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Changes in Tone Production as a Function of Focus of Attention in Untrained Singers

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Abstract

The benefit of an external focus of attention in motor skill learning has been documented in a variety of studies conducted over the past 15 years, but few investigations have examined this benefit in music contexts. We tested differences in tone quality among different focus of attention conditions performed by 30 novice singers. Each participant sang a 3-note pattern a cappella on a continuous [a] vowel under five conditions, each focusing the singer's attention on a different target: (a) singing while feeling the vibrations on the throat with the palm of one hand, (b) singing with the index and middle fingers placed on either side of the nose, directing the sound to the fingertips, (c) directing the sound to a microphone; (d) directing the sound to a point on the wall across the room; and (e) a baseline condition in which we gave no focus instructions.

All participants started with the baseline condition and then performed the remaining conditions in a partially counterbalanced order (Latin square) assigned randomly to each participant. To inhibit memory from one condition to the next, participants read aloud a short passage from a children's book between conditions (approximately one minute for each reading). We analyzed a 2-second excerpt from the last tone of each trial in each condition (15 trials per participant) using the acoustical software Praat.

We found a significant effect of condition on vocal quality, as determined by the ratings of expert listeners, χ^2 (16, N = 150) = 76.33, $p < 0.0001$, Cramer's V = 0.36. As expected, not all participants were affected by conditions to an equal extent. Individual singers' best tone qualities were observed in the mask and microphone conditions more frequently than in the other four conditions.

Keywords

focus of attention, singing tone production, motor skill learning, vocal pedagogy

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Learning to sing beautifully requires careful attention to posture, physical movement, breath, and sound. One role of the teacher is to focus learners' attention optimally among the many different sensory dimensions of singing. Teaching singing is difficult because the physical manipulations that change the tone quality of the voice are often outside the conscious control of the learner, requiring the instructor to connect physical sensation to the perceived sound.

The singer's perception of his or her own sound is different than the perception of the audience or teacher. For example, a beautiful tone to an audience may sound overly nasal to the singer. This phenomenon occurs because the sound exits at the mouth opening, in front of the ears. Much of the self-sound that reaches the ears of the singer has reflected off various environmental surfaces resulting in the dampening and amplification of different frequencies. In addition, vibrations conducted through the bones of the head and face affect the singer's perception of the sound. Therefore, singers must connect their teachers' positive feedback about their tone quality to the physical sensations of breath, mouth opening, and vowel.

During the past decade and a half, researchers have studied how changes in focus of attention affect performance in motor skill learning, but few studies have examined attentional focus in music learning. Various studies of motor skill performance have demonstrated that an external focus of attention is beneficial to performance in balance tasks (McNevin, Shea, & Wulf, 2003; McNevin & Wulf, 2002; Shea & Wulf, 1999), dart throwing (Lohse, Sherwood, & Healy, 2010), golf (Poolton, Maxwell, Masters, & Raab, 2006; Wulf, Lauterbach, & Toole, 1999), volleyball (Wulf, McConnel, Gartner, & Schwarz, 2002), slalom snow skiing (Wulf, Höß, & Prinz, 1998), baseball (Castaneda & Gray, 2007), and jumping (Wulf, Dufek, Lozano, & Pettigrew, 2010). These experiments showed that well-learned physical movements were inhibited when performers focused on the movements of their bodies rather than on the effects their movements produced. Additionally, integrated electromyography (iEMG) evidence revealed that externally-focused performers made smaller and more frequent muscle movements during the execution of assigned tasks than did internally-focused performers (Lohse et al., 2010; McNevin, Shea, & Wulf, 2003; McNevin & Wulf, 2002; Wulf et al., 2010; Wulf, McNevin, & Shea, 2001). Internal focus resulted in larger movement amplitude and slower frequency, suggesting that internal focus hindered the efficiency of movements that had previously been automatized.

The benefits of an external focus of attention were also observed in one of the few focus of attention studies in music (Duke, Cash, & Allen, 2011). Participants performing a short piano sequence focused on the movement of their fingers (internal), the keys (near external), the hammers hitting the strings (distal external), or the sound (far distal external). Duke et al. found that external focus of attention increased evenness of timing for non-pianists. In addition, as participants focused increasingly farther away from the body, the evenness increased. Focus on the sound rather than movement of the fingers created the greatest evenness in timing.

In the present study we sought to examine vocal tone quality under different focus of attention conditions. We asked whether focusing on (i.e., thinking about) internal and external loci would produce differences in untrained singers' (N = 30) tone production in a limited vocalization task. We compared several focus conditions that we derived from informal observations of vocal instruction in individual lessons and choir rehearsals. We assessed tone quality in terms of acoustical properties and in terms of expert listeners' evaluations.

Method

Singer Participants

Participants were 30 untrained singers (8 males, 22 females) between the ages of 18 and 25 years (*Mdn* age = 20 years) who were enrolled in a guitar/recorder/percussion performance class for non-music majors at The University of Texas at Austin. Students received a completion credit for participation in a music research study required for the class. Participants signed up for a convenient 15-minute time period during the final two weeks of the semester, between the hours of 8:30 A.M. and 3:30 P.M.

Two participants had received no formal musical training (voice or instrumental) prior to their enrollment in the class. Of the remaining 28 participants, 12 were instrumentalists who had never participated in choir or taken voice lessons, 4 had singing experience but no instrumental training, and 12 had both singing and instrumental experience. Of the participants with singing experience, 14 had less than two years experience singing in a choir, and most only in elementary school (*n* = 9). Two participants had sung in choir in both middle school and high school, one of them with 2 years of private voice lessons in high school. No students were taking private voice lessons at the time of the study.

Ten of the 24 participants who played an instrument had studied more than one instrument. Sixteen participants had studied piano and six had studied violin. Formal training time (class or private) ranged from 3 months to 18 years, with a median duration of 5 years of instruction. No students were taking private instrumental lessons at the time of the study.

Procedures

Recording took place in a quiet classroom using a Sony PCM-D50 digital audio recorder (96kHz/24 bit) and its on-board microphone. The recorder was placed on a tripod 18 inches in front of the participant at the height of the participant's mouth. Using the recorder's recommended specifications for solo singing, the recorder was placed face up with the unidirectional microphones facing inward forming a 90-degree angle toward the singers mouth with the limiter and low cut filter switches set in the off position. Because we used a within-subject design, we set recording levels specifically to each individual while he or she sang the 3-note pattern repeatedly prior to recording. We adjusted the recording volume so that the peak level did not indicate distortion; the signal was centered around -24 dB on the onboard VU meter of the device. Recording levels were between 4.5 and 6 on the recorder for all participants depending upon on the volume of their voices. Recording was continuous throughout each participant's session so that the gain (recording level) remained constant across all conditions. We also made a separate video recording to document the procedures. Most students acknowledged being somewhat nervous singing alone, but were comfortable completing the task because they had sung aloud regularly during class meetings.

After a brief orientation to the singing task, each participant sang the pitches Eb, F, Eb a cappella using a continuous [α] vowel in the octave appropriate for their vocal ranges. They performed the first two pitches as quarter notes at a tempo of approximately 120 beats per minute. Participants sustained the final tone for approximately 8 beats. Participants listened to the three-note pattern played in tempo on the piano and then echoed the pattern three times in a row (no piano between the three trials) under each of five different conditions. Four females and one male were unable to sing these pitches consistently in tune. Therefore we moved the females down a major or minor third and the male up a major third to a more suitable and successful ranges. We directed participants to stand in a tall, relaxed position, to sing facing the microphone, and to avoid extraneous movement.

Instructions for each condition directed singers to focus their attention on (i.e., to think about) a different target: (a) sing while feeling the vibrations on the throat with either hand; (b) sing with the index and middle fingers placed on either side of the nose along the zygomatic arch, which we referred to as the mask (making sure that all parts of the hand were behind the plane of the mouth opening), while thinking about directing the sound to the fingers; (c) sing while thinking about directing the sound to a microphone 18 inches in front of the singer; (d) sing while thinking about directing the sound toward a point on the wall, 4 inches in diameter, drawn on the white board approximately 18 feet across the room and 6 feet above the floor; and (e) a baseline condition in which no focus instructions were given. It is important to emphasize that these focus of attention instructions did not prompt any gestures or other movement on the part of the singers, but only identified a target on which to focus their attention.

All participants started with the baseline condition (three trials) and then performed three trials of the remaining conditions in a partially counterbalanced order (Latin square), with order assigned randomly to each participant. To inhibit memory from one condition to the next, participants read aloud a short passage from a children's book (approximately one minute for each reading) between conditions.

Because we were interested primarily in the potential effects of the focus conditions on tone production, we analyzed only the final pitch of each 3-note trial, thus limiting variations in intonation, tone onset, and movement between pitches, which are often problematic in untrained singers. We analyzed a 2-second excerpt from the last pitch of each trial in each condition (15 WAV files for each singer, 450 total files) using the acoustical software Praat (Boersma & Weenink, 2011). Through visual inspection of the pitch line image we marked the start point of the excerpted tone. Because the onset of the final tone was not always clear in the visual image, we listened to the recordings through Bose QuietComfort2 Acoustic Noise Cancelling Headphones to make sure the beginning of the 2-second sample had settled on the final pitch. If not, we moved the cursor to the right in increments of 50 milliseconds (ms) until the sound had settled; in no trial did we move the cursor more than 250 ms total. Once we had a clean starting point for the final pitch, we selected an endpoint 2 seconds later. We then saved the recording as a WAV file.

Listener Participants

Three expert listeners evaluated the recordings independently in a quiet, distraction-free room. WAV files were opened on a 15-inch MacBook Pro (Mac OS X version 10.7.5, 2.2Ghz Intel Core i7 Processor) running QuickTime software to play the WAV files. All expert listeners used the same pair of Bose QuietComfort2 Acoustic Noise Cancelling Headphones (the level switch in the headphones was set to high for all listeners) connected to the computer's microphone jack. Expert listeners used the computer volume controls to adjust the playback volume as needed. We invited listeners to play each recording as many times as needed to complete the assigned listening task. Listeners were blind to the performance condition of each WAV file.

We selected for our analyses the most in-tune and steadiest (air flow and intensity) 2-second example from the three trials that each participant performed in each condition. The first author (20 years singing and teaching experience) selected these examples. To assess reliability of these selections, a second expert listener (a PhD student with 10 years of singing and teaching experience) independently evaluated 20% of the participants' performances

(150 sets of three trials, randomly selected); reliability was .80.

From those five representative examples (1 per condition), the primary author ranked the performances from 1-5 (1 = best) for each participant in terms of overall tone quality, considering together the noise content, ring/resonance, evenness/consistency, and relaxed/free tone. Participant performances among the five conditions were in many cases highly similar. Because of this factor, a different independent observer (DMA voice performance major with 30 years teaching and singing experience) listened and selected only the best and worst examples from among the five conditions for 16 of the 30 participants. Reliability with the initial ratings was .88 for the best sounding conditions and .81 for the worst sounding conditions. Again, listeners were blind to the experimental conditions.

We also examined the acoustic data of every participant's best trial of each condition using Praat acoustical software version 5.2.26 (Boersma & Weenink, 2011). We were interested in exploring possible connections between the tone quality as judged by expert listeners and the acoustical measurements. We examined the mean frequency (Hz), formant frequencies, and harmonic-to-noise ratio for each trial.

Results

Using a chi-square goodness of fit test, we found a significant effect of condition on vocal quality, χ^2 (16, N = 150) = 76.33, p < 0.0001, Cramer's V = 0.36, as determined by the expert listeners' ratings of overall tone quality. As expected, not all participants were affected by conditions to an equal extent. Recall that all participants sang the baseline condition (no focus instructions) first and sang the remaining four conditions in a partially counterbalanced design. Among the four focus conditions we found no significant effect of presentation order, χ^2 (3, N = 30) = 5.47, p = 0.14.

Individual singers' best tone qualities occurred more frequently in the mask and microphone conditions (23 participants) than in the other four conditions. Of the remaining seven participants, four of them performed their best tone in the point condition, and three produced their best tone in the throat condition. No participant's baseline was ranked best in overall tone quality, and 18 participants' baseline performances (singing with no focus of attention instruction) were rated lowest (5th). Although singing to a point was ranked the best condition with only four participants, it was never ranked as the worst. See Table 1.

Table 1. *Crosstabulation of Rank by Condition*

		Internal		External	
Rank	Baseline	Throat	Mask	Mic	Point
1st-best	0	3	12	11	4
2nd	0	5	4	8	13
3rd	4	7	4	7	8
4th	8	10	4	3	5
5th-worst	18	5	6	1	0

In addition, we examined the acoustic data for harmonic-to noise ratio and formant frequencies, using one-way repeated measures ANOVAs. Harmonic-to-noise ratio is the ratio of the amplitudes of periodic components to aperiodic components in a complex tone. We found no significant effect of condition on harmonic-to-noise ratio, $F(4,116) = .71$ $p = .59$. The highest harmonic-to-noise ratio (tone quality most free from noise and breath) among the five conditions was present in only 11 of the participants' best-ranked conditions (19 had the highest harmonic-to-noise ratio in a condition that was not ranked as their best overall tone quality).

We heard a difference in ring/resonance between many singers' best- and worst-ranked conditions. More ring or resonance can occur through movements of the tongue, jaw, and larynx that increase amplitude in the higher partials between 2 and 4 KHz (Sundberg, 1974). We identified the formant frequencies for formants 1-5 (F1, F2, F3, F4, F5) using Praat. Some of the formants moved up or down slightly between conditions, but not in any consistent pattern among participants. In this experiment, all participants sang every trial on an [ɑ] vowel. Not surprisingly, the formants determining the vowel sound (F1 and F2) remained fairly consistent among trials and conditions for each participant. We found that the magnitude of difference between F3 and F4 varied between conditions for participants whose tone quality changed, though not consistently so. A one-way repeated measures ANOVA revealed no statistical difference in the distances between F3 and F4 among conditions, $F(4, 116) = .67$, $p = .61$). Visual inspection of the Praat formant data revealed differences in the consistency of the F3 and F4 formant frequencies between the best and worst sounds for participants whose tone quality changed (Figure 1).

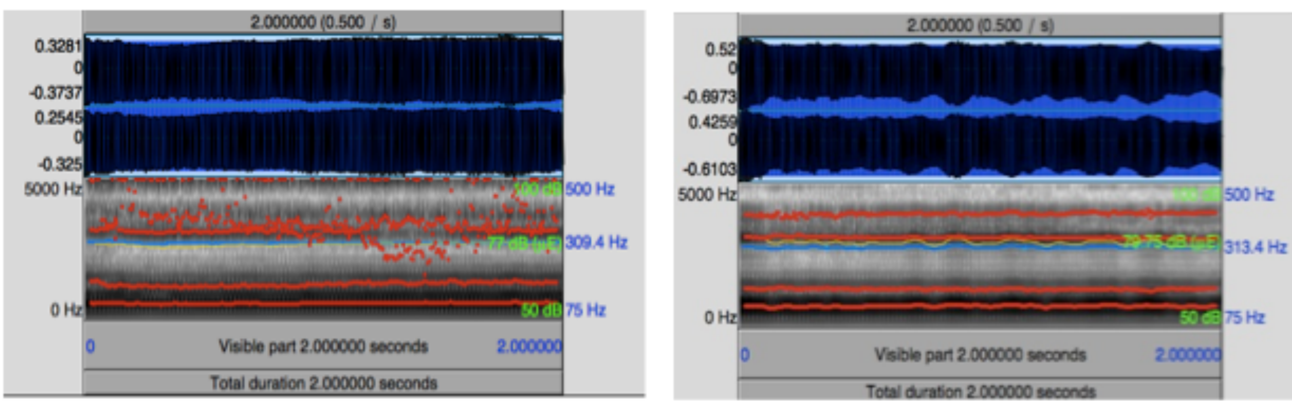

Figure 1. Participant D's worst-ranked condition (left) and best-ranked condition (right)

In Figure 1, the bottom two red lines represent F1 and F2. The [ɑ] vowel remains fairly consistent between the two conditions. The top two red lines represent F3 and F4 and are more clearly evident in the best condition.

Discussion

It is widely accepted that an external focus of attention is often beneficial to motor skill learning, a phenomenon previously demonstrated in a variety of motor tasks for novice and expert learners (for a review, see Wulf, 2013). Effective singing teachers typically focus learners' attention on different aspects of physical sensation, sound, and emotional content to improve their students' tone quality and technique, but the effects of these procedures have not been studied systematically.

In the current experiment we found a significant effect of focus condition on tone quality. Expert listeners perceived this effect, though there were few consistent differences among conditions with regard to acoustical measurements of the tones produced. The internal focus conditions included (a) singing while feeling the vibrations with one hand on the throat and (b) singing while directing the sound to the fingertips along the zygomatic arch (mask). The throat condition may be considered more of an internal focus than the mask condition, in that singers could more readily feel the vibrations in their throat as they sang. Both the throat and mask conditions produced tactile sensory feedback, which may have affected the unconscious movement of the articulators. Yet, only the mask condition seemed to affect the resonance quality in a way that improved tone quality, an affect we observed for 12 of the 30 participants.

Directing the sound to the microphone tended to improve perceived tone quality over the baseline condition. Eleven of 30 participants' microphone condition performances were ranked as the best tone quality; only one participant's microphone condition ranked as the worst tone quality. Focusing on the point on the wall improved perceived tone quality as well, with 17 of the 30 participants producing their best or second best tone in this condition.

The results of the current study cannot be generalized to the larger population of novice singers, of course. All participants were part of a music performance class for non-music majors. They had nearly completed an entire semester singing as a class as they learned guitar, recorder, and percussion. Although the class focused on instrumental performance, not singing, these students may have had more confidence than the general population of untrained singers in this age group. It would be interesting to replicate this study with singers of varied skill levels and experience to determine if the same conditions would have similar effects.

Although we used the same recording and playback equipment throughout the experiment, tone quality is inevitably affected by the characteristics of the devices used. It would seem advisable in future research of this type to devote additional attention to carefully calibrating both the recording and playback equipment in ways that ensure to the greatest extent possible that the reproduction of the recorded sound matches the sound of live performance.

Teaching novice singers to produce a clear resonant tone that carries through a performance hall is often very challenging. Young or inexperienced singers may lack the confidence to sing out and their reticence may further limit their ability to produce a beautiful, resonant tone every time they sing. These findings suggest that directing singers to focus their attention on sending their sound to a distal point in the room or to the fingertips placed in the mask area may improve their tone quality. Both of these techniques have long been used in choral rehearsals and in the voice studio, of course, but this is the first study to systematically assess the effects of these strategies in novice singers.

We found a significant effect of condition on the tone quality evaluations by expert listeners. Most intriguing is how quickly and easily tone quality improved for many participants through simply varying their focus of attention. It seems important to determine whether a more distal focus actually increases efficiency of motor control in the vocal mechanism and to define more precisely the changes that come about as a result of changes in attentional focus. Research that connects effective pedagogical strategies to systematic research in motor skill learning will provide greater insight into the process of music learning and, potentially, improvement in tone quality for singers. ❂ IJRCS

Institutional Review Board Approval and Compliance
The authors obtained approval from an appropriate Institutional Review Board to conduct this research in a manner that assured the ethical treatment of participants and the confidentiality of participant information.

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