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MELISMA SINGING AND PREFERRED STAGE ACOUSTICS FOR SINGERS

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Vocal performance characteristics, such as tempo, colour, and expressiveness of singers are part of the unique artistic impression of individual performers and individual performances. Subjective pair-comparison studies of singers in a previous study demonstrated that singers prefer added reflections with delays in the range of 10–20 ms. However, the range of values between singers, for the effective duration of the autocorrelation of the singer's voice, was limited, and insufficient to demonstrate a relationship between individual vocal characteristics and the preferred delay time of reflections. In this study, to investigate the singer's preferred acoustics with a change in singing style, subjects were asked to perform non-plosive, non-fricative text for the lyrics, using exclusively "la" syllables (*melisma* singing). A resulting shift in preferred time delay was observed. The extent of the shift in preferred reflection time delays is shown to be directly related to the minima of the effective duration of the running autocorrelation function calculated from each singer's voice. Singers were also subjected to training, to assist in identifying sound fields. After training, the average preferred delay time of the reflection did not change, but the statistical variability of the singer's subjective rating of the sound fields was strongly reduced.

1. INTRODUCTION

1.1. A NEED FOR FURTHER SUBJECTIVE SINGER PREFERENCE STUDIES

Musicians are challenged by the acoustic environment of recital and concert hall stages. Concurrent with expressing artistic intent, performers of music must (i) judge and adjust for tonal discrepancy—the tone characteristic of the perceived sound differs spectrally from the sound projected to the audience, (ii) listen to each other for balance and timing while their own instrument is masking the sound of the other performers, and (iii) make adjustments for acoustical differences of each particular stage and auditorium, by listening for the room's response.

Singers are unique, among musicians, in all three of these challenges, and more. In addition to meeting the instrumental performer's challenges of tonal discrepancy, ensemble timing and balance, and stage particularities, singers face additional challenges. The voice as a musical instrument is located very close to the ears. And perhaps more importantly, singers also are subject to significant levels of the sound of their own voice, via bone conduction within the head [1]. In determining sound field conditions for musical performances, singers therefore deserve special attention. Nevertheless, few studies have attempted to delineate the characteristics of the acoustical environment preferred by singers.

No previous study has demonstrated the influence of changes in the style of singing on singer sound field preferences, when performing on different stages. Singers control the artistic effect of their performances by varying colour, tempo, and emotional expressiveness. This study was designed to take a first look at the effect of singing style on singer's preferences by comparing the preferred reflection time delay for singers performing without lyrics, using "la" syllables— known as *melisma* singing— as compared with the preferred delay while singing the same melody line using the musical text.

The acoustical designs for spaces dedicated to singers—namely opera houses— have not benefited from a knowledge of singer subjective preferences in determining the size, shape and surface treatments of the stage, proscenium, or house. In two recent studies of opera house acoustics [2, 3], the acoustics of the stages were not evaluated, nor were judgments of opera performers included, presumably because such an evaluation would necessarily be made in a highly variable environment, unlike the fixed configurations of performance platforms in concert or recital halls. Nevertheless, the Hidaka and Beranek study [3] did admit that the opera stage's quite variable environment is very important in the final assessment of the acoustical quality of an opera house, in the survey opinions of opera conductors. Among the important acoustical concerns raised by the survey participants were the questions: "Can the singers project without forcing?" and "Are there dead spots on stage?" However, questions such as these can be given a firm foundation only by carrying the scientific inquiry directly to the *singers*, eliciting their responses *while performing,* and under more controlled acoustical conditions. Without a determination of acoustical design criteria, based on singer preferences, a truly objective design evaluation of opera stages and opera houses is not possible.

1.2. RESULTS OF THE PREVIOUS SINGER PREFERENCE STUDY

There are few published studies of singer sound-field preference during singing performance. While numerous recent studies have been conducted for improving stage acoustics for orchestral instrumentalists, the preferred acoustical conditions on performing stages for singers is not well known. Two approaches to determining singer stage preferences are possible: (i) opinion surveys collected from singers performing on existing stages and (ii) systematic comparison studies using simulated sound fields.

Both methods of eliciting singer preferences for stage acoustics have their drawbacks. For on-stage performances, the direct comparison between two stage environments necessarily involves a lapse of time as the singer moves from one to the other, nor can the acoustical changes be controlled or varied systematically. In addition, the possibility of random sequence of pair-comparisons to eliminate bias and inconsistency is not possible. On the other hand, if using the simulated sound field approach, singers may be influenced by the unfamiliar surroundings and unusual sound characteristics on entering an anechoic space, and subsequently have difficulty developing a relaxed performance.

The methods used in this study attempted to overcome some of the drawbacks of performing in a simulated environment by allowing the singers a repeat performance experience, over an extended period of time (18 months from the first session to the last), and by including coaching from a professional singer. The final trials of preference testing in this study included sound-field training to adapt the listening discernment of the singers to the changes, and freely allowed them to discuss what they were hearing prior to pair comparison testing.

In the precursor to this study [4], direct observations were made of singer preference using both approaches, with some singers participating in both sessions: (Session A) while performing on a full-scale stage (with variable acoustics) and (Session B) in a simulated acoustical stage. In the first session (Session A), a series of acoustical modifications were simulated on the performing stage platform, utilizing an electronically added, variable time-delay reflection to simulate reconfiguration of the walls surrounding the platform. During fast tempo singing, solo and duet singer preference increased with the addition of short-delay reflections, with the highest preference for a simulated reflection with delays ranging from 20 to 30 ms. The increase in singer preference suggests that new reflectors are likely to produce noticeable improvement in singer preference over the current acoustical environment, with weaker early reflections. The preferred time delay can also be used to determine the location of the reflectors. Adjustable height of the reflectors above the choir platform would permit optimizing singer preference for the music program, based on the minimum of the effective duration of the running ACF for the selected musical source material.

In the second part of the previous study [4] (Session B), a solo singer study was conducted to establish the subjective scale value and preferred range of time delays for a single simulated reflection in an anechoic room. When singing fast tempo music with lyrics, the consensus of preference was statistically significant and the preferred delay averaged 20 ms. As proposed by Ando [5], the measured preferred time delay for each singer also suggested that the preferred time delay was related to the minimum value of the effective duration of the running autocorrelation function (ACF), calculated for each singer, although the range of the ACF values and consistency of the singer pair comparisons was not reliable enough to establish the relationship conclusively.

Measurements on stage at existing opera houses have recently been collected by several investigators aimed at correlating the acoustic parameters extracted from the measurements to subjective criteria, for example at Teatro Communale, Ferrara, Italy [6]. The results from the Teatro Communale study suggested that preferred singer locations on the performing stage, as characterized by reflection time delays from impulse response measurements, can be interpreted using Ando's theory of performer preference, using parameters extracted from the individual singer's voice ACF, and then applied to design improvements for existing opera stages.

1.3. OTHER SINGER PREFERENCE STUDIES OF STAGE SOUND FIELDS

Experimental studies conducted with instrumental musicians [7–9] indicate that strong ceiling reflections are very important both for instrumental soloists and instrumental ensembles. With singers, however, the listening task is influenced by the act of using the voice as the performing instrument, by the extreme proximity of the voice to the ears, and by internal bone conduction, all of which are believed to influence the judgment of preferred acoustical conditions.

Attempts to determine singer preferences while performing on actual or simulated stages are rare. A singer ensemble study [10] in 1985, using no soloists, concluded that performing singers within the ensemble felt reverberation in the simulated environment was the most important acoustical attribute of the sound field, and also responded positively to relatively high reverberant sound levels. Early-arriving simulated reflections were reported to provide only a minor effect in support of the singers. However, the simulated sound fields for this 1985 study were intended to represent actual levels of early-reflected sound energy on typical stages, but reflection sound levels were set at the level of *four* reflections, using the inverse square law, to represent typical reflection sound levels on stages. One would estimate that the combined early reflections from side and rear walls, ceiling, the eight dihedrals between the planes of the floor, walls, and ceiling, and the four corners formed by three planes, are at least 6 dB higher than used in this study, which may explain the lack of preference for reflections by the singer subjects.

A recent investigation [11] of singer preference for sound fields, in the context of singers performing in a choir, examined singer preference for sound levels of other singers relative to the subject singer. This study specifically limited musical source material to monotone vowels (steady single pitches), rather than the more typical acoustical context for evaluating stage acoustics, namely while singing time-varying material. Increasing the relative *level* of sound from other singers was determined to be the primary concern for improving singer preference.

2. EXPERIMENT

2.1. ACOUSTICAL PROPERTIES OF THE SIMULATED STAGE

The acoustical sound fields of opera stages vary with stage size, scenery, which may be elaborate or totally lacking, location of adjacent proscenium surfaces, and reverberant character of the auditorium. For this study, a new facility for generating sound fields was constructed to simulate variations of stage acoustics in scale size, sound levels, time delay, source direction, and reverberation decay times. Singers performing in the previous time-delay study [4] reported discomfort from the atypical scale of the study chamber ($30\,m^3$) compared with the stages normally encountered in solo and choral performance, and the singers felt at times that they were inadvertently suppressing their vocal effort. A $125\,m^3$ semi-anechoic chamber, constructed in the fall of 2000, was specifically developed with sufficient cubic volume to "open up" the singer's vocal effort, producing a more relaxed and expressive performance while conducting subjective preference testing.

2.2. PREPARATION OF SINGERS

Two sessions of preference trials were conducted at this new facility. For both sessions of preference tests, singers were asked to warm up prior to beginning the series of pair comparison of simulated reflections. In the warm-up area, singers were each queried identically, and asked to evaluate each pair of sound fields as if able to switch quickly between two stage locations, and were instructed to state which they preferred. However, for the second series of pair-comparison sessions, the singers were given preparatory training in the simulation room as well. The training consisted of listening to each of the simulated time-delayed reflections, which were presented in order, and the acoustic differences were noted, up to a clearly audible echo, and were freely discussed. The two sessions were conducted after a six month interval, to allow a maximum effect of the training for these singers, who were now experienced with the experiment.

2.3. EXPERIMENT DESIGN AND PROCEDURE

To determine the effect of singing style, melisma singing was chosen for this study as one of several potential means of representing a change in performance style. Change in tempo, as indicated in the previous study, had little effect on the minimum effective duration of the running ACF [4], and a wider range was needed to determine if singers would respond in the same way as instrumentalists. Ando's theory for listeners and performers [5] suggests a strong effect on the temporal (and monaural) parameters of sound fields, such as reverberation or time-delayed reflections, and posits that a fruitful investigation procedure should use the autocorrelation of the sound source signal as the common predictive parameter in determining trends in performer sound field preferences.

Simulated sound fields, consisting of direct sound from the singer's voice to ears, plus one delayed and simulated reflection, were presented to five melisma singers in session one, and to six singers in session two. Preference data for three singers from the earlier study of lyric singing plus one new lyric singer were included for comparison. Sound fields were simulated in this study using a 125 m^3 semi-anechoic chamber. The voice signal was amplified and delayed from a microphone located 10 cm in front and 5 cm below the singers mouth. These distances were set to avoid coloration from feedback and to reduce breath noise from the singer.

The reflection simulation loudspeaker was located 3·0 m behind the singer, reproducing a delayed signal, which was set at –5 dB below the level of the direct sound, as measured by a microphone at the singer's right ear canal entrance, see Figure 1. This level was selected, as in the previous study, by determining the level at which singers were just able to detect the shortest time delay (10 ms in this study, −3 dB for a delay of 5 ms in the previous study [4]). Breath noise was controlled with a wind screen on the voice microphone.

Analysis of each singer's voice was made to determine the minima of the effective duration of the running ACF, which varied among the singers. The running ACF was calculated for A-weighted voice recordings with an integration time of 2·0 s, using a running interval of 100 ms. The singer's *melisma* and textual performances were recorded anechoically, and the 95% confidence interval for the sample means of the minimum running ACF for each singer varied from ±4 to ±18% of the mean values, with an average confidence interval of ±14%. In all cases, the mean minima for lyric singing were

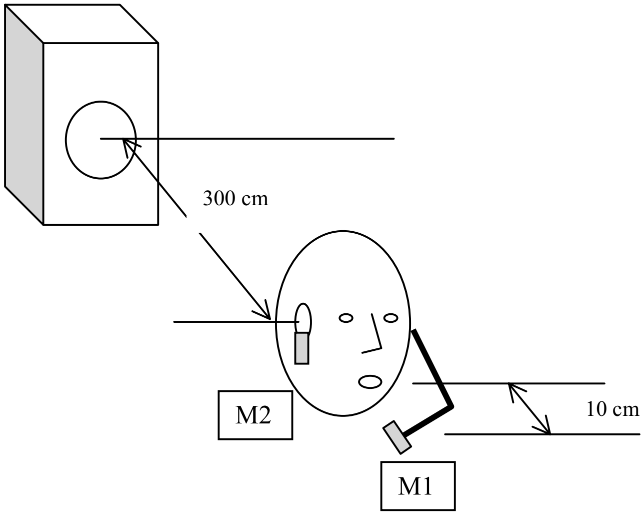

Figure 1. Configuration of time-delayed reflection simulation in the semi-anechoic chamber. Microphone M1 is 5 cm below the level of the singer's mouth, 10 cm in front. Microphone M2 was used to determine the level of the simulated reflection compared with the voice sound level directly from the singer's mouth.

Figure 2. Musical passage sung both with lyrics and without lyrics (*melisma*) by all subjects. The *melisma* melody was sung using the syllable "la".

statistically distinct from the mean minima for melisma singing, for each singer, to a 95% confidence level.

The consistency of singing was maintained throughout the trials with performance coaching delivered by a professional singer recruited for this project, who was a known and respected artist to all the singers.

To encourage consistent performance, the coach employed an electronic metronome indicating a fixed tempo adapted slightly ($\pm 10\%$) to the comfort of each singer, and displayed either as an audible click, prior to each set of six pair comparisons, or as a visual blinking light if needed during the sessions. For the sample melody selected, the singer's tempo was selected to be moderate, and performed in the range of 80–85 bpm. Since tempo has a negligible effect (less than 5%) on the minima of the calculated effective duration of the voice autocorrelation function, for each individual singer, the variation in tempo was deemed acceptable.

The coach was present with all singers for at least the first set of pair comparisons. The singer's voice level was rehearsed at a moderate degree of effort, in the range of 78–84 dB at 1·0 m during sustained vowels. Singers performed the musical selection in a key most comfortable for their musical range. For example, the tenor's starting pitch was G4.

Each of the four simulated sound fields contained one delayed reflection, with a delay Δt_1 of 10, 20, 40, or 80 ms, and the sound fields were in random ordered pairs. The notes of the melody from the traditional Irish melody "Slane" were sung melisma style as the syllable "la". Figure 2 shows the melody and lyrics of the short passage of music used in this study.

Six unique pairs from four sound fields were presented to each singer in five repeats, in random order. The set of repeats constituted one pair-comparison trial. Each singer's scale value of preference for each sound field was determined using Thurstone's method [12], with a trial for each type of singing (lyrics and *melisma*). Statistical tests for consistency and agreement were applied to assess the validity of pair-comparison results. Preferred time delays $[\Delta t_1]_p$ for the singers were measured from a curve fit to the scale values of preference calculated from the singer's response to each simulated sound field.

3. RESULTS

3.1. RESULTS COMPARED WITH NON-MELISMA SINGING

Scale value results calculated for nine preference trial sessions (six singers, three singers twice) are shown in Figure 3, showing the general form of a successful preference evaluation curve, with low scale values at the extremes of short and long delays, and with a distinct maximum in the mid-range of the reflection time delays. Not all singers were available for both trials, unfortunately. One melisma trial did not conform with the general form of the preference evaluation curve, and was not included in the subsequent analysis.

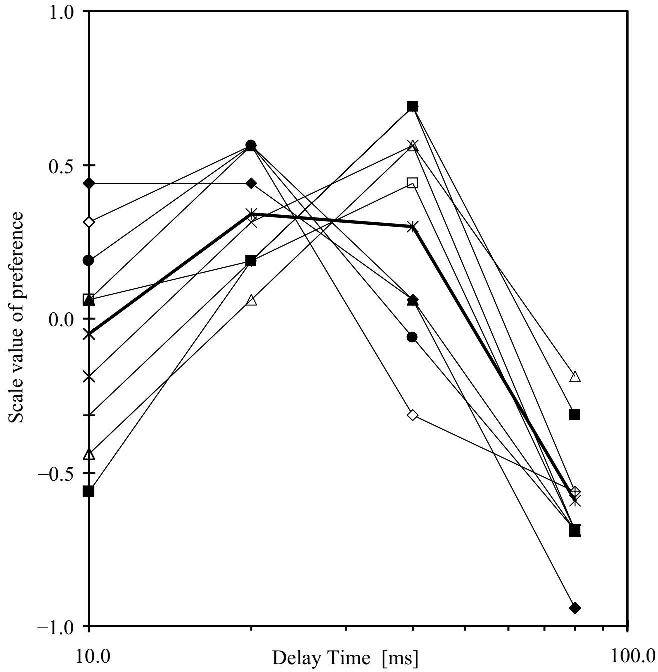

Figure 3. Scale value preference for sound fields with one delayed reflection, *melisma* singing. Global (average) results for nine *melisma* sessions shown with bold line. Different symbols are used for the scale values of the individual singers.

TABLE 1

Individual results of curve fit to scale value data for melisma singing: preferred delay $[\Delta t_1]_p$ for single trials (three singers) and combined double trials (three singers)

Subject		$[\Delta t_1]_p$
A	Soprano	29
B	Alto	18
C	Tenor (2)	15
D	Tenor (2)	26
E	Soprano (2)	28
F	Tenor	26
Global	All singers	23

Preferred time delays $[\Delta t_1]_p$ for the singers were determined from a regression curve fit to the scale values, calculated from each singer's response to each simulated sound field. Singer subjects were two sopranos (subjects A and E), three tenors (subjects C, D, and F), and an alto (subject B), as listed in Table 1. The results show a maximum singer preference for time delayed reflections in the range from 20 to 40 ms, with a 23 ms preferred delay for all singers combined (Table 1).

As shown in Table 2, text (lyric) singing resulted in a preferred sound field with reflection Δt_1 of 10–18 ms, averaging 14 ms, while for *melisma* singing, without the fricative and plosive consonants of the sung lyrics, the maximum preference was observed to

TABLE 2

Comparison of preferred delay times $[\Delta t_1]_p$ for lyric vs. melisma singing

Subject	Melisma	Lyrics	Diff	
A	Soprano	29 ms	None	—
B	Alto	18	10	8
C	Tenor	15	11	4
D	Tenor	26	18	8
E	Soprano	28	NA	—
F	Tenor	26	15	11
Global	All singers	23	14	9

Note: Where no curve fit was possible to determine the preferred delay, "none" is indicated. "NA" indicates the singer was not available for this portion of the experiment.

increase by 4–11 ms, with a difference in the average values of 9 ms, an approximate increase of 60%. The shift from singing lyrics to singing melisma style is monotonic, with no exceptions for any singer. When singers were introduced explicitly to each sound field, and its sound character (singer training trials, as discussed below), the preferred time delay for melisma singing did not change for the global response, but some individuals had strong responses in increased scale value.

3.2. RESULTS DUE TO SOUND FIELD AWARENESS TRAINING OF SINGERS

3.2.1. *Effect on the variance of scale value*

Looking at Figure 3, it is clear that, as the singers judge the shortest time delay (10 ms), their identification of this sound field is low and the range of subjective scaling is relatively large. At this short time delay, the preference judgment is apparently impaired when singers attempt to discriminate this sound field from among the randomly selected alternate sound fields. It also appears that a singer's preferred time delay is selected with more certainty of scaling judgment, since the range of scale values at 20 ms delay is narrowed, compared with 10 ms.

Variances which range up to 0·10 are an indication that the singers are in fairly close agreement with each other in assessing their preference for a particular sound field. Variances for preference trials for singing with lyrics (shown inTable 3A and B) were reduced when fewer trials with higher consistency scores are included. Variance was lowest for time delays of 10 and 20 ms, where the singers were more certain of their preference, which coincides with the range of the most preferred time delays.

When turning to variance of scale value for melisma singing, the preference agreement worsens, with agreement between singers over the subjective scale value for sound fields at high levels, observing a 0·25 variance, or standard deviation $\pm 0{\cdot}5$, (half a scaling point) at the shortest time delay of 10 ms, and 0·32 variance, standard deviation $\pm 0{\cdot}55$ at 40 ms (Table 3C). It appears that melisma singing, without the auditory cues from fricative or plosive consonants, creates a degree of confusion in judging the sound field and therefore in assigning a preference accurately in the pair comparison task. However, training of the singers has a strong impact on the variance of scale value, increasing the preference agreement of the melisma singers to levels similar to that achieved with singers performing with lyrics (Table 3D).

TABLE 3

Variance of scale values for singer preference trials

A: Singing with lyrics, all singers combined

Delay time (ms)	5	10	20	40
Variance	0·11	0·04	0·06	0·11

Note: Variance of scale values for four singers, with trials totalling seven, three at slow tempo and four at fast tempo, combined

B: Singing with lyrics, including only consistent trials

Delay time (ms)	5	10	20	40
Variance	0·07	0·03	0·05	0·15

Note: Variance of scale valuea for four singers, with trials totalling five, two at slow tempo and three at fast tempo, combined

C: Singing melisma style, singers before training

Delay time	10	20	40	80
Variance	0·25	0·07	0·32	0·07

Note: Variance of scale values for five singers, five trials

D: Singing melisma style, singers after training

Delay time	10	20	40	80
Variance	0·15	0·03	0·11	0·05

Note: Variance of scale values for five singers, five trials

3.2.2. *Effect of training on sharpness of preference*

In Ando's scaling theory of total subjective preference, the scaling curve has the form [4]

$$S \sim \alpha|x|^{3/2},$$

where $x = \log\ (\Delta t_1/[\Delta t_1]_p)$ and the factor α represents the width of the preference evaluation curve, for example, the curves in Figure 3. When the curve is broad, the factor is small, and increases as the evaluation sharpens and the curve narrows.

When comparing results with and without training for the singers, there is little difference in the preferred delay time, but the sharpness of preference, as measured by the value of α, is improved. The effect of training also slightly increases the scale value for group averages (Global results) as well, as shown in Table 4A and B:

3.3. INDIVIDUAL DIFFERENCES AMONG SINGERS

A comparison of individual singers with text singing, and without, is shown in Table 5. Melisma singing without training resulted in less sharpness of preference for three of four singers, except for the singer subject A, who reported a suddenly achieved ability to experience sound field differences, while performing during the melisma trials, but not in the previous lyric singing study. Her performance improved from the lyric singing trials, where subject A was not able to clearly identify a preferred time delay (a very broad preference evaluation curve), to achieving the highest sharpness in the preference evaluation curve for any singer in the melisma trials without training. Unfortunately, she

TABLE 4

Results of preference curve fit for melisma singing

Subject	$\Delta t1$(ms)	maxSV	α
A Soprano	29	0·69	3·6
B Alto	none	0·81	none
C Tenor	15	0·56	1·8
D Tenor	34	0·56	2·4
E Soprano	23	0·44	2·6
F Tenor	NA	NA	NA
Global curve fit	22	0·31	2·4
(B) With subject training			
A Soprano	NA	NA	NA
B Alto	18	0·56	2·4
C Tenor	15	0·44	2·5
D Tenor	20	0·56	2·7
E Soprano	32	0·69	3·6
F Tenor	26	0·56	3·6
Global curve fit	23	0·38	2·8

Note: Where no curve fit was possible to determine the preferred delay, "none" is indicated. "NA" indicates the singer was not available for this portion of the experiment.

TABLE 5

Sharpness of preference (α) for all three singer sessions

		Melisma	
Subject	Lyrics	No training	With training
A Soprano	0·6	3·6	—
B Alto	3·1	—	2·4
C Tenor	3·6	1·8	2·5
D Tenor	2·5	2·4	2·7
E Soprano	—	2·6	3·6
F Tenor	—	—	3·6

was not available for the training sessions to determine if her improved sharpness of preference continues to be sustained after a 6-month interval between pair-comparison testing.

For all individual singers, the sharpness of their preference evaluation increased with training during the melisma trials. For subject D, however, no significant change in preference evaluation occurred throughout the three sessions, lyric and melisma alike.

4. DISCUSSION

Melisma singing style, as anticipated, extended the range of the temporal sound source characterization parameter, i.e., the minimum value of the effective duration of the running ACF, and thereby succeeded in demonstrating the relationship with this parameter for each singer. The relationship between singer preference and singing style

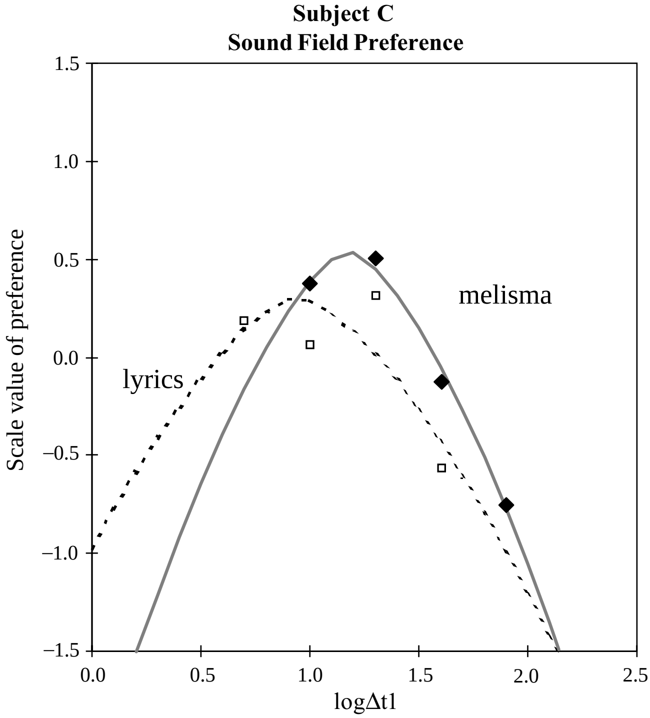

Figure 4. Scale value of preference for subject C, lyric singing and melisma singing. Data are shown with the symbol (□) for lyric singing, and are shown as (◆) for melisma singing. Preferred delay time is determined from the peak of the curve fit to the data.

is shown in Figure 4. In the theory of performer acoustics [5], measured preference values of reflection delays are directly related to the minima of the effective duration of the running ACF for each singer's performance. Figure 5 shows a strongly linear trend as predicted by the theory, and together with the previous preferred delay time data for non-melisma singing [4], extends the range of the linear relationship out to 40 ms.

The increased size of the sound field simulation facility may have helped contribute to better singer performance in obtaining an assessment of sound field preference, despite the difficulty of discriminating between time delays during melisma style singing. Because individual singers were able to successfully achieve a preference evaluation curve, with a well-defined maximum scale value in all but one trial, the linear relationship as established in Figure 5 can be compared to non-singing performers, and is confirmed at the upper end of its probable range, as indicated in Figure 6. However, the preference trend at lower sound levels of the delayed reflection, A_1, is not yet determined. The two upper points of the singer data, as shown in Figure 6, one for non-melisma singing [4], and the results of this study, for melisma singing, are both at the threshold of detection for simulated reflections with 5 and 10 ms delays respectively. Exploratory preference trials with untrained singers were not able to establish sensible (reliable) evaluation curve results, which would have, in turn, enabled the trend at lower reflection strength to be determined, as was possible in the studies for cellists [13] and alto recorder players. Additional training may be required to acquire consistent singer responses to reflections at levels lower than 5 dB below the level of direct sound.

The vowels and consonants of sung text vary markedly in the acoustic energy conveyed by bone conduction [14], which may lead a singer who is singing sibilant lyrics to judge

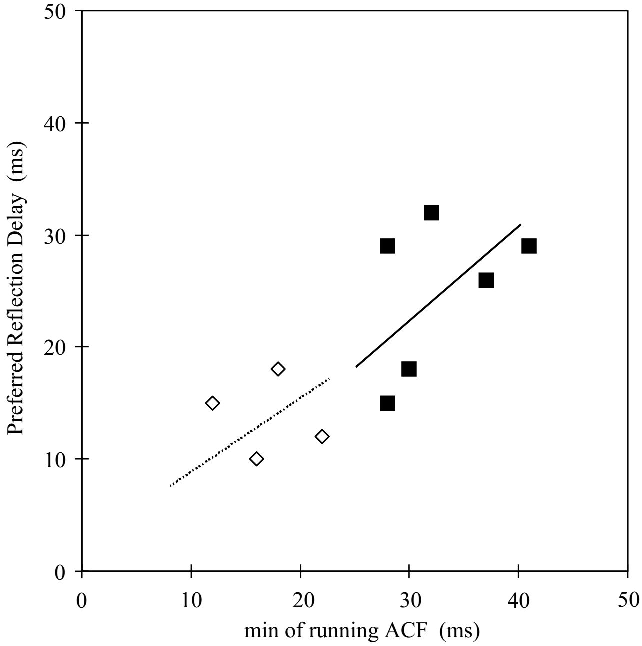

Figure 5. Relationship between singer preferred reflection time delays (ms) and measured minima of effective duration of the running ACF. Data are shown with the symbol (◇) for lyric singing, and are shown as (■) for melisma singing.

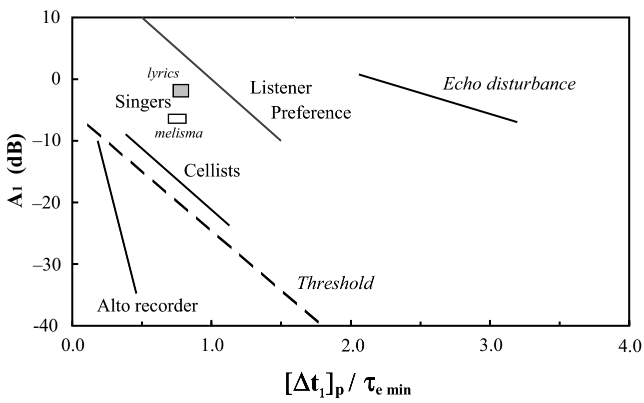

Figure 6. Singer's preferred delay time, while performing, for sound fields with a single reflection. The single reflection is delayed by Δt_1. The delay time is normalized by the effective duration of the ACF τ_e , of the performed music or speech. Singer results were obtained over a limited range of $\Delta t_1/\tau_e$ and are therefore limited to a small range, in comparison with results for cellists, alto recorder players, and listeners.

delayed reflections in a manner more like an instrumentalist, with the instrument close to the ear, as with a flute or violin. The preference for time delays therefore should match well with singers when an instrumentalist's playing is dominated by high-frequency energy bursts (pizzicato, for example) and deviate from the singer's time delay preference when the bone-conducted content of the singing dominates. Further study of sound field preference while varying the spectral content of music for instrumentalists and singers is needed to determine if this is the case.

5. SUMMARY

Subjective preference for delayed reflections was shown to increase with melisma style of singing, versus singing lyrics (text). As anticipated, the linear trend of increasing time delays with melisma singing can be explained by comparison with each singer's minimum of the running ACF of their own voice signal.

On average, no increase in preferred delay time was observed by conducting sound field recognition training of the singers. However, the sharpness of the singers preference evaluation curve increased significantly with training, for individuals and for the average of singer responses. Variance of scale values also improved (decreased). A slight (15%) increase in the average scale value peak at preferred time delays was observed as well, following singer training.

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