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Chorister Perceptions of Real-Time Displays of Spectra in the Choral Rehearsal: A Feasibility Study

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Abstract

Real-time visual acoustic parameter display software has been available commercially for use in singing teaching studios for approximately ten years. While various studies have examined the use of such software in individual voice instruction, its potential use in choral rehearsals has not been widely explored. In this investigation, the authors assessed participant (N=43) perceptions and preferences relative to use of a real-time, visual display of purported spectra during choral rehearsals. For two academic semesters, the authors used the software program VoceVista one day per week in the rehearsals of a women-only (SSAA) chorus of undergraduate music majors and non-majors. A real-time display of acoustic parameters of the choir's sound was projected onto a screen located above or beside the director, so that singers in the choir could see the director and the display simultaneously. Members of the choir were instructed through written materials and through verbal explanations about the display and its potential relationship to singing behaviors. Analysis and display parameters were varied according to the musical works being rehearsed. The authors periodically referred to the display, depending upon the rehearsal needs of the ensemble. Following its final rehearsal each semester, the choir was surveyed to gather preferences and perceptions about the use of the display in rehearsals. Survey responses indicated students thought the use of real-time, visual feedback enhanced their rehearsal experiences. Results were discussed in terms of limitations of the study, practicalities of implementing visual displays in choral rehearsals, and the need for further research.

Real-time acoustic parameter software has been commercially available for use as a form of visual feedback in singing teaching studios for approximately ten years. During that time, several forms of computer-based real-time visual feedback for vocalists have been explored. Welch, Howard and Rush (1989) examined the use of visual feedback in developing pitch accuracy in the singing of primary school-aged children. The program they developed was used for assessment as well as for visual feedback for pitching development (Howard & Welch, 1989; Howard & Welch, 1993). Later, Howard and Angus (1998) used a further refinement of this program in comparing singing pitching in primary school-aged boys and girls as compared with adults.

Rossiter, Howard and DeCosta (1996) then examined the effect of real-time visual feedback on other aspects of singing training besides pitching, using a display of the electroglottograph closed quotient and a display of the ratio of the amplitude of the singer's formant band to the amplitude of the full spectrum with previously untrained subjects. Callaway (2001) tested the usefulness of the spectrograph in vocal lessons with female students in the American collegiate voice studio, although the amount of real-time feedback was limited. Finally, Howard, Brereton, Welch,

Himonides, DeCosta, Williams and Howard (2007) studied the use of an advanced software system in singing studios that provided teachers and singers with up to eight different feedback displays, including F_0 contour, spectrum, narrow band spectrogram, spectral ratio, and vocal tract area function, among other displays. Other staunch advocates for the use of real-time visual feedback to enhance singing training have included Donald Miller, Harm Schutte and colleagues in Groningen (Miller & Schutte, 1990; Miller, Sulter, Schutte &Wolf, 1997) and Garyth Nair (1999).

The spectrograph, which displays variations in frequency and intensity over time, has been used in a variety of choral studies during the last forty years. Goodwin (1980), for example, examined differences in the spectra of singers singing soloistically versus in a unison ensemble. Ford (2003) studied listener preferences for the presence or absence of a strong resonance between 2-4 kHz in the singing of an eight voice chamber choir. Aspaas, McCrea, Morris and Fowler (2004) used long-term average spectra to compare different types of choir formations. Basinger (2006) examined several commercially available software programs in the hope of using spectral displays to assist directors in matching voices to achieve choral blend. However, in none of the above mentioned studies, or in any of the studies cited in Ternström's (2003) review of the choral acoustics literature, was the spectrograph used for real-time feedback in a rehearsal.

Potential Confounding Variables

There are a number of possible reasons why real-time visual feedback in choral rehearsals has not yet been extensively explored. These reasons can be sorted generally into four broad categories: (a) factors pertaining to acoustics and psychoacoustics, (b) factors related to the equipment chosen to record and display feedback, (c) factors related to the type of display chosen and the interpretation of such, and (d) factors that pertain to attention limitations placed upon choir singers and choir conductors by the natural contexts of typical choir rehearsals.

Acoustic and Psychoacoustics. Ternström and Karna (2002) have discussed how choir acoustics and psychoacoustics are the result of complex interactions between the voice production and auditory perception of each individual and the group, between the production and perception of each individual and the gestures and perception of the conductor, and between the group, the conductor, and the room in which the choir sings. Moreover, as Ternström (2003) and Daugherty (2002) have explored, voice production and auditory perception of choir singers may be influenced positively or negatively depending upon the frequency being sung and its intensity, where singers are physically located within the choir in a room or on a stage (along the sides or in the middle of the ensemble), the spacing between individuals in the choir (close, lateral or circumambient), and the formation of the choir (in sections according to voice part or mixed).

All of these factors present researchers and choral directors alike with a large number of potentially confounding variables with which to contend. In addition, Ternström notes that choirs tend to adapt their sound level and vocal production to the reverberation of the room in which they sing, and the reverberation characteristics of the room change with the presence or absence of the choir in the room and the presence/absence of an audience in the room besides the choir (Ternström & Karna, 2002).

Thus, any kind of real-time visual feedback display in choir rehearsals would need to be offered with numerous caveats. What might be displayed spectrally with one group of singers in one configuration in one room with one set of microphones and one type of analysis software, for example, might very well not be displayed under different circumstances.

Equipment. Use of real-time acoustical parameter feedback in a choir rehearsal by necessity requires a microphone or microphones, cables, a computer, a projector and a projection screen. The interaction of factors related to the use of such equipment with multiple singers needs to be carefully considered, because both placement of equipment and various equipment artifacts can alter the display.

Of great importance to the validity and reliability of spectral displays are the issues of how many microphones to use to receive the choir's sound and where to place microphones within the room. If the microphone(s) are placed too close to the choir (inside of the reverberation radius), the sound received will be dominated by the direct sound from the choir. If the microphones are placed beyond the reverberation radius, the diffuse field (the result of many reflections) will be what the microphone

transmits to the computer (Ternström & Karna, 2002).

Another important consideration in the use and placement of microphones is phase cancellation and addition, where certain frequencies which have a wavelength relationship with the distance between two microphones or the distance between a microphone and a reflective surface can be cancelled out or greatly increased in level. A general rule of thumb used in the recording industry to avoid having these cancellations and additions in the output (or in the case of real-time feedback, having them appear as artifacts in the display spectrum) is the "Three to One Rule." This rule states that two microphones should be placed apart from each other at least three times the distance that either microphone is from the intended sound source (Dennis, 1997). This rule can also be applied to microphones near reflective surfaces: microphones should be placed away from a reflective surface by at least three times the distance that the microphone is placed from the sound source (Dennis, 1997).

Choosing and Interpreting a Display. Other questions remain, among them: (a) what kinds of analysis/parameter displays should be used? and (b) what aspects of a chosen display should be considered relevant? Choral acoustics research often looks at changes in the long-term average spectrum, or LTAS. However, singers in a rehearsal seeking real-time feedback may benefit from a shorter analysis window, with a display that is constantly being updated.

This tack enables focus upon brief events that may be most relevant to singers during the act of singing, such as types of vocal onset (breathy, coordinated or glottal), accuracy of pitching at voice onset, clarity of pitch transitions, consonant articulation, vowel choices, dynamic changes, synchrony of musical events and vibrato extent.

However, the sound the microphone(s) receive is a collective sound of the choir as it occurs in a specific environment. Any display of vocal onset, consonant articulation, and vibrato, in particular, will likely be blurred somewhat with multiple singers in a reverberant environment. Yet individuals within the choir may attempt to make personal behavior choices in vocal production based upon the display of the whole group's sound. The potential for well intentioned but inefficient or less than desirable vocal behaviors may be quite high. So directors and investigators must advise the singers carefully in how to interpret and react to visual displays.

Attention Limitations. The spectrum of a choir is very complex. Multiple singers phonate multiple pitches, vowels and consonants at varying dynamic levels simultaneously and not precisely in a synchronous manner. This complex spectrum may provide more information than singers and conductors and perhaps even researchers can process and apply "on the fly" in the context of a rehearsal, where typically a host of musical and educational objectives must be accomplished within a defined timeframe.

Display of a spectrogram, which shows the course of spectrum changes over time, is less complicated in some respects than the display of a spectrum. Nonetheless, a spectrogram contains a wealth of information that can be challenging to understand in real-time. There are limits to the amount of stimuli to which individuals can attend.

A choral singer, for instance, must look at his/her music, respond to its directions and the text, watch the conductor and respond to his/her directions, monitor his or her own vocal output (self) and monitor the output of singers and accompanying instruments nearby (other). While some individuals may be more adept at managing multiple "inputs" than others, adding the visual feedback of a spectral display to such rehearsal tasks conceivably could prove distracting to some musicians, diverting their attention from other necessary rehearsal obligations.

Assumptions and Purpose of this Investigation

Given such an array of potentially confounding variables, one might well conclude that investigating use of visual spectra displays in choral rehearsals is so problematic at the present time that undertaking such research would be fruitless. As discussed above, corporate vocal performance is a very complex event. Choral sound always occurs within a very specific context. No two choirs are exactly alike. They are made up of singers of varying abilities, ages, and experiences. Choirs sing in a variety of venues, each of which has its own particular acoustic characteristics. Any choral ensemble's sound, both within the choir and as received and perceived by listeners, depends as much, if not perhaps more, upon the venue's characteristics, the placement of the choir within the venue, and

the location of the listeners than it does on the ensemble by itself.

Moreover, what is displayed on a projection screen by a software program like VoceVista is quite dependent upon the type of microphone(s) used, the placement of the microphone or microphones within the room and their placement relative to the choir, the reverberation rate and other acoustic parameters of the room, the very nature of the software itself (how the software processes sound), the processing capacity of the computer being used, the quality of the cables and connectors, and even the resolution capabilities of the projector. In short, it is entirely possible that artifacts may exist in the display that are not directly caused by the choir and the room acoustics, but rather by these other factors just mentioned. Employing software in the choral rehearsal in a meaningful way requires users to control carefully as many of these potential variables as possible.

The present study, however, proceeds under two main assumptions. First, previous investigations suggest use of visual feedback in individual voice study may be beneficial. While incorporation of such visual feedback in group singing contexts introduces complexities not present in using visual displays with solo singers, seeking knowledge of any under-researched phenomenon entails starting somewhere. Second, there is a small piece of this research problem that logically can be investigated at this time, namely how incorporation of any visual display per se in choral rehearsals is perceived by choristers. Without answers to this very basic, practical consideration, any future research may be limited in its application to real-world choral singing contexts.

If real time visual displays of spectra are to be pedagogically useful to real-life choirs and conductors, such displays should be used in places where a choir typically rehearses. This real-world consideration acknowledges the impracticality of moving a choir into a controlled laboratory environment each time real-time visual feedback is desired, as well as the fact that the spectra displayed will of course change once singers return to their regular rehearsal or performance venues.

Therefore, the purpose of this preliminary investigation was to assess the perceptions and preferences of choral singers with respect to use of real-time visual displays of purported spectra and other acoustic parameters during rehearsals of an undergraduate women's choir across two academic semesters. In other words, this study asked choristers to proceed *as if* the visual displays were an accurate depiction of acoustical phenomena, in order to ascertain if such displays were perceived as pedagogically viable.

The following research questions guided this study: (a) What are the preferences and perceptions of choir members regarding the use of visual displays of purported spectra and other acoustic parameters during choral rehearsals, as revealed by a researcher-designed survey? and (b) Do choir members' preferences and perceptions vary significantly with respect to previous coursework in physics, acoustics, or voice anatomy and physiology, current participation in private voice instruction, familiarity with computers, and years of choir singing experience.?

Future studies may examine the contents and validity of what is displayed, how optimally to place microphones and other equipment for best results in particular environments, how to develop software that can distinguish the contributions of the room from that of the singers, what analysis functions may be most useful in this respect, and many other factors. Such questions, however, were not the focus of this particular study, whose purpose was to assess chorister perceptions and preferences relative to the regular use of visual displays per se in typical choral rehearsal environments.

Results of this descriptive study, moreover, are limited to its particular participants, rehearsal environments, and procedures employed. Findings should be interpreted with caution, particularly with respect to generalizing results to other choirs and rehearsal environments.

METHOD AND PROCEDURES

Participants

Permission to survey human subjects for purposes of this study was granted by the internal review board at the investigators' university. An auditioned, women-only SSAA chorus (*N*=28 semester one; *N*=25 semester two) was chosen for this particular investigation.

Members of this auditioned ensemble ranged in age from 18-35 years, with a median age of 20 years. As is typical in a university setting where course credit is granted according to hours per semester, overall choir membership varied across the two semesters of this study. Sixteen first-semester singers did not participate

during the second-semester, and thirteen new singers joined the group at the beginning of semester two. Twelve choristers sang with the choir in both semesters.

Most participants were music majors (66%, semester one; 79% spring two), with 50% of participants in both semesters concentrating in music education. All participants had previous choral singing experience, ranging from 2 – 10+ years, with over ten years as the modal number of years of prior choir experience.

At the time of the study, most participants (54% semester one, 79% semester two) were enrolled in private voice lessons. Comparatively fewer participants (12% semester one, 7% semester two) reported no current or prior private voice study.

The majority of these singers reported using computers on a daily basis (89% semester one, 79% semester two). A majority of participants (62% semester one, 57% semester two) had also taken courses in either physics or acoustics. However, most singers (93% semester one, 79% semester two) reported no prior coursework in voice anatomy and physiology.

One reason for using a women-only chorus was that women sing at higher fundamental frequencies than men. Thus it might be expected they would exhibit more widely spaced harmonics on a typical linear frequency-versus-amplitude spectral display. In other words, more widely spaced harmonics might make for a "simpler" display. While the visual simplicity of wider spaced harmonics would make discerning formant locations more difficult, it was not envisioned that such discernment would play a vital role in this particular study, whose purpose was to explore perceptions and preferences regarding use of a visual display per se during choir rehearsals.

Display Procedures and Set Up

The choir, a regularly scheduled for-credit course, rehearsed three times per week during the semester for 85 minutes per meeting. A visual feedback display was used at one rehearsal per week across two consecutive semesters.

An Audio Technica PRO41 dynamic cardioid pattern microphone was placed in front of the choir, centered, next to the ensemble director at a height of 1.5 meters (close to the director's ear height), so that the sound received by the microphone was similar to that reaching the ears of the director. A computer processed the audio signal using VoceVista 3.0.2 software. A real-time display of spectra was projected onto a large screen behind and above the director so that singers in the choir could see the director and the display simultaneously. The choir's director, however, was not able to watch the screen without turning away from the group. Figure 1 illustrates this basic set up.

Figure 1. A first semester rehearsal of the University of Texas at San Antonio (UTSA) Women's Choir.

This ensemble rehearsed in a different venue for the second semester of this study than it did for the first semester. Because dimensions of these two venues were different, the microphone was placed 1.5 meters from the first row of singers during the first semester, and 3 meters from the first row of singers during the second semester. Microphone height from the floor, however, remained consistent at 1.5 meters. See Table 1 for a summary description of equipment used, rehearsal venues, spacing and formation of singers, and placement of equipment during the course of the two semesters across which this study occurred.

Table 1

Summary of Equipment, Placement, and Procedures

Item:	*First Semester*	*Second Semester*
Analysis computer	Dell Optiplex GX250 PC	Dell Inspiron 8500 laptop computer
Analysis software	VoceVista 3.0.2	VoceVista 3.0.2
Projector	Epson Powerlite 81P	Panasonic LB10U
Screen size	3.66 m wide x 1.83 m high with rear projection	Portable projection screen 2.03 m wide x 1.52 m high
Image size	2.44 m wide x 1.83 m high	1.97 m wide by 1.44 m wide
Screen location	2.03 m above floor and 1.83 m behind conductor	Screen placed on the floor immediately to the conductor's left side
Microphone location and height	1.5 m high and 1.5 m from first row of singers; centered	1.5 m high from stage floor; 3 m from first row of singers; centered.
Type of Microphone	Audio Technica PRO41 dynamic cardioid pattern microphone	Audio Technica PRO41 dynamic cardioid pattern microphone
Other equipment	PRO CO DynaMike 2245 XLR audio extension cords; Realistic adapters; Quiklok adjustable microphone stand	PRO CO DynaMike 2245 XLR audio extension cords; Realistic plug adapters; Quiklok adjustable microphone stand; Kay adapter (XLR to phono) KAY/Pentax CBL XFDR18
Piano	Baldwin upright	Yamaha concert grand
Rehearsal space description	188-seat lecture hall; 10 rows of seats; rows terraced, with 0.3 m of vertical separation between each. Singers sat/stood on first 4 levels facing the stage area	500 seat recital hall; 20 rows of seats; rows terraced, with 0.15-0.33 m of vertical separation between each (greater separation farther from stage). Stage elevated by 0.61 m. Singers sat/stood on first two rows facing the stage
Number of singers	28	25
Spacing and formation of singers	Lateral spacing in sections; S1 A1 S2 A2 Spacing somewhat determined by fixed seating	Lateral spacing in sections; S1 A1 S2 A2 More lateral space than in first semester; larger, wider hall with bigger seats

The investigators chose to use relatively inexpensive, durable, and easily portable equipment, particularly with respect to the microphone used. This choice was in large part confirmed when choir members would sometimes trip on microphone cords and bump into the microphone itself during rehearsals. Also, other classes met in the venues used for this study immediately before and after each choir rehearsal. These scheduling realities dictated using equipment that could quickly be set up and broken down after each rehearsal.

Survey Instrument

A researcher-designed survey solicited participant perceptions and preferences. This survey, constructed in consultation with faculty colleagues in music education and perception, was administered at the end of each semester. (See Appendix A).

The survey contained 31 items divided into 3 sections. Section one solicited demographic information such as age, major, previous choral singing experience, and participation in private

voice study. Section two inquired about participants' use of computers and previous coursework in physics, acoustics, and voice anatomy and physiology. Section three of the survey asked participants to share perceptions and preferences with respect to the use of the visual display in choir rehearsals by responding to both multiple choice and open-ended survey questions.

Use of Displays During Rehearsals

Members of the choir were informed about the displays and their potential relevance to vocal production through written materials and through verbal explanations during rehearsals. Figure 2 shows fifteen seconds of a typical display captured during one of the choir's rehearsals. In this instance, mm. 45-48 of "Amazing Grace," arranged by Joan Szymko for SSAA a cappella chorus is illustrated. The microphone signal is displayed above and the spectrogram is below.

This display used a narrow band spectrogram (10 Hz bandwidth), with the spectrogram frequency scale set at 0-8000 Hz. Red horizontal frequency markers were set at 392 Hz or G4 in musical notation (which is the last note to be sung in the piece and the tonic note of the key of the work) and 5000 Hz, respectively. The VoceVista software allows users to set or change these and other parameters as desired.

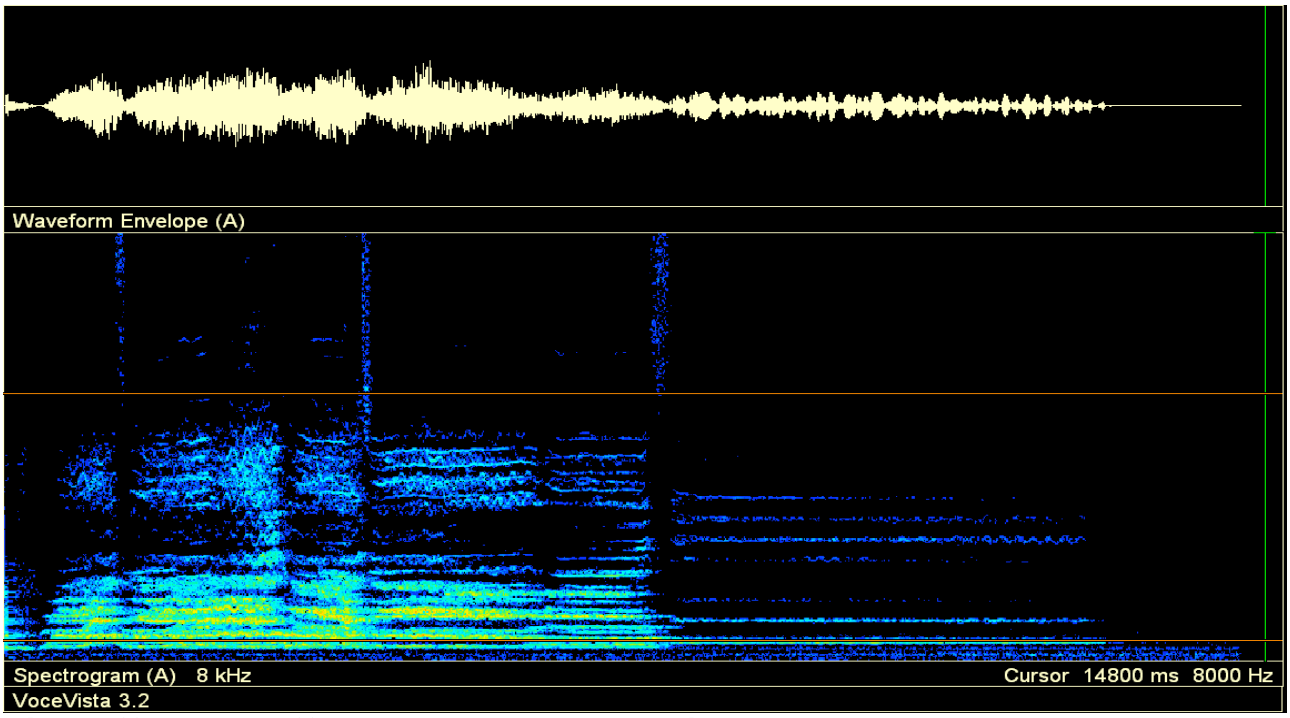

Figure 2. Sample display from 15 seconds of a rehearsal of the UTSA women's choir. Microphone signal is displayed displayed above, spectrogram below. IPA of sung text appears below the spectrogram. From mm. 45-48 of "Amazing Grace," arranged by Joan Szymko for SSAA a cappella chorus. Analysis settings: narrow band spectrogram (10 Hz bandwidth); 0-8000 Hz frequency scale; 15 second time history of spectrogram; 20 ms audio segment length; red horizontal frequency markers set at 392 Hz (G4) and 5000 Hz, respectively. Note the rise in F2 during the transition to the vanishing vowels in the [a:I] dipthongs, the high frequency elements (5000 Hz and beyond) of the /z/, /t/ and /s/ consonants, the prominent vertical gaps in lower frequency portions of the spectrogram at plosive consonants, and the intonation of the choir's unison final note (slightly below the red cursor line at G4 or 392 Hz).

This example was saved on the display screen so it could be discussed immediately after the choir finished singing in this particular rehearsal segment. Choir members were shown how the transition to the vanishing vowel in the [a:I] diphthongs in the words "blind" and "I" causes a rise in the second formant, which can be seen in the display, and told to use the

display as a cue in delaying the vanishing vowel of the diphthong in these words. The high frequency elements (5000 Hz and beyond) of the /z/, /t/ and /s/ consonants were pointed out to the choir, as were the prominent vertical gaps in lower frequency portions of the spectrogram at plosive consonants. Choir members were instructed to use the visual feedback as a means of monitoring the synchrony and duration of these consonants. Finally, the choir was reminded about the intonation of the final unison note in the piece, which was slightly below the desired pitch and which appears slightly below the red cursor line at G4 or 392 Hz on the display.

Throughout the course of the study, the investigators varied the analysis and display parameters according to the rehearsal needs of the choir director and the characteristics of the musical compositions sung. In general, a display similar to that shown in Figure 2 was used. Parameters regularly adjusted included: (a) the upper frequency range of the spectrogram, which was set at 8-10 kHz when consonant articulation was being addressed in the rehearsal, or at 5kHz when vowel tuning was being highlighted; (b) the time history of the spectrogram display, which was varied with the tempo of the musical selection; and (c) the use or non-use of red indicator lines at various frequency points on the spectrogram.

The presence of potential confounding variables associated with choral sound and venue acoustics, as previously mentioned, made it difficult to know with certainty what precisely was captured and displayed on the screen at particular moments. However, such matters as relative consonant articulation and diphthong transitions would seem to be logical possibilities for visual feedback in choir rehearsals, as would, perhaps to a lesser degree, intonation of unison pitches, vibrato, relative dynamics, and types of entrances and cutoffs. Thus, the study proceeded under those assumptions.

RESULTS

Results are presented according to the research questions posed for this study. Because survey data were at the nominal level, chi square testing was employed to determine significance at a pre-determined alpha level of .05.

Two surveys were administered during the course of this study, one at the conclusion of semester one and one at the conclusion of semester two. Because choir membership varied across the two semesters, results are given separately for each survey administration

Research Question One

The first research question asked about preferences and perceptions of choir members regarding the use of visual displays of purported spectra and other acoustic parameters during choral rehearsals. Two survey items (19-20) addressed this question directly and globally, while eleven survey items (16-18, 21-28) sought responses about various aspects potentially contributing to participant perceptions and preferences.

Participant responses to item 19 ("Did you find the display of the analysis of the choir's sound helpful or not helpful in rehearsals?") indicated a significant majority of respondents in both semesters perceived the displays as helpful (78%, semester one, $\chi 2$ (2, N=15) = 98.03, p = >.05; 86% semester two, $\chi 2$ (2, N=28) = 130.06, p = >.05). Other respondents indicated they were "not sure" (22%, semester one; 14% semester two). No participant in either semester reported perceiving the display as "not helpful."

Survey item 20 asked participants to write comments on how, specifically, they perceived the visual feedback as either helpful or not helpful. See Table 2 for a compilation of these responses. Among participants perceiving the display as helpful, one respondent commented, "If you watch the monitor, you can see trends and patterns that apply when certain sounds are produced." Another said the display "Gave visual [reference] to help align entrances and consonants and to create a more unified sound." Among respondents not sure how helpful the visual display was, one respondent noted the display "Was not really explained or utilized by the conductor." Another respondent commented, "Sometimes it was visually distracting; it usually affirmed what I was hearing."

Survey item 28 asked respondents whether they thought having a visual display enhanced the rehearsal experience or made that experience more difficult for them. Among choristers surveyed, nearly all thought having the display either greatly or somewhat enhanced rehearsals (97% semester one, 93% semester two). A few singers thought the display did not make much difference to them (3%, semester one, 7% semester two). No respondents in either semester thought the display made rehearsals more difficult.

Survey items 23-26 invited participants to self-report the frequency of their viewing the display per rehearsal, and if the frequency of that viewing changed during the course of the semester. Responses indicated singers were divided on this matter. In both semesters, a majority of participants reported referring to the display "sometimes" (6-10 times per rehearsal) or "frequently" (over 10 times per rehearsal (59% semester one, 58% semester two). However, 44% of semester one participants and 43% of semester two participants reported referring to the display "seldom" (2-5 times per rehearsal) or "almost never" (0-1 times per rehearsal). Similarly, two questions about whether or not frequency of viewing changed during the course of the semester yielded mixed responses.

Table 2

Participant Comments about Perceived Helpfulness or Non-helpfulness of a Visual Spectral Display in Choir Rehearsals

Semester One Comments:

- coming in on time, crescendos, vibrato amount; let us know exactly what we were doing
- could see the entrances, sharp consonants, scoops
- Cutoffs
- helped with consonants and vowels
- helps to see what is coming out when we sing; how strong our consonants are and our pitch quality
- I think if I knew more about it in the choral sense I would benefit from it more. I know it really helps in private lessons.
- it helped to show visually what problems to correct instead of having to guess
- it helped us see the clarity of our entrances/cutoffs, pitches and articulation. It also showed visually the difference in sound when we sang with different colors/techniques
- it was easy to see when we missed cutoffs (instead of just trying to hear it)
- it was easy to see where the consonants and vowels were placed and should be placed
- it was educational as a whole, but definitely helped make it visible when we had bad consonants or scooping, etc.
- it was helpful at times for consonants and entrances; sometimes it was distracting; during my singing I had to pretend it wasn't there in order to concentrate on my part
- it was helpful in seeing how much intensity we needed and vowels that we choose and space
- it's a visual representation of the sounds we are producing; good for visual people like me; also, we can't always hear what is going on in the entire choir but this helps us to see what the choir is doing as a whole
- showed us crisp consonants and longer vowels
- showed when voice wasn't consistent, consonants, etc.
- sometimes it was visually distracting; it usually affirmed what I was hearing
- was able to see a concrete difference in contrasting sounds; could see when the choir wasn't singing as it should
- was fun to watch and on occasion it helped, but I was mainly intrigued by how the sounds would look
- we could see consonants; it was kind of hard to interpret otherwise
- we were able to see things such as cutoffs and consonants when they were together or not
- when he explained things and showed us examples of how the right and wrong way looked, that helped
- You can realize better visually what/how you need to sing and phrase

Semester Two Comments:

- If you watch the monitor you can see trends and patterns that apply when certain sounds are produced
- Visually helpful seeing vibrato and overtones
- I better understand the physics of sound waves
- We were made aware how we could improve our sound
- Was not really explained or utilized by the conductor
- You could actually see when we were singing together and correctly, even if you couldn't hear a difference
- Vowels, dynamics, seeing overtones and vowel placements
- Gave visual to help align entrances and consonants and to create a more unified sound
- To see if entrances and cut offs were accurate. It was also nice to see dynamics visually
- It helped to see the scoops when they happen or the crisp starts

In semester one, 63% of participants reported their viewing frequency changed during the course of that semester, with 26% reporting it became more frequent and 33% reporting that frequency of viewing varied from piece to piece. By contrast, 52% of semester two participants reported either that viewing frequency did not change over the course of the semester or that they were "not sure."

When asked what aspects of the display they watched for, semester one singers indicated "entrances and cutoffs" (78%), "diction" (74%), "dynamics" (67%), and "vibrato" (59%). "Other" aspects supplied by respondents included "pitch of overall choir," "formants and harmonics," and "which vowel to use." Semester two singers reported they watched for "entrances and cutoffs" (86%), "dynamics" (86%), "vibrato" (79%), and ""diction" (71%).

Participants were also asked whether or not they noticed that display parameters were sometimes varied. Most respondents responded affirmatively (89%, semester one; 86%, semester two). Most respondents also thought these changes in display parameters, according to the piece sung or aspects being focused on by the director, were helpful (63%, semester one; 79%, semester two).

When asked about the explanations given about the displays over the course of the semester (survey item 21), a majority (93%) of first semester respondents indicated such explanations were both "detailed enough to be clear" and "easy to understand." Among first semester respondents, two singers (7%) thought the explanations were "not detailed enough" and "confusing." A majority (80%) of second semester respondents likewise thought explanations were both "detailed enough to be clear" and "easy to understand." Among second semester participants, three singers (20%) thought the explanations were "too detailed," while two persons (13%) thought they were "not detailed enough" and one singer (6%) found them "confusing."

Survey items 16-18 inquired about the presence in rehearsals of another faculty member, who operated the equipment and displays and periodically participated in the rehearsals. Most respondents thought having another faculty member present and periodically participating was either a positive aspect (85%, semester one; 79%, semester two), or had no impact positively or negatively (15%, semester one; 21%, semester two). Similarly, most of these singers thought having the choir's singing monitored by another faculty member who operated a computer either a positive experience (89%, semester one; 64%, semester two) or viewed such monitoring neither positively nor negatively (11%, semester one; 36%, semester two).

Research Question Two

The second research question asked whether choir members' preferences and perceptions would vary significantly according to previous coursework in physics, acoustics, or voice anatomy and physiology, current participation in private voice instruction, familiarity with computers, and years of choir singing experience. To answer this question, response distributions to four pairs of survey items were cross-tabulated.

Items 14 and 19. When responses to item 19 ("Did you find the display helpful or not helpful in rehearsals?") were disaggregated according to responses to item 14 ("Have you ever taken a physics or acoustics course?"), results varied according to semester. There was no significant difference in first semester responses to item 19 according to whether participants had had a prior physics or acoustics course, $\chi 2$ (1, N=28) = .37, p = < .05. In semester two, however, response distributions indicated those who had taken a prior physics or acoustics courses found the display helpful to a significantly higher degree than those who had not taken a prior physics or acoustics course, $\chi 2$ (1, N=15) = 4.58, p = > .05.

Items 6 and 28. Response distributions to items 6 ("Are you currently taking applied voice lessons?") and 28 (whether respondents viewed the feedback from a visual display as enhancing the rehearsal experience or not making much difference) were also compared. Semester one students who were taking private voice lessons viewed the visual feedback as enhancing the rehearsal experience to a significantly greater degree than respondents who were not taking private voice lessons, $\chi 2$ (1, N=26) = 8.41, p = > .05. There was no significant difference on this matter among responses of semester two participants.

Items 11 and 28. Comparison of response distributions to items 11 ("Do you use computers on a daily basis?" and 28 (whether respondents viewed the feedback from a visual display as enhancing the rehearsal experience or not making much difference) yielded no significant differences in either semester.

Items 4 and 28. Comparison of response distributions to items 4 ("Years of choir singing experience") and 28 (whether respondents viewed the feedback from a visual display as enhancing the rehearsal experience or not making much difference) yielded no significant differences in either semester, suggesting that amount of previous choir singing experience was not a factor in the perception of participants overall that the visual display enhanced their rehearsal experiences.

DISCUSSION

The major finding of this feasibility investigation is that participants to a significant degree think that a visual display used during a third of their choir rehearsals each semester both enhances and is helpful to the rehearsal process. In other words, participants do not perceive that use of such a display distracts from the rehearsal process. Such perceptions, moreover, appear not to vary significantly according to years of previous choral singing experience, private voice study, self-reported familiarity with computers, and previous coursework in anatomy, physiology, or acoustics.

This finding, of course, is limited to the context, participants, and procedures of this particular study. Nonetheless, it addresses a very practical matter important to future investigations of the use of visual spectral feedback displays in choral rehearsing. Whether or not such displays and the procedures associated with them can be refined to yield consistently reliable and valid choral sound data in real-world rehearsal contexts remains an open question at this juncture. However, if choral singers were to perceive incorporation of these displays as intrusive or as making their rehearsals more difficult, then there would be little point, at least from a practical perspective, to proceeding with efforts to explore, refine, and advance protocols that might address the many confounding variables presently associated with use of real-time displays of spectra in naturalistic choral singing contexts.

This investigation may also provide some clues for how such efforts might proceed. For the most part, as indicated by responses to multiple-choice survey questions and written comments, participants preferred to refer to the display for visual feedback regarding entrances and cutoffs, and diction (e.g., diphthong transitions and consonants). Perhaps initial research efforts might focus on finding ways to record, process, and display those types of data more reliably, taking into consideration, for instance, such variables as microphone placement and venue acoustics.

Another aspect of undertaking this investigation is the learning opportunity it afforded the investigators with respect to the practicalities of using a visual display of spectra in the context of actual choral rehearsals. On the basis of our experiences in this study, we offer the following recommendations to others who may wish to follow suit:

1. For the foreseeable future, two persons are likely required if feedback from a visual display is to be incorporated into a choir rehearsal without sacrificing accomplishment of what must happen in particular rehearsals as a matter of course. The choir director, obviously, must place priority on leading and sequencing the rehearsal. Another person is needed to operate the computer, and constantly adjust and optimize the display parameters as the rehearsal progresses. In university settings, this second person might well be a graduate student interested in learning more about choir acoustics.
2. The computer operator needs to have in advance of a rehearsal the music scores and the director's lesson plan for that particular rehearsal so that he or she might anticipate which analysis parameters and display settings to use. Joint development of the rehearsal plan might also be an option in order to make the most of the technology.
3. Both the choir director and the computer operator need to be able to provide concise explanations of the displays to the choir.
4. Some rehearsal time will need to be set aside for educating choir singers on what the display can and cannot do.
5. It would be preferable, in our view, that the display screen be set up in such a way that the choir director can see it without having to turn away from the choir. Perhaps this tack would involve two monitors, one for the choir and one for the director. Were that the case, the director could view the feedback on his or her monitor while selectively giving or withholding visual feedback from the choir. In other words, singers' attention could be focused on those moments and phenomena the director discerns as particularly amenable to visual feedback, rather than having the display run throughout the entirety of the rehearsal.

6. The projection screen visible to choristers should be placed as near to the conductor as possible (preferably above and slightly behind her/him), so that singers can view the screen without having to look drastically away from the director's conducting gestures.

7. Singers must be positioned with a clear line of sight to the conductor and to the screen.

8. The screen image should be large enough for details in the display to be readily visible.

9. All users need to understand how room acoustics, microphone placement, and positioning of the singers can impact the display.

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Appendix A: Survey

Section One:

1. Your age: ___

2. Role in this ensemble:
   (a) singer
   (b) accompanist
   (c) director

3. What voice part do you usually sing in this ensemble:
   (a) Soprano I
   (b) Soprano II
   (c) Alto I
   (d) Alto II

4. How many years have you sung in choirs? ____

5. How long have you sung in THIS choir?
   (a) one semester
   (b) two semesters
   (c) three semesters
   (d) four semesters
   (e) more than four semesters

6. Are you currently taking applied voice lessons?
   (a) yes
   (b) no

7. If you are not taking applied lessons now, have you taken private voice lessons in the past?
   (a) yes
   (b) no
   (c) N/A (taking now)

8. How much private voice instruction have you had? Count a school semester as ½ of a year. _____ years

9. What is your major?
   (a) Music Performance
   (b) Music Marketing
   (c) Music Education
   (d) BA in Music
   (e) Music minor
   (f) Not a music major. My major is: _____

10. What class are you in school?
   (a) Freshman
   (b) Sophomore
   (c) Junior
   (d) Senior
   (e) Other: _____

Section Two:

11. Do you use computers on a daily basis?
   (a) yes
   (b) no

12. Do you prefer Mac or PC type computers?
   (a) Mac
   (b) PC
   (c) No preference

13. Have you taken courses in the use of computers? Mark all that apply.
    (a) Yes, in college
    (b) Yes, in high school
    (c) Yes, privately
    (d) Yes, technical school
    (e) No

14. Have you ever taken a physics or acoustics course?
    (a) Yes, in college
    (b) Yes, in high school
    (c) No

15. Have you ever taken a class in voice anatomy and physiology?
    (a) yes
    (b) no

Section Three:

16. This semester, another faculty member was present at some of the class meetings, and periodically participated in the class. Did you find this:
    (a) A positive aspect?
    (b) A negative aspect
    (c) Had no impact positively or negatively

17. Overall, did you find having he singing of the choir monitored by another faculty member operating a computer…
    (a) A positive experience
    (b) A negative experience
    (c) Neither a positive nor negative experience

18. If the experience was not positive, was it
    (a) distracting
    (b) uncomfortable
    (c) other: _____
    (d) not applicable

19. Did you find the display of the analysis of the choir's sound helpful or not helpful in rehearsals?
    (a) helpful
    (b) not helpful
    (c) not sure

20. In what ways was it helpful or not helpful? _____

21. Were the explanations you received about the displays (mark all that apply):
    (a) too detailed
    (b) detailed enough to be clear
    (c) not detailed enough
    (d) easy to understand
    (e) confusing

22. The analysis displays were sometimes varied, according to the piece being sun or the aspects being focused on by the group''s director. Did you notice these changes in the display?
    (a) yes
    (b) no

23. If you noticed these changes, did the changes help you in your rehearsing?
    (a) Yes, the changes helped
    (b) No, changes didn't help, but were not a distraction
    (c) No, the changes did not help and were a distraction
    (d) I am not sure

24. At rehearsals in which the analysis display was used, about how often did you typically refer to the screen for feedback?
    (a) Almost never (0-1 times per rehearsal)
    (b) Seldom (2-5 times per rehearsal)
    (c) Sometimes (6-10 times per rehearsal)
    (d) Frequently (more than 10 times per rehearsal)

25. Did your referring to the screen change in the course of the semester?
    (a) Yes
    (b) No
    (c) Not sure

26. If you feel your referring to the screen for feedback changed, how did it change?
    (a) Became more frequent
    (b) Became less frequent
    (c) Varied from piece to piece
    (d) Other: _____

27. What aspects did you watch for in the display? Mark all that apply.
    (a) Dynamics
    (b) Vibrato
    (c) Entrances and cutoffs
    (d) Diction
    (e) Other: _____

28. Overall, would you rate having this type of feedback positively (it enhanced the rehearsal experience) or negatively (made rehearsing more difficult)?
    (a) Greatly enhanced rehearsals
    (b) Somewhat enhanced rehearsals
    (c) Did not make much difference to me
    (d) Made rehearsals somewhat more difficult
    (e) Made rehearsals more difficult