited least vocal change in placement/spacing 6-5-4. It should be noted that placement/spacing 654 also showed less vocal change that its opposite placement. It may be further noted that both examples of lateral spacing showed less change than either example of close spacing. With Singer 6 in the first position, lateral spacing reduced vocal change for Singer 5, regardless of placement. However, there remained a direct correlation of placement to reduced vocal change.

The most dramatic example of the effect of placement on vocal function for Singer 6 was between Examples 6-53 and 6-54. The spectral shift between these placements was 48.07, 0.08 dB. The most dramatic example of the effect of spacing on vocal function for Singer 6 was between Examples 6-52 and 6-54. The spectral shift between these spacings was 54.04 Hz, 0.77 dB. With Singer 4 in the first position, Singer 6 exhibited the least vocal change in placement/spacing 4-5-6. It should be noted that placement/spacing 456 also showed less change than its opposite placement. With Singer 4 in the first position, the specific placement reduced vocal change, regardless of spacing. With Singer 5 in the first position, Singer 6 exhibited the least vocal change in placement/spacing 564. It should be noted that placement/spacing 5-6-4 showed less change than its opposite spacing. With Singer 5 in the first position, the specific placement reduced vocal change for Singer 6, regardless of spacing. When in the first position, Singer 6 exhibited least vocal change in placement/spacing 645. It should be noted that placement/spacing 6-4-5 showed less change than its opposite placement. It should also be noted that both examples of close spacing showed less change than either example of lateral spacing. When in the first position, the specific placement reduced vocal change for Singer 6, regardless of spacing.

Singer 4 showed the least average vocal change, irrespective of placement or spacing, 3.44 Hz, -1.73 dB. Singer 6 showed an increased average vocal change, irrespective of placement or spacing, -6.67 Hz, 4.43 dB. Singer 5 showed the most average vocal change, irrespective of placement or spacing, 13.92 Hz, 2.94 dB.

In two instances, both examples of close spacing showed less overall change than either example of lateral spacing: Examples 5-47 and 5-48, placement/spacing 546 and 564; and Examples 6-47 and 6-48, placement/spacing 546 and 564.

For Singer 4, one set contained a direct correlation between placement and vocal consistency. For Singer 5, one set contained a direct correlation between placement and vocal consistency. For Singer 6, each set contained a direct correlation between placement and vocal consistency.

For Singer 4, two examples exhibiting the least vocal change were close spacing and one example was lateral spacing. For Singer 5, two examples exhibiting the least vocal change were close spacing and one example was lateral spacing. For Singer 6, two examples exhibiting the least vocal change were close spacing and one example was lateral spacing.

Singer 4 Trios showed slightly elevated rates of change compared to Duets. Singer 5 Trios, conversely, showed reduced rates of change compared to Duets. Singer 6 Trios showed slightly elevated rates of change compared to Duets in placements, but showed markedly elevated rates of change in spacing.

Once again, the results were consistent with the conclusion that attention to acoustic placement is superior to random placement. The outcomes, further, show that acoustic placement alone more consistently produced the opportunity for vocal process consistency than spacing alone. Acoustic placement in combination with spacing offered more opportunity for vocal consistency than spacing alone. Finally, acoustic placement in combination with spacing offered slightly more opportunity for vocal consistency than placement alone.

The results clearly attest that placement retained greater impact on vocal function than spacing. The results also suggest that the combination of placement and spacing impacted vocal function only slightly more often than placement alone.

It may be noted that both Singers 4 and 5, in pairings with each other, experienced the greatest amount of vocal change not only in the same placement, but also in lateral spacing.

The Trio results demonstrate that close spacing, with specific attention to acoustic placement, produced less requisite change both in singers with fairly consistent and more malleable vocal process. Both Singers 4 and 5 exhibited the overall least amount of change when in the first position, respectively. Singer 6 showed the least change with Singer 5 in the first position.

Singer 4 Trios showed slightly lesser rates of change compared to Duets in examples of placement, but elevated rates in examples of spacing. Singer 5 Trios exhibited significantly reduced rates of change compared to Duets, for both placement and spacing. Singer 6 Trios showed lesser rates of change compared to Duets for examples of placement, but markedly elevated rates of change in spacing.

Group 2 Summary

In ten of fifteen sets there was a direct correlation between singer placement and reduced change in vocal function. In four of fifteen sets both examples of close spacing showed less vocal function change than either example of lateral spacing. In two of these sets there remained a direct relationship of placement to the reduction of change in vocal function. One set showed less vocal function change in both examples of lateral spacing than in either closely spaced example; this set, however, also showed a direct relationship to placement.

Nine of the sets exhibited the least amount of vocal change in examples of close spacing. Six of the sets exhibited the least amount of vocal change in example of lateral spacing.

In Group 2 Trios, when the examples of least overall change in each set were examined, close surpassed lateral spacing by a margin of six to three. This elucidates that acoustic placement was a greater factor in decreasing vocal change than spacing. It further shows that acoustic placement, in combination with spacing, was less likely to decrease vocal function change than placement alone.

The results clearly illustrates that both placement and spacing effect vocal change upon the individual singer. Overall, in Group 2 Duets, there was slightly more frequency change between changed placement than changed spacing. There was also more decibel change between changed placement than changed spacing.

Overall, in Group 2 Trios, there was slightly more frequency change between changed placement than changed spacing. There was also more decibel change between changed placement than changed spacing.

The results clearly indicate that placement retained greater impact on vocal function than did spacing. The results also suggest that the combination of placement and spacing positively impact vocal function only slightly more often than placement alone.

The Duet results demonstrate that specific attention to acoustic placement produced less requisite change in all singers. Close and lateral spacing produced equal opportunity for vocal consistency. Singers with more consistent vocal process were either most consistent completely in lateral spacing or completely in close spacing. Singers with less consistent overall vocal process were equally likely to find lateral or close spacing most effective. Moreover, singers with less consistent vocal process were more likely to be significantly impacted by changed placement and spacing, making attention to these details even more crucial.

The Trio results demonstrate that specific attention to acoustic placement produced less requisite vocal change. Close spacing was more likely to produce less change than lateral spacing. It may be noted that both Singer 4 and Singer 5 experienced the least amount of vocal change when placed in the first position. Singer 6 experienced the least amount of vocal change with Singer 5 in the first position, and Singer 6 in the second position. The trio results clearly delineate that acoustic placement alone surpasses spacing alone, and acoustic placement in combination with spacing is superior to spacing alone.

The Group 2 Duets and Trios exhibit fairly equal results in terms of overall change. In no case did spacing exhibit dominance in terms of spectral shift over acoustic placement. Acoustic placement did exhibit a direct relationship in ten of fifteen sets.

Singer 4 showed slightly elevated rates of change between Duets and Trios in both placement and spacing. Singer 5 showed a reduction in the rate of change from Duets to Trios. Singer 6 showed slightly elevated rates of change in placement, but spacing showed a significant increase in the rate of change from Duets to Trios. This information confirmed that an increased number of singers requires greater attention to acoustic placement.

Summary of Groups 1 & 2 Findings:

The results from both Groups confirm that both placement and spacing contributed to variant levels of vocal change in individual singers. In nineteen of thirty total examples there was a direct correlation of acoustic placement to vocal process consistency. The results further reveal that changed placement generated more overall vocal modification than changed spacing. This confirms the expectation that acoustic placement alone more significantly contributes to consistency of vocal process than spacing alone. The results also indicate that the combination of acoustic placement and spacing contributed only slightly more opportunity for reduced vocal change than acoustic placement alone.

In only six of thirty sets did both examples of lateral spacing show less overall vocal function change than either example of close spacing. These appeared predominately in Group 1, and in four of these examples, further, there remained a direct correlation of placement to the reduction of change in vocal function. In five of the thirty sets, both examples of close spacing showed less overall vocal function change than either example of lateral spacing, one example from Group 1 and four examples from Group 2. Three of the sets showed a direct correlation of placement to reduced vocal change. The contribution of close and lateral spacing to vocal consistency, regardless of placement, was shown to be virtually equal. Of the ten total sets in which either close or lateral spacing made the greatest difference, regardless of placement, seven retained a direct correlation of acoustic placement to reduced vocal change. The equal likelihood of the occurrence of either close or lateral spacing, in tandem with the probability that acoustic placement would retain influence in the midst of spacing, served to disqualify the notion that spacing alone facilitated a greater possibility of vocal consistency over acoustic placement, or acoustic placement combined with spacing. The results of both Groups establish that the probability of decreased vocal change was far greater for placement than for spacing, and that the combination of placement and spacing only slightly contributed to the overall outcomes, in only four of twenty total sets where a direct relationship of placement was shown.

Of great significance is confirmation of the assumption that the likelihood for vocal change increased as the number of constituent voices increased. This finding holds crucial implications for use in a larger ensemble context. Acoustic placement significantly reduced the amount of vocal change, and acoustic placement combined with spacing showed a less often, but significant amount of, reduction of vocal change. This verifies the hypothesis that placement is the fundamental component of vocal consistency in ensemble singing.

Modified Question 1B
What was the relationship of the examples of least vocal change for each singer compared to the other singers?

Each singer participating in this study exhibited varied amounts of vocal change. Reduction of the overall individual amount of vocal change was most specifically related to the individual placement within the group of singers, but also included some relationship to the amount of space between singers. Given that the acoustic data demonstrated measurable trends and amounts of individual vocal change, it became necessary to investigate whether or not the same placement/spacing elicited a decreased amount of vocal change for each singer in a given example.

Group 1 Duets

In Set 1, Examples 1-4/2-4, placement/spacing 12, each exhibited the least amount of vocal change for Singers 1 and 2. The average vocal change for Singers 1 and 2 was 5.87 Hz. Both examples of close spacing showed less average change for all Singers than either example of lateral spacing, and placement needed to be changed for different spacings.

The least amount of vocal change in Set 2 for Singers 1 and 3 was found in Examples 1-9/3-11, placement/spacing 31/3-1. It may be noted that, although the amount of change in Example 1-11 is not the least amount in Set 2 for Singer 1, placement/spacing 31, 4.04 Hz, the amount of change in Example 11 for Singer 1, -8.01 Hz, is less than that of Singer 3, 8.34 Hz. Example 11, therefore, obliges each Singer to modify vocal production in nearly equal amounts, 8.17 Hz, and shows the least average change for both Singers in Set 2. Although both examples of lateral spacing showed less average change for all Singers, there was also a specific relationship of placement to the reduction of average vocal change.

The least amount of vocal change in Set 3 for Singers 2 and 3 was discovered in Examples 2-14/3-15, placement/spacing 2-3/3-2. It may be noted that the opposite Examples for both Singer 2 and 3 show double or triple the amounts of vocal change. Example 15, placement/spacing 3-2 provided the least average vocal change for both Singers, 15.56 Hz. Example 12, placement/spacing 23, showed an average vocal change of 15.78 for both Singers, a shift increase of only 0.22 Hz from Example 15. Placement was an important part of the average reduction of vocal change and needed to be changed for different spacings. It may be noted that the variance between the examples of least and most change for this Set was only 2.01 Hz.

Group 1 Trios

In Set 4, Singers 2 and 3 showed least vocal change in Examples 2-16/3-18, placement/spacing 123/1-2-3. Singer 1 showed the least amount of change with the opposite placements, placement/spacing 132/1-3-2; the spectral shift between these spacings was 0.71 Hz. It may be noted that Singer 2 showed only a spectral shift of 0.79 Hz from its example of least vocal change to placement/spacing 1-3-2. Singer 3 showed a spectral shift of 16.93 Hz from its example of least vocal change to placement/spacing 1-3-2; however, its overall rate of change for placement/spacing 1-3-2 was 5.95 Hz less than the change shown by Singer 1. Example 19 provided the least average vocal change for all

Singers, 16.96 Hz. Set 4 showed a specific relationship of placement to reduced average vocal change for all Singers, regardless of spacing.

In Set 5, Examples 1-23/2-23 each exhibited the least amount of vocal change for Singers 1 and 2. It may be noted that, although Example 23 did not correspond to the example of least change within this set for Singer 3, the amount of change for Singer 2 in Example 23, 9.83 Hz, was greater than the amount of change in Singer 3, -6.89 Hz. Example 23 provided the least average vocal change for all Singers, 6.13 Hz. The rate of change for Example 22 was 8.41 Hz, a shift increase of 2.28 Hz. It may be noted that both examples of lateral spacing showed less average change than either example of close spacing. Placement was an important part of the reduction of average vocal change for all Singers, but needed to be changed with changed spacing.

In Set 6, Singers 2 and 3 displayed least vocal change in Examples 2-24/3-26, placement/spacing 312/3-1-2. Singer 1 showed the least amount of change in Example 1-27, placement/spacing 3-2-1, -9.04 Hz. Example 1-26, placement/spacing 3-1-2, -11.47 Hz, showed a shift increase of only 2.33 Hz from Example 1-27, but Example 1-24, placement/spacing 312 showed the highest rate of change for Singer 1, 16.98 Hz. Nevertheless, the least average vocal change for all Singers was found in Example 24, placement/spacing 312, 9.55 Hz. Specific placement showed a direct relationship to the reduction of average vocal change, regardless of spacing.

Group 2 Duets

In Set 7, Examples 4-31/5-31 each exhibited the least amount of vocal change for pairings of Singers 4 and 5, placement/spacing 45. The average vocal change for both Singers was 3.90 Hz. The specific placement showed a direct relationship to reduced vocal change, regardless of spacing.

In Set 8, Examples 4-37/6-37 each exhibited the least amount of vocal change for pairings of Singer 4 and 6, placement/spacing 4-6. The average vocal change for both Singers was 4.80 Hz. The specific placement showed a direct relationship to reduced vocal change, regardless of spacing.

In Set 9, no single example showed the least vocal change for both singers. Singer 5 showed least vocal change in Example 6-42, 2.17 Hz. Singer 5 showed least vocal change in Example 5-39, 2.23 Hz; however, Examples 5-39 and 5-42 only showed a difference of 0.06 Hz. The least average change for each Singer was in Example 42, placement/spacing 6-5. Placement showed a reduction in the amount of vocal change, but needed to be changed with changed spacing.

Group 2 Trios

In Set 10, Singers 4 and 6 shared Examples 4-45/6-45, placement/spacing 4-5-6 as the example of least vocal change. It may be noted that Singer 4 exhibited the least overall change of any Singer in any Example of the entire study in Example 4-45, 0.47 Hz. Singer 5 showed least vocal change in Example 5-43, placement/spacing 456, and Example 5-45 showed nearly double the amount of vocal change. The least average change for both Singers was in Example 43, placement/spacing 456, 6.52 Hz. It should be noted that Example 45, placement/spacing 4-5-6 showed a shift increase of only 0.10 Hz. The specific placement showed a direct relationship to reduced vocal change, regardless of spacing.

In Set 11, Singers 4 and 6 shared Examples 4-48/6-48, placement/spacing 564, as the example of least vocal change. Singer 5 showed least vocal change in Example 5-47, placement/spacing 546, -2.27 Hz; however, Example 5-48, placement/spacing 564, 3.01 Hz, showed a shift increase of 0.64 Hz. It may be noted that both examples of close spacing for Singers 5 and 6 showed less change than either example of lateral spacing, and there was also a direct relationship of specific placement to reduced vocal change. The least overall change for all Singers was Example 48, placement/spacing 564, 2.68 Hz.

In Set 12, Singers 4 and 6 shared Examples 4-51/6-51 as examples of least vocal change, placement/spacing 645. Singer 5 showed least vocal change in Example 5-54, placement/spacing 6-5-4. The least overall change for all Singers was Example 51, placement/spacing 645, 14.63 Hz. Example 54 showed a change of 14.98 Hz, a shift increase of only 0.35 Hz. Placement was shown to reduce vocal change, but needed to be changed with changed spacing.

Timbre is defined as the relative strength (dB) of the characteristic frequencies (Hz) of a selected voice. Twenty-six examples from among the sixty comparison pairs not only showed a change in frequency, but also a change in frequency direction that directly corresponded to changed placement. Fourteen examples exhibited a change in dB direction due to changed placement. Twenty-one examples showed not only a change in frequency, but also a change in frequency direction directly corresponding to changed spacing. Fifteen examples exhibited a change in dB direction due to changed spacing.

Among the twelve Sets, two showed least vocal change in both examples of close spacing, and two showed least vocal change in both examples of lateral spacing. If spacing were the crucial component in the reduction of vocal change, this ratio would greatly favor examples of lateral spacing. In only four of twelve Sets did examples of the same spacing show greatest reduction of vocal change, and these were equally distributed between examples of close and lateral spacing. Moreover, in only five of twelve sets did the example of least vocal change switch to another placement with changed spacing. These results served to underscore that, compared to spacing, acoustic placement increases the opportunity for the reduction of vocal change, and thereby the consistent individual utilization of characteristic frequencies.

Modified Question 1C
What was the relationship between auditor preference and placement/spacing?

Twenty-five private voice teachers and choral directors were identified as a prospective group of auditors. These auditors ranged in responsibility from church musicians to high school and university level choral directors and vocal instructors. Auditors were surveyed as to their preferences concerning blend among selected examples. Auditors were also asked to delineate certain aspects of their background with respect to choral conducting, private vocal instruction, and uses of choral blending techniques.

Auditors reported various responsibilities, including conducting ensembles and private vocal instruction to various types of administrative responsibilities dealing with choral/vocal music. Four respondents reported choral directing as their primary area of expertise. Two reported private vocal instruction and two reported both choral conducting and vocal instruction as areas of expertise. Years of experience with choral conducting ranged between no experience and fifty-six years of experience. Three auditors reported over twenty years of experience with choral conducting and three reported twenty or more years of private voice instructing. Five of the auditors reported terminal degrees; a sixth reported a degree in progress. Emphases included choral conducting, vocal performance, music education, and church music.

When asked to describe the differences in vocal technique between choral and solo singing, four auditors reported no desire to have singers employ differing techniques. Other auditors suggested requisite changes to include timbre and vibrato.

With respect to blending procedures, more respondents reported the use of voice matching procedures than spacing procedures; two respondents either offered no response or had no experience with choral directing. The improvements reported as the direct result of voice matching included better blend and easier vocal production. One auditor reported significant improvements in individual singer rhythmic accuracy. The improvements reported as the direct result of spacing included better blend and a fuller, freer sound.

When asked to consider the greater asset to overall choral sound, auditors presented a slight edge to voice matching. When considering the facilitation of individual vocal freedom, auditors chose spacing.

Auditors were surveyed as to their preferences of ensemble blend from among the placements and spacings of each Group. Auditors first selected from among examples of different placements. Next, auditors chose from among examples of different spacing. Finally, auditors chose the best example of blend from between the best examples of placement and spacing. Trends related to the placement and spacing of ensemble members emerged from among the responses. The results from this survey can be found in Appendix C.

Group 1

Responses concerning Set 1 showed a specific relationship of Auditor preference to placement. Both placement/spacing 21 and 2-1 were selected as the examples of best blend compared to the opposite placements. Sets 2 and 5 each showed placement preferences to change with changed spacing. Sets 3, 4, and 6 each produced one example in which auditor preference was evenly divided. The difference of opinion in Sets 3 and 4 was between examples of opposite placement/close spacing. The preference among the lateral spacing examples for these Sets was unanimous. Set 6 was divided between its examples of opposite placement/lateral spacing; however, the preference among the example of close spacing for this Set was nearly as ambiguous.

Auditors preferred examples of lateral spacing as the best example of blend for each Set. Placement/spacing 3-1 was selected as the best version of Duet blend. Placement/spacing 3-1-2 was selected as the best version of Trio blend. Although Auditors selected placement/spacing 2-1 as the best blend for combinations of Singers 1 and 2, the choice of placement/spacing 3-1 and 3-1-2 exhibited a direct relationship of Auditor choice to both placement and spacing for Singers 1 and 3 between Group 1 Duets and Trios.

Group 2

Responses concerning Sets 8, 10, and 11 showed a specific relationship of Auditor preference to placement. Placement/spacing 64/6-4, 456/4-5-6, and 564/5-6-4 were selected as the examples of best blend compared to the opposite placements. Set 7 showed placement preferences to change for different spacings. Sets 9 and 12 each produced one example in which Auditor preference was evenly divided. The difference of opinion in Set 9 was between examples of opposite placement/close spacing, and the difference of opinion in Set 12 was between examples of opposite placement/lateral spacing. The examples of lateral spacing for Set 9 were more clearly expressed, but the examples of close spacing for Set 12 were nearly as ambiguous as for lateral spacing.

Auditors preferred examples of lateral spacing as the best example of blend for three sets, and close spacing for three sets in Group 2. Placement/spacing 64 and 5-4 were selected equally as the best versions of Duet blend. Placement/spacing 4-5-6 was designated as the best version of Trio blend.

Several auditors commented that, due to the similar character of the compared sounds in both Groups, choosing between certain, but non-specified, examples was difficult. No specific quality of sound, i.e., equally poor or fine, was delineated. However, in four of five Sets in which Auditor preference was equally divided between two examples, Auditors chose an example other than these two as the example of best blend. From this information it may be concluded that when Auditor preference was divided, the examples were likely equally poor examples of blend.

Comparison of Groups 1 and 2

In Group 1, Auditors selected examples of lateral spacing as the best example of blend in each Set. In Group 2, Auditors selected an equal number of examples of close and lateral spacing as the best examples of blend. Divided opinion occurred in five of twelve total Sets, and was equally likely to exist in examples of close or lateral spacing. In nine of twelve Sets the selected example of overall best blend was the example that most clearly exhibited Auditor preference in initial comparisons. Among the seven Sets where clear placement comparison was possible, four possessed a specific relationship of placement to auditor preference, regardless of spacing, while the remaining three Sets showed a change in auditor preference in placement coinciding with changed spacing. In Group 1, auditor selection demonstrated that acoustic placement in combination with spacing is superior to spacing alone. In Group 2, auditor selection demonstrated that either acoustic placement or acoustic placement in combination with lateral spacing are superior to spacing alone. Moreover, while auditors showed equal preference for close and lateral spacing in Group 2 Duets, Group 2 Trios showed a preference for close spacing. These results clearly show that acoustic placement is more vital to choral blend than spacing.

Modified Question 1D
How did the examples that acoustically demonstrated the least amount of vocal change for each singer correspond to the preferences of auditors?

The acoustic analyses clearly reflected a relationship between specific placement and the reduction of vocal change for the individual singer. The examples of best blend, selected by auditors, exhibited a trend for acoustic placement or acoustic placement in combination with lateral spacing. Proponents of voice matching assert that the examples of best blend through acoustic placement reduce the necessity of vocal change on the part of individual singers. "Voice positioning techniques . . . ideally, do not compromise the vocal production of individual singers." (Giardiniere 23) "Proponents of [voice matching] believe that blend is thus enhanced naturally through acoustic phenomena, allowing singers substantial individuality in vocal timbre and freedom in vocal production." (Eckholm, 2000 3) The identification of specific trends in both acoustic analysis and auditor preference imparts preliminary credence to the claims listed above. Taken as a whole, however, the acoustic and auditor trends should be expressed in similar examples to validate the entire principle. Therefore, the acoustic analyses were compared to the blend preferences of auditors.

Group 1 Duets

Auditor selection did not match the example of least average vocal change in Set 1. Auditors chose placement/spacing 21 as the best example of blend, 9.63 Hz, and Singers 1 and 2 exhibited least vocal change in placement/spacing 12, 5.87 Hz. In both examples, Singer 2 exhibited nearly double the amount of vocal change exhibited by Singer 1. The acoustic analyses revealed, however, that the additional vocal change served to eliminate overlapping frequency peaks in the region of the singer's formant. The example of best blend for Set 1, selected by Auditor preference, showed the second least amount of vocal change, and the shift increase from the best acoustic example was 3.76 Hz.

In Set 2, auditor selection corresponded to least vocal change for all Singers, Example 11, placement/spacing 3-1, 8.17 Hz. Example 3-11 also was the least amount of change for Singer 3. Auditors chose Example 11 as the best example of blend from among Group 1 Duets.

In Set 3, auditor preference, Example 14, placement/spacing 2-3, 16.83 Hz, did not correspond to the example of least average change. Example 15, placement/spacing 3-2, 15.58 Hz. Example 14 did, however, show the least overall change for Singer 2.

Group I Trios

In Set 4, auditor selection, Example 19, did correspond to the example of least average change, Example 19, placement/spacing 1-3-2, 16.96 Hz. While Example 19 showed the least average change, it also showed the second least amount of vocal change for each Singer.

Auditor selection for Set 5, Example 23, did correspond to the example of least average vocal change, placement/spacing 2-3-1, 6.13 Hz. Example 23 did show the least vocal change for both Singer 1 and 2.

In Set 6, auditor selection, Example 26, placement/spacing 3-1-2, 12.22 Hz, did not correspond to the example of least average change, Example 24, placement/spacing 312, 9.55 Hz. Auditor selection did correspond to the examples of least vocal change for Singers 2 and 3. It may be noted that this Example was the best example of reduced vocal change for Singer 2 for all Trio Examples. It may further be noted that, for this Example, the rate of change for Singer 2 was double that of Singer 3, and the rate of change for Singer 1 was double that of Singer 2. Auditors chose Example 24 as the best example of blend among Group 1 Trios.

Group 2 Duets

In Set 7, auditor selection, Example 34, placement/spacing 5-4, 20.96 Hz, did not match the example of least average change, Example 31, placement/spacing 45, 3.90 Hz. Example 31 showed least overall change for both Singers 4 and 5. Example 34 showed the most average change in all Singers among the Examples in Set 7. Example 34 was one of the auditors' selections for best blend among Group 2 Duets.

In Set 8, auditor selection, Example 36, placement/spacing 64, 23.63 Hz, did not match the example of least average change, Example 37, placement/spacing 4-6, 4.80 Hz. Example 36 showed the most overall vocal change for Singer 4 of any Duet example. Example 36 was one of the auditors' selections for best blend among Group 2 Duets.

In Set 9, auditor selection, Example 42, did correspond to the example of least average change, placement/spacing 6-5, 2.23 Hz. Example 42 showed least overall change for Singer 6, and the shift increase for Singer 5 from the example of least vocal change was only 0.06 Hz.

Group 2 Trios

In Set 10, auditor selection, Example 45, placement/spacing 4-5-6, 6.62 Hz, did not match the example of least average vocal change, Example 43, placement/spacing 456, 6.52 Hz. It should be noted that these Examples showed a direct relationship to placement, and that the shift increase between these Examples was only 0.10 Hz. It should be noted that Example 45 was selected by auditors as the best example of blend from among Group 2 Trios.

In Set 11, auditor selection, Example 47, placement/spacing 546, 5.78 Hz, did not match the example of least average vocal change, Example 48, placement/spacing 564, 2.68 Hz. Example 47 did show least overall change for Singer 5. Example 47 showed the second least amount of vocal change among Examples in Set 11, and showed a shift increase of 3.10 Hz.

In Set 12, auditor selection, Example 52, placement/spacing 654, 23.00 Hz, did not match the example of least average vocal change, Example 51, placement/spacing 645, 14.63 Hz. Example 52 showed the most average change of all the examples in Set 12.

Summary

In Group 1 Duets, the example exhibiting the least average vocal change (5.87 Hz) was Example 4, placement/spacing 2-1. Overall, Group 1 Duets showed acoustically a 50% relationship to placement, regardless of spacing. Auditors selected Example 11, placement/spacing 3-1, average change of 8.17 Hz, as the example of best overall blend. Auditor selection showed a definite relationship to specific placement, but each selection for best overall blend was an example of lateral spacing.

In Group 1 Trios, the example exhibiting the least average vocal change (6.13 Hz) was Example 23, placement/spacing 2-3-1. Overall, Group 1 Trios showed acoustically a 66% relationship to placement, regardless of spacing. Auditors selected Example 26, placement/spacing 3-1-2, average change of 12.22 Hz, as the example of best overall blend. Auditor selection showed changed placements for different spacing, and each selection for best overall blend was an example of lateral spacing.

Auditors chose examples of lateral spacing as the best examples of blend for each Set in Group 1; however, there was a strong relationship of placement to both acoustic analysis and auditor selection. Of great significance to this study was that one-half of the Sets in Group 1 showed some ambiguity on the part of auditor selection. Given that no specific reference was offered as to whether the choices were considered equally poor or fine, Group 1 did not present any evidence toward the establishment of a probable vocal match.

In Group 2 Duets, the example exhibiting the least average vocal change (2.23 Hz) was Example 42, placement/spacing 6-5. Overall, Group 2 Duets showed acoustically a 66% relationship to placement, regardless of spacing. Auditor preference was divided between Example 34, placement/spacing 5-4, that showed an average change of 20.96 Hz, and Example 26, placement/spacing 64, that showed an average vocal change of 23.63 Hz. Auditor selection showed a definite relationship to placement, and overall selection was divided between close and lateral spacing.

In Group 2 Trios, the example exhibiting the least average vocal change (2.65 Hz) was Example 48, placement/spacing 546. Overall, Group 2 Trios showed acoustically a 56% relationship to placement, regardless of spacing. Auditors selected Example 45, placement/spacing 4-5-6, that showed an average change of 6.62 Hz, as the example of best blend. Auditor selection showed a definite relationship to placement, and overall selection was divided between close and lateral spacing.

Auditors selected an equal number of close and lateral spacings in Group 2. Of consequence is that auditors preferred examples of close spacing two-to-one for Group 2 Trios. Of greatest significance to this study is that Singers 4 and 6 matched in terms of least amount of vocal change in each Example in which they both sang. Of further interest is that, in two of four Examples, the least amount of vocal change in Singers 4 and 6 matched the auditor choice for best blend. These facts indicated that Singers 4 and 6 might constitute a vocal match. Additional credence is given to this assumption when corroborated with auditor choice for Group 2 Duets. Auditors selected both Examples 36 and 38, placement spacing 64 and 6-4, over their respective opposite placements. Example 36 was selected as the best Example of blend from Set 3, and Example 38 was second. These Examples continued this relationship as the best Examples from Series 3. Examples 36 and 38 could then be assumed to hold information concerning acoustic evidence of a vocal match.

The results of this study clearly establish that individual vocal change takes place when multiple voices sing simultaneously. While auditors did not select any example of least vocal change as the example of best blend in either Group Duet or Trio settings, auditors typically selected as the best blend examples with a low average rate of vocal change. In Group 1, the combination of placement and lateral spacing provided the best alliance of acoustic analysis and auditor preference, at a rate of 54% for placement/lateral spacing and 46% for placement/close spacing. In Group 2, placement alone provided the best alliance of acoustic analysis and auditor preference, at a rate of 50% each for close and lateral spacing. The findings demonstrate that when the assembled voices do not match acoustically, such as Group 1, lateral spacing combined with placement provided the best opportunity for both blend and reduced vocal change. When a vocal match appears to exist, such as in Group 2, lateral and close spacing had equal potential to provide the opportunity for best blend and least vocal change, elevating the significance of attention to individual placement.

This set of findings elucidates the seemingly inconsistent assertions of the studies discussed earlier in this paper. In studies and examples where no specific attention was given to acoustic placement (Warland, Daugherty) lateral spacing would most likely provide the best opportunity for reduction of vocal change and auditor selection of best blend. The results of this study suggest that, in these instances, the addition of acoustic placement would have served to enhance both the reduction of vocal change for the singers and the desired aim of choral blend. In contrast, in studies where specific attention was given to the acoustic placement of individual singers, (Tocheff, Giardiniere, Eckholm) attention to spacing was not a requisite part of either the reduction of vocal change or choral blend.

Modified question 1E
What was the relationship of acoustic evidence and auditor selection to Singer preference?

Two groups of male singers were recorded in various placements and spacings. Following the recording sessions, all singers were asked to complete a survey outlining their personal choral/vocal experiences and their perceptions concerning the effects of the various placements and spacings on the individual and ensemble singing that had just occurred. The only instruction given to the Singers prior to the recording was to "sing normally." Singers were not, therefore, instructed to listen to each other or to react to changed placement or spacing. The Singer Survey and its results can be found in Appendices G and H.

The singers used in this study were university students, ages 19 and 20. They varied in vocal and choral experience from one to fourteen years. Three reported that they were generally most comfortable in solo settings and three others reported that they were generally most comfortable in choral settings. Five singers reported that in choral experiences prior to this study they had been asked to alter vocal production specifically for the sake of blend. Five singers also reported that prior to this study they had been placed next to someone whose voice was in conflict with their own; four of these felt that it was difficult to maintain normal vocal production in such situations.

Four singers had prior experience with voice matching procedures and three had experience with spacing. Three singers stated that in their prior experiences spacing had offered more advantages than voice matching, and one reported voice matching as having possessed greater advantages.

When responding to questions concerning their experiences during this study, neither Singer 2 nor Singer 4 expressed a preference in terms of a specific singing partner. Singer 1 sensed greatest compatibility with Singer 2, while Singer 3 sensed greatest compatibility with Singer 1. Auditors selected the combination of Singers 1 and 3, placement/spacing 3-1, as the example of best blend for Group 1 Duets, and placement/spacing 3-1-2 as the example of best blend for Group 1 Trios. Singer 5 sensed the most vocal compatibility with Singer 6, but Singer 6 felt the best match with Singer 4. Auditors selected both combinations of Singer 4 and 5, placement/spacing 5-4, and Singers 4 and 6, placement/spacing 64 as examples of best blend for Group 2 Duets, and placement/spacing 4-5-6 as the example of best blend for Group 2 Trios. Group 1 showed a direct relationship of placement for both Duets and Trios. Group 2 showed changed placement between Duets and Trios. I conclude from these results that when a vocal match is not apparent, the significance of placement increases as the number of singers increases. I also conclude that, although a vocal match between two singers has been established, the addition of other voices warrants further attention to the best acoustic placement for the total group of assembled singers.

Singer 2 preferred placement on the stage-right side of the ensemble in both Duets and Trios. None of the other Singers consistently expressed a specific preference for any single position, but some reported preferences for specific Duet and Trio placements. In Trios, Singer 1 preferred the stage-left position, Singer 2 the stage-right position, and Singer 3 the middle position. Singer 4 preferred either side position, while both Singers 5 and 6 preferred the middle position.

Singers reported that both placement and spacing audibly affected the overall sound. Singers 1 and 6 asserted that placement made the greatest difference in the overall sound. Singer 4 reported that spacing made the biggest difference. Singers 2 and 3 reported that a combination of placement and spacing obtained the greatest overall sound difference. Singer 5 did not report any specific changes with either placement or spacing.

Group 1 Duets

In Group 1 Duets, Singer 1 sensed the greatest compatibility with Singer 2, but exhibited the least overall vocal change with Singer 3, placement/spacing 31, 4.04 Hz. Singer 1 also expressed that "it was easier to hear Singer 3 in close spacing." Singer 2 expressed no preference for either Singer, but exhibited the least change with Singer 1. Singer 3 sensed greatest compatibility with Singer 1, but exhibited least overall change with Singer 2, placement/spacing 3-2, 6.37 Hz. Acoustic analysis showed the least average change for pairings of Singers 1 and 2, placement/spacing 12, average change 5.87 Hz, but auditors preferred the combination of Singers 1 and 3, placement/spacing 3-1. Group 1 Duets did not show a specific relationship between acoustic analysis and Singer preference, but did show a specific relationship between auditor preference and Singer 3 preference.

Group 1 Trios

In Group 1 Trios, Singer 1 sensed greatest compatibility in placement/spacing 321, but exhibited least overall change in placement/spacing 2-3-1, 1.67 Hz. When possible, Singer 1 preferred the stage-left position, but preferred Singer 2 to his immediate left when in other placements. Singer 2 did not sense compatibility in any specific placement/spacing, although he preferred to sing in the stage-right position. Singer 2 exhibited least overall vocal change in placement/spacing 312, 7.59 Hz. Singer 3 sensed greatest compatibility in placement/spacing 312, but exhibited least overall change in placement/spacing 2-1-3, -1.12 Hz. Acoustic analysis showed the least average change in placement/spacing 2-3-1, but auditors preferred placement/spacing 3-1-2. Group 1 Trios did not show a specific relationship between acoustic analysis and Singer preference. Auditor preference, placement/spacing 3-1-2, did show a relationship of placement to the least overall change for Singer 2, placement/spacing 312, and the preference of Singer 3, placement/spacing 312.

Group 2 Duets

In Group 2 Duets, Singer 4 sensed no specific compatibility with either Singer, but exhibited the least overall acoustic change with Singer 5, placement/spacing 45, -5.18 Hz. Singer 5 both sensed greatest compatibility and exhibited the least overall change with Singer 6, placement/spacing 56, 2.23 Hz. Singer 6 sensed greatest compatibility with Singer 4, but exhibited the least overall change with Singer 5, placement/spacing 6-5, 2.17 Hz. Acoustic analysis showed the least average change in placement/spacing 6-5, 2.23 Hz, but auditors preferred either placement/spacing 5-4 or 64. In Group 2 Duets, acoustic analysis showed a relationship to Singer 5 preference, and auditor preference showed a relationship to Singer 6 preference.

Group 2 Trios

In Group 2 Trios, Singer 4 did not express a sense of compatibility in any specific placement/spacing, but preferred either the stage-right or stage-left position. Singer 4 showed the least overall change in placement/spacing 4-5-6. 0.47 Hz. Singer 5 generally preferred the center position and sensed greatest compatibility in placement/spacing 456, but showed least overall change in placement/spacing 546, -2.27 Hz. Singer 6 did not express a sense of compatibility in any specific placement/spacing, but generally preferred the center position. Singer 6 showed the least overall change in placement/spacing 564, -1.46 Hz; this placement corresponded to the center position preference. Acoustic analysis showed the least average change in placement/spacing 564; this corresponded to the side position preference of Singer 4 and the center position preference of Singer 6. In Group 2 Trios, auditors chose placement/spacing 4-5-6 as the best example of blend; this corresponded to the side position preference of Singer 4 and the center position preference of Singer 5. The placement/spacing from both acoustic analysis and auditor preference correspond to the preferences of two Singers and show the least overall change for one Singer.

Summary

Singers perceived changes in sound with both changed placement and spacing. Group 1 Duets did not show a specific relationship between acoustic analysis and Singer preference, but did show a specific relationship between auditor preference, placement/spacing 3-1, and Singer 3 preference. Group 1 Trios did not show a specific relationship between acoustic analysis and Singer preference. Auditor preference, placement/spacing 3-1-2, did show a relationship of placement to the least overall change for Singer 2, placement/spacing 312, and the preference of Singer 3, placement/spacing 312.

In the acoustic analysis of Group 2 Duets, placement/spacing 6-5 showed a relationship to Singer 5 preference, and auditor preference, placement/spacing 64 showed a relationship to Singer 6 preference. In Group 2 Trios, acoustic analysis showed the least average change in placement/spacing 564; this corresponded to the side position preference of Singer 4 and the center position preference of Singer 6. Auditors chose placement/spacing 4-5-6 as the best example of blend; this corresponded to the side position preference of Singer 4 and the center position preference of Singer 5. The placement/spacing from both acoustic analysis and auditor preference correspond to the preferences of two Singers and show the least overall change for one Singer.

In Group 1, neither Duets nor Trios showed any relationship of Singer preference to acoustic analysis. In Group 2, both Duets and Trios included some relationship of Singer preference to acoustic analysis. Both Group 1 and Group 2 exhibited some relationship between auditor preference and Singer preference. I conclude from these results that Group 2 shows a stronger relationship between acoustic analysis, auditor preference, and Singer preference. Further, the results from the series of modified questions, scrutinizing specific evidence pertaining to acoustic results, auditor preferences, and Singer preferences, indicate the absence of a clear vocal match in Group 1 and the probability of a vocal match in Group 2.

2) Is there an acoustic phenomenon that delineates, points to, or allows a vocal match?

The specific relationship of pitch and vowel frequencies to timbre is not fully understood, although vocal pedagogy uses variations of pitch and vowel as markers of vocal function. Simply, timbre is defined as the relative level of strength (dB) of the various frequencies (Hz) of an acoustic spectrum. It was determined that a comparison of frequency strength between individual singers and the acoustic spectrum recorded by the area microphone used for this study would reveal some evidence that may be labeled as an acoustic marker of blend and an acoustic marker for a vocal match. Tables comparing these frequencies can be found in Appendix I.

Blend was defined for auditors as "the aggregate sound of voices when individual vocal timbre or character is not readily discernible." Auditors were asked to specifically focus on timbre rather than issues of balance or vowel shapes. It was determined that a majority selection by the independent auditors would serve as the seminal factor in examining the data for an acoustic delineation of blend.

A *vocal match* was defined as "... when the production of vocal sounds by individuals concurs to form a new conglomerate sound in which individual vocal characteristics are present, but not noticeable." (Giardiniere 111) Since combinations of non-complimentary frequencies produced "beats," or noticeable individual vocal traits within the conglomerate sound, it was, therefore, likely that an acoustic phenomenon existed that retained a relationship both to acoustic function and to the examples of best blend selected by auditor trend. The results from the series of modified questions used in this study indicate that a vocal match was most likely to be found in the various placement/spacings from Group 2.

Daugherty asserts that it is not the adjacent placement of voices that facilitates blend, but rather the space between dissimilar voices. This was clarified with the discovery that when voices did not present a clear vocal match, as in Group 1, auditors preferred lateral spacing in all examples, and when voices presented a probable vocal match, as in Group 2, auditors were equally likely to choose either close or lateral spacing. While auditors chose examples of lateral spacing two-to-one for Duets in Group 2, auditors chose examples of close spacing for Trios by the same ratio. Individual amounts of change, further, exhibited equal probability for both the lowest and highest amounts of individual vocal change in either spacing. While voice matching procedures may discover the existence or lack of a vocal match within a random group of singers, proponents of voice matching advocate using it as a primary tenet of ensemble auditions. Further, confirmation of the variable nature of spacing necessitated a more consistent procedure, such as voice matching.

The objectives of both placement and spacing procedures were to assist the individual singer in vocal consistency while providing a means to choral blend. These essential qualities lead to the question of an identifiable acoustic trait that delineates a vocal match.

Auditors commented that they were sometimes asked to choose between two examples exhibiting nearly equal blend; the choice was sometimes between two equally poor examples of blend. No clear acoustic phenomenon was apparent in cases where auditor preference was less than decisive.

The most clear acoustic phenomena existed in examples in which auditor preference was nearly or wholly unanimous. While auditors exhibited clear preference between different placement and spacing of the same group of voices, the preference was less marked when comparing the best examples of different groups of voices. This can be explained by differences of opinion in terms of desired choral color. Eckholm found that voice teachers and choral directors differed significantly in terms of desired choral color. It became clear in this study that differences in pitch and vowel contributed significantly to the perception of differing individual sounds within the aggregate ensemble texture. What is further clear is that the major differences occurred not when dB levels were changed within spectra of similar shape, but when the overall spectral shape was altered by significant changes in dB level.

Singers need to hear themselves in a balanced relationship to hearing others (the self-to-other ratio). Individual sound pressure level naturally increases in order to rectify that balance, if the singer hears less of himself than he hears of those around him. This is called the "Lombard" effect. Both placement and spacing seemed to have significant impact on this effect. Daugherty has shown that non-standard spacings can assist in creating a balanced self-to-other ratio. Non-standard spacings, however, are not always readily available, certainly not for tour concerts or contests where spacing may be dictated by platform area, and where inadequate rehearsal time would negate the ability to "discover" the appropriate spacing for the particular ensemble in the specific setting. Acoustic placement consistently reduces the amount of vocal function change that must be maintained in order to sing in an ensemble with other singers, and has direct correlation to auditor blend preferences. Eckholm's findings are that less change occurred in acoustically placed formations when singers sang "soloistically" than when altering vocal function to blend, or placed in random formations. Acoustic placement, with or without spacing, was shown to be the available remedy for these issues.

Group 1 and Group 2 exhibited clear trends in both acoustic analysis and auditor preference. The Duet and Trio preferences of auditors for both Groups were selected for discussion concerning the acoustic phenomenon of the vocal match. For Group 1, these were Examples 11 and 26. For Group 2, these were Examples 36/38 and 45.

No combination of auditor preferences or vocal consistencies exposed any tendency for a vocal match in Group 1. Nevertheless, auditor preferences revealed clear trends and there was a specific relationship between placement, spacing, and vocal consistency. Specific trends, further, emerged in the combinations of spectra. Where the frequency and decibel levels of combined singers were similar, the combined frequency spectrum tended to occur at a decreased dB level. This manifested itself most clearly in formants below 1500 Hz, the areas of pitch and vowel identification. The greatest variance between individual spectra was exhibited between 2500 and 4000 Hz, the region of the singer's formant. Formant peaks in this region did not match between the Singers from Group 1. Singers 1 and 2 showed overlapping average formant frequencies at a similar dB level, while the average formant for Singer 3 occurred at a much higher frequency and a lower dB level.

The crossover of these major timbral frequencies had profound effects on the area spectra. The area spectrum represents the aggregate ensemble sound that would be processed by listeners. In combinations of Singers 1 and 2 the area spectra tended to emphasize the formant peaks of Singer 2 and to suppress the peaks of Singer 1. The relative amount of this suppression, and the perception of this suppression by both singers, likely contributed considerably to the altered vocal function observed in the ensemble settings. This acoustic suppression changed with both placement and spacing, but the specific effects of right and left ear hearing differences is not fully understood.

Examples 11 and 26 from Group 1 illustrated that, although a given group of singers may not readily present vocal matches, attention to acoustic placement would serve to address the issue of non-matching frequencies. The area spectrum for Example 11, placement/spacing 3-1, exhibited manifestation of the frequency peaks of both Singers. Similarly, Example 26, placement/spacing 3-1-2, exhibited frequency formants that corresponded to the frequency peaks of the combined Singers.

The formant frequencies of Singers from Group 2 showed a greater tendency to correspond than those of Singers from Group 1. Spectral peaks and dips did, however, change frequency in direct relationship to placement, causing the same issues of frequency conflict. Auditor preference and acoustic evidence suggested a possible vocal match between Singers 4 and 6. Examples 36/38 and 45 were chosen by auditors as best examples of blend. Singers 4 and 6, in each possible case, also showed a direct correlation of least vocal change. Example 48 was the closest example in the study to match the least amount of vocal change in each singer, with a variance in Singer 5 of 0.74 Hz, -0.73 dB.

In each of the singers, the most substantively altered frequencies were found in the region of the singer's formant. Individual timbre is the result of the relative strength of frequencies within the acoustic spectrum. One variable not considered as part of this study was the opinion of the auditors as to which singers were singing well and which were not. General references by auditors described nasal and vibrato-less sounds, but without reference to specific singers. Further, no delineation was made as to the potential benefits to a less skilled singer changing vocal process to match the quality of a more skilled singer. Not all participants in choral ensembles have had the benefit of private studio instruction; however, private studio instruction is no guarantee of a high level of vocal proficiency. Vocal process changes in the choral setting, for singers with poor vocal habits, may actually work to the benefit of the individual singer. Nevertheless, the variable under scrutiny was the placement of singers in an ensemble position where their individual voices would blend, with least possible vocal process change.

Acoustic comparisons of ensemble sound and blend will, no doubt, appear differently for contrasting groups of voices. For the Singers in Group 2, a vocal match was discovered when the frequencies of the constituent voices were compatible without significant individual alteration. It was discovered that the solo spectra from the ensemble examples produced complimentary frequencies within the region of the singer's formant. The overall shape of the individual frequency spectra showed a high degree of similarity from singer to singer. The individual characteristics of each voice were maintained due to the variant dB levels of the similar frequencies.

The effect of blend in Group 1 was facilitated by the combination of placement and spacing that allowed the aggregate frequencies to exhibit major, separate timbral peaks from each singer, spread over a range of 1000 Hz.

The effect of blend in Group 2 was facilitated by the discovery of a vocal match. The character of the vocal match was the existence of a series of complimentary frequency peaks within an average range of 600 Hz. Moreover, while the frequency peaks of one Singer from Group 1 corresponded with the frequency dips of another, frequency peaks and dips were commonly shared among the various singers from Group 2 at different dB levels, but in directly comparable proportion to one another. Blend may exhibit different properties within different groups of singers. A greater cohort of specific, predetermined voice matches would be needed to corroborate this finding.

It is true that vocal matches may not be discovered in all groups of singers. Proponents of voice matching advocate using voice matching procedures as a requisite part of the ensemble audition process. The discovery of a vocal match within an ensemble or ensemble section initiates the possibility of a consistent and mutually productive relationship between solo and choral singing modes.

Nevertheless, the results of this study also clearly demonstrate that, even in the absence of a vocal match, specific attention to acoustic placement has a highly beneficial impact on both the quality of choral blend and the ability of the individual singers to maintain vocal process consistency.

The conflict between choral directors and teachers of singing has largely centered around the concept of deliberately and significantly altered vocal production. Acoustic analysis and auditor preference confirmed that the use of acoustic placement curtails the requisite amount of vocal process change for the individual singer, allowing the possibility for both the consistency and flexibility required to successfully navigate vocal musicianship.

Summary

There has been a long-standing tenure of conflict between choral directors and voice teachers surrounding the notion and practice of vocal process and technique, with the perception that significant individual vocal process alterations must be made in order to participate in both modes of music making. Perceptions by voice teachers concerning certain permutations of the practices of some early twentieth-century choral directors remain at the heart of this ongoing debate, in particular the "straight-tone" approach of the St. Olaf tradition and the "soloistic" Westminster tradition, and their variant procedures concerning choral blend and the alteration of individual vocal production.

The need for this study was based both on the desirability of choral blend and the ambition to achieve this end without significant alteration of individual vocal process. The procedures related to voice matching appeared to have provided the best solution to the resolution of these issues. Recent periodical publications have cast a dubious light on the ability of voice matching to effectively contribute to this end.

Various writers have addressed concepts and techniques related to blend. These have included attention to intonation, vowel shape, and vibrato. Other studies have concentrated more fully on formation techniques that have been developed and implemented in order to achieve blend. More than twenty years ago, Goodwin confirmed that significant alteration of individual vocal process takes place during the attempt of individual singers to blend with other singers in an ensemble.

The practice of spacing between singers has gained much attention of late, as a means to facilitate choral blend while curtailing the need of individual vocal change. James Daugherty has published many articles based on his study (1996) concerning the properties of spacing between singers. Daugherty concluded that spacing was superior to formation; his conclusions, however, were based neither on comparisons with acoustic placements of singers nor any acoustic analysis. His chief argument was that his findings were empirical, compared to the highly subjective results of formation studies. Daugherty's other complaint was that voice matching procedures are not replicable. In spite of this specific assertion, Daugherty's continuing series of articles suggest a multitude of possible spacings, depending on the need of the particular ensemble. He even encourages experimentation with spacing concepts, rather than emphasizing one specific replicable pattern of spacing.

Several studies (Tocheff, Giardiniere, Eckholm) have explored various concepts and uses of voice matching procedures such as those used by Weston Noble. Each of these studies found that attention to acoustic placement significantly improved both the overall blend and the ease with which individual singers were able to contribute to it. Eckholm's study used voice teachers to evaluate the amount of change that occurred in individual singers in both random and acoustic placements, attempting to blend and to sing soloistically. Evaluators found that individual vocal change was a requisite part of ensemble singing, but that acoustic placement significantly reduced the amount of individual change.

The purpose of this study was to discover whether there was any discernible acoustic phenomenon that delineated or defined when a vocal match was made, or if a vocal match was merely a matter of conductor preference with regard to timbre, vibrato, intonation, and balance. A reductionist approach regarding the variables for the study permitted detailed, quantifiable data pertinent to this purpose.

To this point no study had empirically addressed the issue of identifying replicable acoustic data to support the aural identification of choral blend. This study addressed this specific need for the choral/vocal community using a series of questions: Is there an acoustic phenomenon that delineates, points to, or allows a vocal match?; Can an individual singer blend with other singers without alteration of the basic vocal process of any of the singers?; What are the acoustic differences between close and lateral spacing of voices? Using both subjective and objective tools, this study has answered these questions by delineating specific acoustic characteristics inherent in choral blend, along with the corroborating preferences of both singers and expert choral/vocal auditors.

A recording procedure was established to facilitate quantitative acoustic analysis of both choral blend, and the effect of varied placement and spacing on individual vocal process. Two groups, each comprise of three male university students, were professionally recorded in all possible placements and spacings. No attempt was made to pre-select the specific members of either group, and each singer was instructed to sing normally; no attempt was made to shape sounds through conducting gesture or by classifying certain formations as better examples of blend.

The recorded sounds were acoustically analyzed for the amount of individual change from solo recording to individual recording within an ensemble setting. The individual recordings were further compared to recordings of the aggregate ensemble sound taken from a microphone placed in front of the singers. No attempt was made to separate individual sounds by using anechoic material.

Timbre is defined as the relative strength (dB) of the characteristic frequencies (Hz) of a selected voice. The recorded examples were analyzed with regard to the variables of Hz and dB. Twenty-six examples from among the sixty comparison pairs not only showed a change in frequency, but also a change in frequency direction that directly corresponded to changed placement. Fourteen examples exhibited a change in dB direction due to changed placement. Twenty-one examples showed not only a change in frequency, but also a change in frequency direction directly corresponding to changed spacing. Fifteen examples exhibited a change in dB direction due to changed spacing.

The overall rates of change for the combinations of paired voices from Group 1 were noted. An analysis of the results suggests the improbability of a vocal match between these three voices. Taken together, however, the results imply that the best example of blend would likely be discovered in a formation that placed Singer 1 between Singers 2 and 3, but that the formation would have equal chance to be in close or lateral spacing. Moreover, the basis for this implication was not merely the separation of the voices least likely to blend, but more specifically the discovery of the positional relationship of Singer 1 to Singers 2 and 3. Placement was clearly shown to be more crucial to the reduction of vocal change than spacing.

The overall rates of change for the combinations of paired voices from Group 2 were noted. An analysis of the results suggests a greater probability than Group 1 of a vocal match among these three voices. Taken together, the results imply that the best example of blend would likely be discovered in a formation that placed Singer 6 between Singers 4 and 5, but that the formation would equal chance to be in close or lateral spacing. Moreover, the basis for this implication was not merely the separation of the voices least likely to blend, but more specifically the discovery of the positional relationship of Singer 6 to Singers 4 and 5. Placement was clearly shown to be more crucial to the reduction of vocal change than spacing.

Among the twelve Sets, two showed least vocal change in both examples of close spacing, and two showed least vocal change in both examples of lateral spacing. If spacing were the crucial component in the reduction of vocal change, this ratio would greatly favor examples of lateral spacing. In only four of twelve Sets did examples of the same spacing show greatest reduction of vocal change, and these were equally distributed between examples of close and lateral spacing. Moreover, in only five of twelve sets did the example of least vocal change switch to an opposite placement with different spacing. These results served to underscore that, compared to spacing, acoustic placement increased the opportunity for the reduction of vocal change, and thereby the consistent individual utilization of characteristic frequencies or timbre.

A group of choral/vocal auditors, possessing varying degrees of professional experience in choral conducting and private vocal instruction, were surveyed regarding their assessment of the best examples of blend from among recorded examples. Respondents were asked to complete a survey that took approximately twenty minutes. Auditors were asked to select the best example of blend between either two or three sound examples, and no limit was placed on the amount of times each example could be heard. Auditors were given the opportunity to choose between examples of changed placement and changed spacing.

The results of the acoustic analysis and auditor survey were noted and compared. No single placement, spacing, or combination of placement and spacing provided the least overall vocal change for all singers. Auditors revealed a definite relationship between acoustic placement and blend preferences, although auditor preference did not precisely match the examples of least acoustic change. Group 2 had a higher incidence of coordinated results between acoustic analysis and auditor preference than Group 1. The relationship between acoustic analysis and auditor preference revealed that in groups of voices where no vocal match is readily apparent, as in Group 1, acoustic placement combined with lateral spacing was the overall preference. In groups of voices where a vocal match is apparent, as in Group 2, acoustic placement played a significant role, but spacing was equally likely to be close or lateral.

The results of this study clearly established that individual vocal change takes place when multiple voices sing simultaneously. While auditors did not select any example of least vocal change as the example of best blend in Duets or Trios from either Group, auditors typically selected as the best blend examples with a low average rate of vocal change. In Group 1, the combination of placement and lateral spacing provided the best alliance of acoustic analysis and auditor preference, at a rate of 54% for placement/lateral spacing and 46% for placement/close spacing. In Group 2, placement alone provided the best alliance of acoustic analysis and auditor preference, at a rate of 50% each for close and lateral spacing. The findings demonstrated that when the assembled voices do not match acoustically, such as in Group 1, lateral spacing combined with placement provided the best opportunity for blend with least vocal change. When a vocal match appeared to exist, such as in Group 2, lateral and close spacing had equal potential to provide the best opportunity for blend with least vocal change, elevating the significance of attention to individual placement. Proponents of voice matching advocate the use of voice matching procedures as part of the ensemble audition process.

This set of findings elucidated the seemingly inconsistent assertions of the studies discussed in this paper above. In studies and examples where no specific attention was given to acoustic placement (Warland, Daugherty) lateral spacing seemed to provide the best opportunity for the reduction of vocal change and auditor selection of best blend. The results of this study suggested that, in these instances, the addition of acoustic placement would have served to enhance both the reduction of vocal change for the singers and the desired aim of choral blend. In contrast, in studies where specific attention was given to the acoustic placement of individual singers (Tocheff, Giardiniere, Eckholm) attention to spacing was not a requisite part of either the reduction of vocal change or the perception of choral blend.

Singers perceived changes in sound with both changed placement and spacing. In Group 1, neither Duets nor Trios showed any relationship of Singer preference to acoustic analysis. In Group 2, however, both Duets and Trios included some relationship of Singer preference to acoustic analysis. Both Group 1 and Group 2 exhibited some relationship between auditor preference and Singer preference. I conclude from these results that Group 2 shows a stronger relationship between acoustic analysis, auditor preference, and Singer preference. Further, the results from the series of modified questions, scrutinizing specific evidence pertaining to acoustic results, auditor preferences, and Singer preferences, indicate the absence of a clear vocal match in Group 1 and the probability of a vocal match in Group 2.

When frequencies were shared by multiple singers the dB level of those frequencies was generally lower than that of any of the individual singer in the area spectra. The area spectra further revealed an acoustic suppression of certain individual characteristics corresponding with placements. The individual perception of this suppression accounted for the greater change in individual vocal process, in correlation with the Lombard effect of increased vocal intensity. There was no appreciable reduction of this effect correlating to lateral spacing alone. Acoustic placement and acoustic placement in combination with spacing offered the best opportunities for the reduction of vocal process change.

The inquiry into the acoustic phenomenon of vocal matches revealed that when vocal matches occurred it was because the timbral frequencies of each singer tended to be similar in Hz, with a proportional dB relationship. The best examples of blend took on different appearances in this study, due to the existence or lack of a direct vocal match in each Group.

The effect of blend in Group 1 was facilitated by the combination of placement and spacing that allowed the aggregate frequencies to exhibit major, separate timbral peaks from each singer in the region of the singer's formant.

The effect of blend in Group 2 was facilitated by the discovery of a vocal match. The character of the vocal match was the existence of a series of shared, complimentary frequency peaks in the region of the singer's formant in the solo spectra of each singer. Moreover, while the frequency peaks of one Singer from Group 1 corresponded with the frequency dips of another, frequency peaks and dips were commonly shared among the various singers from Group 2 at different dB levels, but in directly comparable proportion to one another. Blend may, however, exhibit different properties within different groups of singers. A greater cohort of specific, predetermined voice matches would be needed to corroborate this finding.

This study showed, on the strength of the corroboration of both quantitative and qualitative evidence, that acoustic placement is a requisite part of the choral/vocal experience. Acousticians assert that the human ear is a more sensitive receptor of choral/vocal sound than is any current instrumentation. Proponents of voice matching suggest that matching procedures ought to be a requisite portion of the audition process. Nevertheless, choral blend is achievable with a minimum amount of vocal process alteration, through attention to the acoustic placement of individual singers. Taken together, I conclude from the results that attention to acoustic placement is the crucial factor in the effect of choral blend.

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APPENDIX A: Independent Auditor Letter

Title and name of auditor
Address 1
Address 2
Address 3

Greetings. I am a doctoral candidate at the University of Oklahoma, a student of Dennis Shrock. My culminating project is an investigation into the acoustics of choral blend, and I'm hoping to solicit your assistance. Enclosed you will find a survey and an audio CD. Please return the completed survey in the envelope included in this packet. It takes approximately 20 minutes to complete the survey, using the CD.

The goal of the survey is for you to assess the best examples of blend among the recorded examples. Although studio-quality equipment was employed, the level will be lower than commercially produced music CD's. No effects were utilized at any stage of the production of the CD; however, there is ambient "reverb" from the auditorium itself.

I'm planning to complete this project by late June. Thank you for taking time to assist in this crucial portion of this project.

Gratefully,

Neal W. Woodruff
630 S. Rosewood Ave
Kankakee, IL 60901
nwoodruf@olivet.edu

APPENDIX B: Independent Auditor Survey

A. **Personal Data:**
The data collected will be used solely for the purpose of reporting the experience and opinions of the auditors. No names will be included in the final report. Please answer in the space provided.

1. Current position
   a. Title

   b. Responsibility

   c. Do you consider your expertise choral directing, private voice instruction, or both?

2. Experience
   a. Years of Choral Directing

   b. Years of Private Studio Voice Instructing

   c. Degrees Held

3. In what ways does vocal technique differ between choral singing and solo singing?

4. Have you ever used a voice matching procedure to determine the seating/placement of the individual members of a choral ensemble? (Voice matching is defined as placing individual singers in relationship to one another in such a way that no individual vocal sound is discernible from another, without requiring any singer to alter vocal production.)

5. Briefly describe the changes in choral sound you have observed through the use of voice matching; i.e., blend, intonation, diction, rhythm.

6. Have you ever used a spacing procedure in the placement of the individual members of a choral ensemble? (Spacing is defined as placing a specific distance between adjacent singers, and rows of singers.)

7. Briefly describe the changes in choral sound you have observed through the use of spacing; i.e., blend, intonation, diction, rhythm.

8. Which is the greater asset to choral sound: voice matching or spacing?

9. Which better facilitates individual vocal freedom?

10. Have you ever used a combination of voice matching and spacing in the placement of individual singers in a choral ensemble?

Additional comments:

B. Explanation:

It is the intention of this study to determine which combinations of voices produce the most blended sounds. The recorded voices will sing the opening 3 phrases of "My Country, 'tis of Thee" in unison. You will be asked to select the recording that is the **most blended**. Blend will be defined as the aggregate sound of voices when individual vocal timbre or character is not readily discernible. Focus should be placed on the merger of timbral character rather than balance or the timing of individual consonants and vowels.

The recording process was conducted in a manner to preserve the sounds of individual singers for acoustic analysis. As such, the volume level of this CD will be less than that of a commercially produced music recording. No effects processing was used in the recording, transfer or production of the CD. The reverberation in the recording is due to the ambient quality of the auditorium used during the recording process.

C. Instructions:

- Each *Series* will included three *Sets* of recorded singing.
- For each Set, circle the letter on the Answer Sheet corresponding to the *Track* that **best** fits the definition of blend, listed above. (Track numbers correspond to the CD track.)
- For each group of two Sets select the best example of blend. Write the letter corresponding to the selected Track on the line provided.
- For the final question of each Series select the best example of blend from among the Tracks selected as the best for each group. Write the answer on the line provided.

D: Answer Sheet

Series 1:

Set

1) a. Track 1 b. Track 2

2) c. Track 3 d. Track 4

Best example from the circled Tracks in Sets 1 and 2 ______

3) e. Track 5 f. Track 6

4) g. Track 7 h. Track 8

Best example from the circled Tracks in Sets 3 and 4 ______

5) i. Track 9 j. Track 10

6) k. Track 11 l. Track 12

Best example from the circled Tracks in Sets 5 and 6 ______

Choose the best example of blend from among the best examples in Sets 1-6.

______

Series 2:

Set

7) a. Track 13 b. Track 14

8) c. Track 15 d. Track 16

Best example from the circled Tracks in Sets 7 and 8 ______

9) e. Track 17 f. Track 18

10) g. Track 19 h. Track 20

Best example from the circled Tracks in Sets 9-10 ______

11) i. Track 21 j. Track 22

12) k. Track 23 l. Track 24

Best example from the circled Tracks in Sets 11-12 ______

Choose the best example of blend from among the best examples in Sets 7-12.

______

Series 3:

Set

13) a. Track 25 b. Track 26

14) c. Track 27 d. Track 28

Best example from the circled Tracks in Sets 13-14 ______

15) e. Track 29 f. Track 30

16) g. Track 31 h. Track 32

Best example from the circled Tracks in Sets 15-16 ______

17) i. Track 33 j. Track 34

18) k. Track 35 l. Track 36

Best example from the circled Tracks in Sets 17-18 ______

Choose the best example of blend from among the best examples in Sets 13-18.

______

Series 4:

Set

19) a. Track 37 b. Track 38

20) c. Track 39 d. Track 40

Best example from the circled Tracks in Sets 19-20 ______

21) e. Track 41 f. Track 42

22) g. Track 43 h. Track 44

Best example from the circled Tracks in Sets 21-22 ______

23) i. Track 45 j. Track 46

24) k. Track 47 l. Track 48

Best example from the circled Tracks in Sets 23-24 ______

Choose the best example of blend from among the best examples in Sets 19-24.

______

Additional Comments:

APPENDIX C: Results of Independent Auditor Survey

A. Personal Data

1. Current Position
    a. Title
        i. Conductor, Nordic Choir
        ii. Professor Emeritus
        iii. Professor of Music
        iv. Assistant to the Director of Media and Technical Support
        v. Director of Choral Studies
        vi. Professor of Music
        vii. Associate Professor of Music
        viii. Assistant Professor, Coordinator of Voice

    b. Responsibility
        i. oversee 7 choirs, 3 bands, 2 orchestras
        ii. n/a
        iii. 3 choirs, conducting, music history
        iv. faculty member in charge of faculty technology
        training
        v. directing 4 choirs, conducting courses
        vi. choral, voice, music appreciation
        vii. private and class voice, diction, conductor of Women's Choir
        viii. Applied Voice teaching

    c. Do you consider your expertise choral directing, private voice instruction, or both?
        i. choral directing
        ii. both
        iii. choral directing
        iv. I know more about choral directing
        v. choral directing
        vi. both
        vii. private voice instruction
        viii. private voice instruction

2. Experience
    a. Years of Choral Directing
        i. 56 years
        ii. 37 years

iii. 21 years
iv. 1 ½ years
v. n/a
vi. 18 years
vii. 6+
viii. 0

b. Years of Private Studio Voice Instructing
   i. n/a
   ii. 37 years
   iii. 8 years
   iv. ½ semester
   v. n/a
   vi. 20 years
   vii. 6+
   viii. 29

c. Degrees Held
   i. B.A., M.M., 2 Honorary Doctorates
   ii. B.M.S., B.A. (Church Music), B.A. (Music Education), M.M. (Voice), D.M.A. (Church Music)
   iii. B.M. (Church Music/Voice), M.M. (Choral Conducting), D.M.A. (Choral Conducting)
   iv. B.A. (Music Education)
   v. D.M.A. (Choral Conducting)
   vi. B.S. (Music Education), M.Mus., D. Arts
   vii. B.S. (Music), M.Mus. (Performance)
   viii. B.M. (Applied Voice), B.M.E. (Vocal Emphasis), M.M. (Vocal Performance), D.M.A. (A.B.D., Vocal Performance)

3. In what ways does vocal technique differ between choral singing and solo singing?
   i. n/a
   ii. The soloist may need to make slight modifications.
   iii. Shouldn't really differ. Both require <u>flexibility</u> and sensitivity and a desire to do both with the right attitude.
   iv. Technique should not necessarily be different. While focus in choral singing is

more on blend, proper vocal technique is appropriate in both settings.

v. n/a

vi. Choral singing sometimes requires a singer to match timbre to another singer or to other singers, and often to control variables such as vibrato, etc.

vii. I prefer that singers use a consistent, good vocal technique. (no changes from solo technique in the choral setting)

viii. Ideally, it should not differ.

4. Have you ever used a voice matching procedure to determine the seating/placement of the individual members of a choral ensemble? (Voice matching is defined as placing individual singers in relationship to one another in such a was that no individual vocal sound is discernible from another, without requiring any singer to alter vocal production.)

i. yes

ii. yes

iii. yes

iv. no, but much experience singing in voice matched choirs

v. n/a

vi. yes

vii. yes

viii. n/a

5. Briefly describe the changes in choral sound you have observed through the use of voice matching; i.e., blend intonation, diction, rhythm.

i. major changes in blend, intonation, diction, and rhythm: "slow" singer moves in tempo

ii. better blend and intonation; easier to sing; increased body in the ensemble sound without forcing of straining; the singers feel better about it

iii. better blend… you don't get as many audible "beats" with proper voice matching. The singers are usually more comfortable as well.

iv. A much more unified sound occurred, as well as an increase in output and resonance.

Blend increased and a natural ease of singing was demonstrated by the singers.

v. n/a

vi. cleaning up some vibrato problems, as well as intonation.

vii. Good blend is much easier to attain- in sections and in the choir as a whole; intonation improves dramatically

viii. n/a

6. Have you ever used a spacing procedure in the placement of the individual members of a choral ensemble? (Spacing is defined as placing a specific distance between adjacent singers, and rows of singers, in order to facilitate blend.)

    i. yes
    ii. no
    iii. yes
    iv. no
    v. n/a
    vi. yes
    vii. no
    viii. n/a

7. Briefly describe the changes in choral sound you have observed through the use of spacing; i.e, blend, intonation, diction, rhythm.

    i. everything better
    ii. n/a
    iii. wider is usually better as long as it's not so far they can't hear. Usually a fuller, freer sound.
    iv. n/a
    v. n/a
    vi. more distance between singers resulted in more careful listening, and better blend.
    vii. n/a
    viii. n/a

8. Which is the greater asset to choral sound: voice matching or spacing?

    i. matching 51, spacing 49
    ii. n/a
    iii. spacing

iv. voice matching
v. n/a
vi. voice matching, but not by much
vii. n/a
viii. With no experience of trying these, my logic would go with matching.

9. Which better facilitates individual vocal freedom?
    i. spacing
    ii. n/a
    iii. Both, but if I had to pick- spacing.
    iv. While spacing seems like the obvious choice here, from my experience, a well-matched group of voices enhances the vocal freedom of the members individually.
    v. n/a
    vi. spacing
    vii. n/a
    viii. matching

10. Have you ever used a combination of voice matching and spacing in the placement of individual singers in a choral ensemble?
    i. yes
    ii. n/a
    iii. yes
    iv. no
    v. n/a
    vi. yes- the two techniques work well together
    vii. n/a
    viii. n/a

Additional comments:

There is great benefit in voice matching.

D. Answer Sheet

Series 1

1) Track 1: 2 Track 2: 6

2) Track 3: 2 Track 4: 6

Best example from the circled Tracks in Sets 1 and 2

Track 4: 4; Track 1: 1; Track 2: 1; Track 3: 1; n/a: 1

3) Track 5: 5 Track 6: 3

4) Track 7: 2 Track 8: 6

Best example from the circled Tracks in Sets 3 and 4

Track 8: 3; Track 5: 2; Track 7: 2; Track 6: 1

5) Track 9: 4 Track 10: 4

6) Track 11: 8 Track 12: 0

Best example from the circled Tracks in Sets 5 and 6

Track 11: 4; Track 10: 2; Track 9: 1; Track 12: 0; n/a: 1

Choose the best example from among the best examples in Sets 1-6.

Track 8: 3; Track 7: 1; Track 5: 1; Track 9: 1; Track 10: 1; n/a: 1

Series 2

7) Track 13: 4 Track 14: 4

8) Track 15: 0 Track 16: 8

Best example from the circled Tracks in Sets 7 and 8

Track 16: 6; Track 13: 2; Track 14: 0; Track 15: 0

9) Track 17: 6 Track 18: 2

10) Track 19: 3 Track 20: 5

Best example from the circled Tracks in Sets 9 and 10

Track 20: 4; Track 19: 3; Track 9: 1Track 18: 0; n/a: 1

11) Track 21: 3 Track 22: 5

12) Track 23: 4 Track 24: 4

Best example from the circles Tracks in Sets 11 and 12

Track 23: 4; Track 22: 2; Track 24: 2; Track 21: 0

Choose the best example of blend from among the best examples in Sets 7-12.

Track 23: 3; Track 16: 1; Track 19: 1; Track 22: 1; Track 24: 1; n/a: 1

Series 3

13) Track 25: 5 Track 26: 3

14) Track 27: 1 Track 28: 7

Best example from the circled Tracks in Sets 13 and 14

Track 28: 3; Track 25: 2; Track 26: 1; Track 27: 1; n/a: 1

15) Track 29: 3 Track 30: 5

16) Track 31: 2 Track 32: 6

Best example from the circled Tracks in Sets 15 and 16

Track 30: 4; Track 29: 2; Track 32: 2; Track 31: 0

17) Track 33: 4 Track 34: 4

18) Track 35: 2 Track 36: 6

Best example from the circled Tracks in Sets 17 and 18

Track 36: 5; Track 33: 1; Track 35: 1; Track 34: 0; n/a: 1

Choose the best example of blend from among the best examples in Sets 13-18.

Track 28: 2; Track 30: 2; Track 33: 1: Track 31: 1; Track 34: 1; n/a: 1

Series 4

19) Track 37: 5 Track 38: 3

20) Track 39: 5 Track 40: 3

Best example from the circled Tracks in Sets 19 and 20

Track 39: 4; Track 40: 2; Track 37: 1; Track 38: 1

21) Track 41: 2 Track 42: 6

22) Track 43: 3 Track 44: 5

Best example from circled Tracks in Sets 21 and 22

Track 42: 4; Track 44: 2; Track 43: 1; Track 41: 0; n/a: 1

23) Track 45: 3 Track 46: 5

24) Track 47: 4 Track 48: 4

Best example from the circled Tracks in Sets 23 and 24

Track 46: 4; Track 45: 2; Track 47:1; Track 48: 1

Choose the best example of blend from among the best examples in Sets 45-48.

Track 39: 2; Track 42: 1; Track 44: 1; Track 45: 1; Track 46: 1; Track 48: 1; n/a: 1

Additional Comments:

Some examples sounded very close.

In a given example, there was some inconsistency from one phrase to the next.

Sometimes vowel production was not unified. It would be interesting to know how much vocal instruction the singers had in this area of vocal production.

To one degree or another, subjectivity may be part of the listening experience.

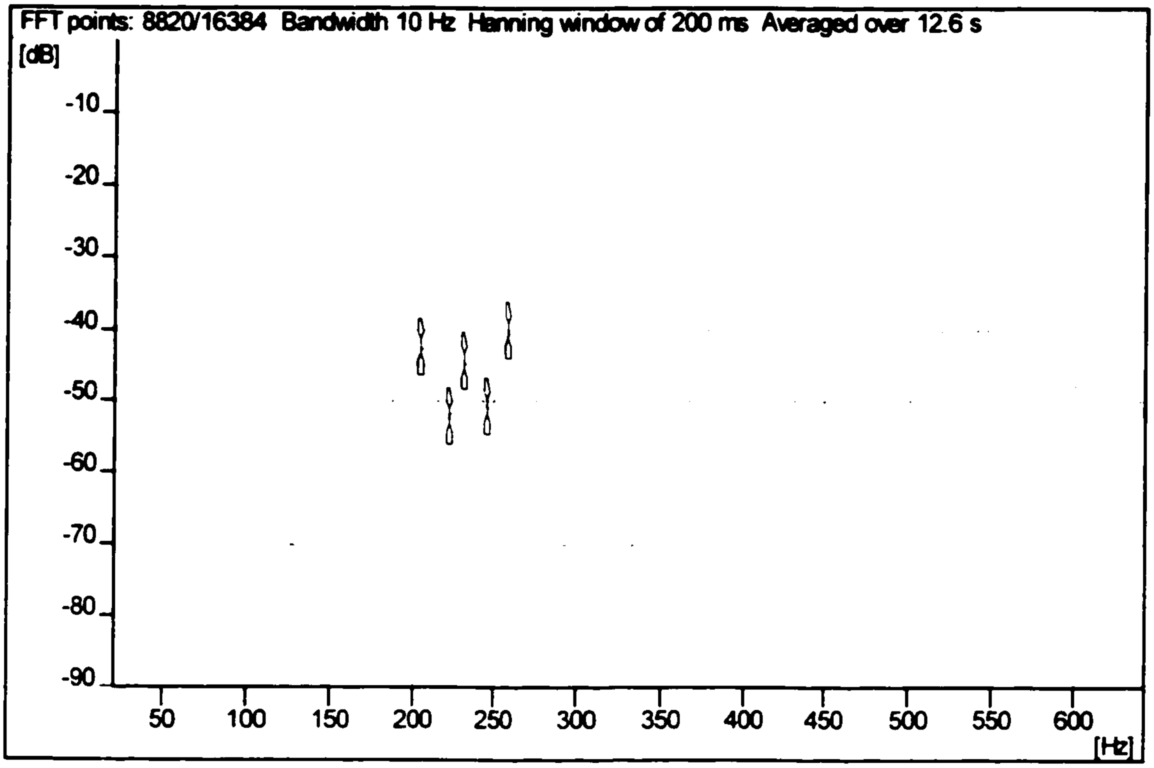
Many times the differences were very slight.

The voices without vibrato made the matching easier, but I didn't like the resulting sound as much.

Tone quality and intonation suffered greatly when vibrato was cut down.

Sometimes the choice was between two equally poor examples.

APPENDIX D: Sample Acoustic Graph with Selected Peaks and Dips, and the Corresponding Frequency (Hz) and Decibel (dB) Levels.



Peaks and Dips Highlighted on the Sample Graph

Hz	dB
204.57	-42.69
220.72	-52.46
231.48	-44.86
244.94	-51.25
258.40	-40.56

APPENDIX E: Order of Recordings

The order of the recordings was designed to quantify to effect of each possible placement and spacing in each group of singers. Adjacent numbers indicate close spacing. Hyphenated numbers indicate lateral spacing. The Singer numbers identify the individual singers. Changes in Singer number order indicate the specific change in placement.

Group 1		Group 2	
Recording #	Singer Placement/ Spacing	Recording #	Singer Placement/ Spacing
1	1	28	4
2	2	29	5
3	3	30	6
4	12	31	45
5	21	32	54
6	1-2	33	4-5
7	2-1	34	5-4
8	13	35	46
9	31	36	64
10	1-3	37	4-6
11	3-1	38	6-4
12	23	39	56
13	32	40	65
14	2-3	41	5-6
15	3-2	42	6-5
16	123	43	456
17	132	44	465
18	1-2-3	45	4-5-6
19	1-3-2	46	4-6-5
20	213	47	546
21	231	48	564
22	2-1-3	49	5-4-6
23	2-3-1	50	5-6-4
24	312	51	645
25	321	52	654
26	3-1-2	53	6-4-5
27	3-2-1	54	6-5-4

APPENDIX F: Acoustic Data for Groups 1 and 2

TABLE 3

Group 1 Duets: Singer 1			
Paired with Singer 2			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
1-4	12	7.95	0.75
1-5	21	-11.98	0.31
1-6	1-2	11.86	0.57
1-7	2-1	18.33	0.56

TABLE 4

Group 1 Duets: Singer 1			
Paired with Singer 3			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
1-8	13	13.59	-0.74
1-9	31	4.04	0.20
1-10	1-3	4.69	-0.02
1-11	3-1	-8.01	0.33

TABLE 5

Group 1 Duets: Singer 2			
Paired with Singer 1			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
2-4	12	-3.79	0.63
2-5	21	7.28	-0.92
2-6	1-2	20.25	0.05
2-7	2-1	12.54	-1.38

TABLE 6

Group 1 Duets: Singer 2			
Paired with Singer 3			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
2-12	23	13.76	-1.76
2-13	32	22.60	0.73
2-14	2-3	12.91	0.54
2-15	3-2	24.78	1.00

TABLE 7

Group 1 Duets: Singer 3			
Paired with Singer 1			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
3-8	13	32.96	-3.00
3-9	31	24.36	-5.17
3-10	1-3	13.79	-1.53
3-11	3-1	8.34	-2.92

TABLE 8

Group 1 Duets: Singer 3			
Paired with Singer 2			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
3-12	23	17.79	-2.26
3-13	32	12.54	-4.56
3-14	2-3	20.74	-1.39
3-15	3-2	6.37	-3.01

TABLE 9

Group 1 Trios: Singer 1			
Singer 1 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
1-16	123	-20.76	-1.23
1-17	132	-16.66	-0.47
1-18	1-2-3	46.33	1.58
1-19	1-3-2	-17.37	1.97

TABLE 10

Group 1 Trios: Singer 1			
Singer 2 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
1-20	213	-18.20	0.34
1-21	231	2.69	1.32
1-22	2-1-3	-10.83	-0.18
1-23	2-3-1	1.67	1.80

TABLE 11

Group 1 Trios: Singer 1			
Singer 3 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
1-24	312	16.98	0.24
1-25	321	-14.68	0.51
1-26	3-1-2	-11.47	1.61
1-27	3-2-1	-9.04	1.65

TABLE 12

Group 1 Trios: Singer 2			
Singer 1 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
2-16	123	21.29	-1.66
2-17	132	35.05	1.21
2-18	1-2-3	27.62	1.33
2-19	1-3-2	22.08	2.34

TABLE 13

Group 1 Trios: Singer 2			
Singer 2 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
2-20	213	-18.48	-0.71
2-21	231	47.59	-0.55
2-22	2-1-3	13.28	0.41
2-23	2-3-1	9.83	0.59

TABLE 14

Group 1 Trios: Singer 2			
Singer 3 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
2-24	312	7.59	1.36
2-25	321	22.94	-0.21
2-26	3-1-2	20.00	2.26
2-27	3-2-1	25.28	1.77

TABLE 15

Group 1 Trios: Singer 3			
Singer 1 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
3-16	123	18.51	-2.66
3-17	132	13.13	-3.45
3-18	1-2-3	5.51	0.02
3-19	1-3-2	-11.42	-0.75

TABLE 16

Group 1 Trios: Singer 3			
Singer 2 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
3-20	213	-10.57	-2.09
3-21	231	29.81	-4.61
3-22	2-1-3	-1.12	-1.13
3-23	2-3-1	-6.89	-2.13

TABLE 17

Group 1 Trios: Singer 3			
Singer 3 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
3-24	312	-4.07	-2.85
3-25	321	5.71	-1.20
3-26	3-1-2	-5.19	-0.82
3-27	3-2-1	18.12	0.52

TABLE 18

Group 1: Comparison of Findings				
Average Change for Duets				
	Placement		Spacing	
	Hz	dB	Hz	dB
Overall	9.46	1.29	11.67	0.90
Singer 1	12.11	0.44	13.59	0.32
Singer 2	9.85	1.48	8.08	0.84
Singer 3	6.43	1.95	13.33	1.54

TABLE 19

Group 1: Comparison of Findings				
Average Change for Trios				
	Placement		Spacing	
	Hz	dB	Hz	dB
Overall	19.08	1.05	17.25	1.70
Singer 1	22.55	0.74	18.38	1.46
Singer 2	18.06	1.05	17.18	1.54
Singer 3	16.63	1.35	16.19	2.10

TABLE 20

Group 2 Duets: Singer 4			
Paired with Singer 5			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
4-31	45	-5.18	1.89
4-32	54	-5.32	2.36
4-33	4-5	-12.38	3.39
4-34	5-4	-13.53	2.26

TABLE 21

Group 2 Duets: Singer 4			
Paired with Singer 6			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
4-35	46	17.23	-0.32
4-36	64	36.20	0.24
4-37	4-6	-5.86	-1.68
4-38	6-4	27.32	-0.45

TABLE 22

Group 2 Duets: Singer 5			
Paired with Singer 4			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
5-31	45	2.62	-2.41
5-32	54	-13.41	-5.08
5-33	4-5	-4.75	-3.39
5-34	5-4	28.39	-4.75

TABLE 23

Group 2 Duets: Singer 5			
Paired with Singer 6			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
5-39	56	2.23	-4.60
5-40	65	-3.91	-2.37
5-41	5-6	-3.91	-5.30
5-42	6-5	2.29	-1.33

TABLE 24

Group 2 Duets: Singer 6			
Paired with Singer 4			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
6-35	46	-5.15	-1.55
6-36	64	11.05	-2.37
6-37	4-6	-3.74	-1.43
6-38	6-4	14.57	-3.46

TABLE 25

Group 2 Duets: Singer 6			
Paired with Singer 5			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
6-39	56	-5.56	-1.41
6-40	65	-21.71	-4.80
6-41	5-6	-6.73	-1.10
6-42	6-5	2.17	-3.15

TABLE 26

Group 2 Trios: Singer 4			
Singer 4 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
4-43	456	-3.63	-3.03
4-44	465	16.76	-2.55
4-45	4-5-6	0.47	-3.45
4-46	4-6-5	6.73	-2.08

TABLE 27

Group 2 Trios: Singer 4			
Singer 5 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
4-47	546	-11.37	-2.82
4-48	564	3.57	-1.27
4-49	5-4-6	7.07	-1.18
4-50	5-6-4	-7.94	0.07

TABLE 28

Group 2 Trios: Singer 4			
Singer 6 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
4-51	645	1.71	-3.82
4-52	654	24.70	0.38
4-53	6-4-5	9.49	-1.03
4-54	6-5-4	-6.32	-0.03

TABLE 29

Group 2 Trios: Singer 5			
Singer 4 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
5-43	456	6.17	-4.41
5-44	465	16.56	-1.68
5-45	4-5-6	11.61	-2.41
5-46	4-6-5	8.50	-1.13

TABLE 30

Group 2 Trios: Singer 5			
Singer 5 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
5-47	546	-2.27	-3.75
5-48	564	3.01	-3.02
5-49	5-4-6	19.53	-3.71
5-50	5-6-4	14.89	-3.90

TABLE 31

Group 2 Trios: Singer 5			
Singer 6 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
5-51	645	29.25	-2.35
5-52	654	19.95	-3.65
5-53	6-4-5	18.84	-1.44
5-54	6-5-4	8.92	-3.77

TABLE 32

Group 2 Trios: Singer 6			
Singer 4 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
6-43	456	-9.77	-3.06
6-44	465	17.67	-4.88
6-45	4-5-6	7.78	-2.37
6-46	4-6-5	23.35	-3.73

TABLE 33

Group 2 Trios: Singer 6			
Singer 5 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
6-47	546	3.69	-4.32
6-48	564	-1.46	-4.91
6-49	5-4-6	8.66	-3.11
6-50	5-6-4	4.15	-4.01

TABLE 34

Group 2 Trios: Singer 6			
Singer 6 in the 1st position			
Example	Placement/	Average Change from Solo Spectrum	
	Spacing	Hz	dB
6-51	645	12.93	-6.54
6-52	654	24.34	-4.87
6-53	6-4-5	18.37	-5.72
6-54	6-5-4	-29.70	-5.64

TABLE 35

Group 2: Comparison of Findings				
Average Change for Duets				
	Placement		Spacing	
	Hz	dB	Hz	dB
Overall	17.03	1.83	11.22	1.77
Singer 4	15.95	0.85	11.83	0.83
Singer 5	15.33	2.57	14.33	3.70
Singer 6	20.63	2.08	7.50	0.79

TABLE 36

Group 2: Comparison of Findings				
Average Change for Trios				
	Placement		Spacing	
	Hz	dB	Hz	dB
Overall	14.19	1.33	12.54	0.94
Singer 4	15.58	1.63	13.81	1.17
Singer 5	8.77	1.30	8.27	0.75
Singer 6	18.21	1.07	15.55	0.91

APPENDIX G: Singer Survey

A. Experience

1) Age

2) Height

3) How many years of choral experience do you have?

4) How many years of vocal training do you have?

5) Have you ever experienced conflict between the demands of studio training and choral experience? In what ways? Specifically with regard to blend?

6) Are you more comfortable singing in a choir or as a soloist? Why?

7) Have you ever been asked to alter vocal production for the sake of blend?

8) In what ways does your vocal training facilitate blend?

9) Have you ever been placed next to someone whose voice was in conflict with yours?

10) Did you find it difficult to maintain normal vocal production under such conditions?

11) Have you ever taken part in voice matching procedures? (Voice matching is defined as placing singers in different formations to facilitate blend.)

12) Have you ever been instructed to place space between yourself and other choral singers, specifically to facilitate blend?

13) If you have experienced both voice matching and spacing, in which circumstances did you find singing easier?

B. <u>This Study</u>

1) Did you sense vocal compatibility with a specific singer? With whom?

2) Did the overall sound change when singer position was changed?

3) Did you sense duet compatibility changes when position was changed?

4) Did you prefer close or lateral spacing for the duets? Did that preference change with singing partner?

5) Did the overall sound change when spacing between singers changed?

6) Did you sense duet compatibility changes when spacing was changed?

7) Did you sense compatibility with the trio of voices? With which formation?

8) Did you sense trio compatibility changes when singer position was changed? In what ways?

9) Did you sense trio compatibility changes when spacing changed? In what ways?

10) In trio formation did you prefer a side position, or the center position? Did this preference change with formation? With spacing?

11) Did you consciously alter your normal singing process in order to blend in duet? In trio? In what ways did you change your normal singing process?

12) Did the position of voices seem to affect blend?

13) Did the space between voices seem to affect blend?

14) Which made the greater difference in the overall sound:
    a) placement of singers
    b) spacing of singers

c) combination of placement and spacing
d) no difference

APPENDIX H: Singer Survey Results

A. <u>Experience</u>

1) Age

1.	19	4.	20
2.	20	5.	20
3.	19	6.	20

2) Height

1.	5'10"	4.	6'
2.	5'11"	5.	5'10"
3.	5'11"	6.	5'11"

5) How many years of choral experience do you have?

1.	7	4.	7
2.	9	5.	14
3.	7	6.	7

6) How many years of vocal training do you have?

1.	1	4.	3
2.	2	5.	14
3.	7	6.	2

7) Have you ever experienced conflict between the demands of studio training and choral expectation? In what ways? Specifically with regard to blend?

1.	no	4.	no
2.	no	5.	no
3.	no	6.	no

8) Are you more comfortable singing in a choir or as a soloist? Why?

1. soloist; because of blending
2. choir; I enjoy the choir setting
3. soloist
4. soloist; I like the freedom
5. choir; interaction with other people
6. choir; I don't feel I have a solo voice

7) Have you ever been asked to alter vocal production for the sake of blend?

1.	yes	4.	yes
2.	yes	5.	yes
3.	no	6.	yes

8) In what ways does your vocal training facilitate blend?

1. good support on all notes equals better overall blend
2. being more vocally flexible
3. it teaches me not to oversing
4. my tone has become more rich; I learned how to control my vibrato
5. improved diction
6. it keeps everyone singing the same way

9) Have you ever been placed next to someone whose voice was in conflict with yours?

1.	yes	4.	yes
2.	no	5.	yes
3.	yes	6.	yes

10) Did you find it difficult to maintain normal vocal production under such conditions?

1.	yes	4.	yes
2.	n/a	5.	no
3.	yes	6.	yes

11) Have you ever taken part in voice matching procedures? (Voice matching is defined as placing singers in different formations to facilitate blend.)

1.	yes	4.	no
2.	yes	5.	yes
3.	yes	6.	no

12) Have you ever been instructed to place space between yourself and other choral singers, specifically to facilitate blend?

1.	yes	4.	no
2.	yes	5.	yes
3.	no	6.	no

13) If you have experienced both voice matching and spacing, in which circumstances did you find singing easier?

1.	voice matching	4.	n/a
2.	spacing	5.	spacing
3.	spacing	6.	n/a

B. This Study

1) Did you sense vocal compatibility with a specific singer? With whom?

1.	yes; singer 2	4.	no
2.	no	5.	yes; singer 6
3.	yes; singer 1	6.	yes; singer 4

2) Did the overall sound change when singer position was changed?

1.	yes	4.	no
2.	yes; I could hear better when I was on the right side	5.	no
3.	yes	6.	yes

3) Did you sense duet compatibility changes when position was changed?

1.	yes	4.	no
2.	yes	5.	no
3.	yes	6.	yes

4) Did you prefer close or lateral spacing for the duets? Did that preference change with singing partner?

1.	lateral; it was easier to hear Singer 3 in close spacing	4.	lateral; no
2.	lateral; no	5.	lateral; no
3.	lateral; yes	6.	lateral; no

5) Did the overall sound change when spacing between singers changed?

1.	no	4.	no
2.	no	5.	no
3.	no	6.	no

6) Did you sense duet compatibility changes when spacing was changed?

1.	yes	4.	yes
2.	yes; I could hear better	5.	no
3.	yes; I could hear myself easier	6.	no

7) Did you sense compatibility with the trio of voices? With which formation?

1.	yes: 321	4.	no
2.	no; I preferred to sing on the right side of the group	5.	yes: 456
3.	yes: 312	6.	no

8) Did you sense trio compatibility changes when singer position was changed? In what ways?

1.	yes; easier blending	4.	yes; I could hear myself more easily
2.	no	5.	I couldn't tell
3.	yes; more together	6.	yes; I sang most like the person next to me

9) Did you sense trio compatibility changes when spacing changed? In what ways?

1.	yes; different volume	4.	yes; we were able to hear each other more easily
2.	yes; hearing each other is easier with added space	5.	no
3.	yes; I found it easier to hear	6.	yes; louder voices led blending

10) In trio formation did you prefer a side position, or the center position? Did this preference change with formation? With spacing?

1.	left side; preferred singer 2 to my left, with space, if possible	4.	left or right side; no; no
2.	right side; no; no	5.	center; no; no
3.	center position for both	6.	I like the center for both; it was easier to blend with more volume around me

11) Did you consciously alter your normal singing process in order to blend in duet? In trio? In what ways did you change your normal singing process?

1.	no; no; none	4.	both; I sang more softly
2.	no; no; none	5.	no; no
3.	no; no; none	6.	yes; yes; I changed some sounds to try to match my neighbors

12) Did the position of voices seem to affect blend?

1.	yes	4.	yes
2.	yes	5.	no
3.	yes	6.	yes

13) Did the space between voices seem to affect blend?

1.	no	4.	yes
2.	yes	5.	no
3.	yes	6.	yes

14) Which made the greater difference in the overall sound:

a) placement of singers
b) spacing of singers
c) combination of placement and spacing
d) no difference

1.	placement	4.	spacing
2.	combination	5.	no difference
3.	combination	6.	placement

APPENDIX I: Formant Peaks for Examples of Blend

TABLE 37

Group 1 Formant Peaks		
Solo Examples		
Singer 1	Singer 2	Singer 3
2993.12 -49.00		
	3184.22 -55.15	
3273.05 -53.09		
	3434.55 -55.66	
		3620.27 -62.55
		3789.94 -62.57
		3900.20 -61.89

TABLE 38

Group 1 Formant Peaks		
Example 11		
Singer 1	Singer 3	Area
2971.58 -52.61		2882.76 -58.66
3141.16 -54.33		3141.16 -58.37
	3709.09 -58.42	3625.65 -66.46
	3824.84 -58.80	
	3868.67 -60.05	3878.67 -63.68

TABLE 39

Group 1 Formant Peaks			
Example 26			
Singer 1	Singer 2	Singer 3	Area
2971.58 -54.28			2955.43 -59.23
3133.08 -56.41	3133.08 -55.60		3133.08 -55.96
	3391.48 -55.61		3396.86 -56.36
		3663.34 -62.98	3544.90 -62.93
		3803.30 -60.26	3765.62 -66.09
		3878.67 -63.55	3908.95 -68.89

TABLE 40

Group 2 Formant Peaks		
Solo Examples		
Singer 4	Singer 5	Singer 6
	2917.75 -52.55	2993.12 -61.12
	3176.15 -53.88	3111.55 -63.21
3340.94 -50.33	3353.80 -58.58	3345.72 -60.29
	3523.37 -58.06	3493.76 -57.79
		3625.65 -58.74

TABLE 41

Group 2 Formant Peaks		
Example 36		
Singer 4	Singer 6	Area
	2985.04 -59.24	2912.37 -59.08
	3065.79 -61.03	3243.44 -61.11
3324.19 -49.43	3324.19 -56.01	3324.19 -53.95
	3501.84 -52.94	3413.01 -56.26
	3582.59 -57.41	3574.51 -58.93

TABLE 42

Group 2 Formant Peaks		
Example 38		
Singer 4	Singer 6	Area
	2971.58 -55.47	2933.90 -59.85
	3133.08 -54.29	3133.08 -58.08
3286.51 -48.77	3256.90 -54.01	3243.44 -58.41
	3345.72 -55.16	3383.40 -53.59
	3450.70 -52.03	3426.47 -56.89
	3655.26 -61.21	3625.65 -63.41

TABLE 43

Group 2 Formant Peaks			
Example 45			
Singer 4	Singer 5	Singer 6	Area
	2985.04 -57.29	3001.19 -54.94	2971.58 -55.79
3095.40 -50.25	3081.94 -52.38	3073.86 -58.06	3081.94 -57.08
3302.66 -47.27	3340.34 -54.40	3281.12 -54.46	3273.05 -55.47
3450.70 -49.34	3515.30 -53.89	3493.76 -53.00	3472.23 -54.31
	3596.04 -52.24	3620.27 -59.00	3633.73 -60.91
	3701.02 -56.05	3840.99 -61.93	

TABLE 44

Group 2 Formant Peaks			
Example 48			
Singer 4	Singer 5	Singer 6	Area
	2993.12 -57.14	3014.65 -53.56	2993.12 -59.19
3116.93 -51.88	3103.47 -52.90	3103.47 -53.59	3103.47 -53.40
3345.72 -47.91	3361.87 -54.32	3316.11 -50.15	3345.72 -50.95
3464.15 -49.61	3485.69 -54.54	3472.23 -52.26	3442.62 -57.02
	3620.27 -56.13	3612.29 -51.08	3612.19 -55.81
	3722.55 -55.39		3722.55 -62.25