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Focus of Attention Affects Singers' Tone Production

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Focus of Attention Affects Singers' Tone Production

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Dedication

To my beautiful family, Lloyd, Blake, and Katy

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Focus of Attention Affects Singers' Tone Production

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It is now well understood that skilled motor behavior is affected by performers' focus of attention. This effect has been demonstrated in numerous and varied motor tasks, from golf-putting to piano playing.

I conducted two experiments with college-aged singers to test the extent to which trained singers' vocal tone is affected by their focus of attention while singing. In Experiment 1 (N = 11) participants sang a 3-note sequence and an excerpt of a well-learned melody under six different focus conditions. In Experiment 2 (N = 20) participants sang 3-note sequences in both high and low vocal registers, a well-learned melody, and an unpracticed, familiar melody under seven different focus conditions.

Focus of attention affected participants' vocal tone in all of the singing tasks. The results of the two experiments are consistent with the results of related investigations of attentional focus in motor skill performance. Singers' tone was rated most highly and described most positively by expert listeners when singers' focused their attention on external rather than internal targets. Focusing on distal targets (i.e., targets that were far removed from the vocal mechanism) in particular was associated with high ratings and positive descriptions of vocal tone.

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CHAPTER 1: INTRODUCTION

For many generations, choir directors and private voice instructors have employed an array of strategies to help singers attend to breath, posture, the vocal mechanism, emotional expression, and sound to improve singers' tone production. Learning to sing beautifully is a time-consuming process that requires learners to strategically switch their focus of attention among the physical, auditory, and emotional aspects of singing. In this effort, teachers and conductors work to refine singing through the use of analogies, movement, and imagery, in addition to giving direct instructions about the vocal mechanism. Many of the well-worn strategies that have become part of teachers' repertoires have developed over time through intuition and trial and error (Nair, 1999, p. 1), though few have been subjected to systematic examination.

Major challenges in refining singing stem from the fact that the mechanisms of tone production are within the body and thus are not directly observable, and that many of the parts of the mechanism are not under the singers' direct volitional control. In working to unify the sounds of sung vowels across register changes, for example, teachers may ask students to raise and lower the larynx, or change the position of the tongue and other articulators to achieve an optimum sound on each vowel. Although movements of the tongue are controllable in relation to shaping vowels, movement of the larynx is not an aspect of motor behavior that most individuals experience with conscious awareness. When singers attempt to exert control over aspects of the vocal mechanism in ways that are unfamiliar or difficult to monitor directly, unwanted muscular tension may result, degrading vocal tone quality.

In order for singers to develop effective habits of singing, they must come to associate specific auditory and kinesthetic outcomes with specific physical, auditory, and musical intentions. This is particularly challenging in that many of the physical movements that are ongoing during beautiful singing are too rapid and too subtle to be controlled consciously by the singer. In fact, even excellent singers are often entirely unaware of these precise movements. Motor control in this regard is developed through repetition, during which singers begin to connect auditory and kinesthetic feedback in ways that gradually modify the neuromuscular control required to produce a beautiful tone (Nair, 1999, pp. 13–14).

Directed skill learning is often approached through a focus on correct body positioning and movement. This type of focus on what the learner is doing is typical in many activities, including athletic skills, driving, sewing, table games, and a host of other human activities, including singing. These approaches focus the attention of learners on how their bodies are positioned and how they are moving. Of course, this seems entirely appropriate, since learning to perform a new and perhaps unfamiliar task requires preliminary attention to the parts of the body that affect the performance of the task. But it has become clear that skilled movement is often guided by attention directed to the effects that the body's movements are intended to create.

A great deal of systematic research in skill learning shows that focusing on the effects of movements (an external focus of attention) is often more advantageous in terms of learning and performance than is focusing on movements of the body (internal focus) (Wulf, 2013). Golfers who focus on the swing of the putter or the trajectory of the ball, volleyball players who focus on shifting their weight to the target during a volleyball serve, and guitarists who focus on pressing the strings more firmly against the neck of the guitar, all exemplify external focuses of attention. Their attention is directed to movement goals rather than to the movements themselves.

The most widely accepted theory explaining this phenomenon is the constrained action hypothesis (Wulf, McNevin, & Shea, 2001). This hypothesis suggests that focusing on well-learned and highly automated movements interferes with learned automaticity, bringing to conscious attention aspects of movement that have been under implicit control, whereas focusing on the effects of the movement recruits these automatized movement structures as they are applied in skilled behavior.

Studies using electromyography (EMG) to measure muscle activations provide evidence that the less thought and attention given to the movement of the body, the better the body performs automatized functions (as indicated by lower EMG activity). In general, the movements of muscles under implicit control tend to be smaller in amplitude and higher in frequency than are the same movements when the performer directs conscious attention to the body (Lohse, Sherwood, & Healy, 2010, 2011; Marchant, Greig, & Scott, 2009; McNevin & Wulf, 2002; Vance, Wulf, Töllner, McNevin, & Mercer, 2004; Wulf, Dufek, Lozano, & Pettigrew, 2010; Wulf, Mercer, McNevin, & Guadagnoli, 2004; Zachry, Wulf, Mercer, & Bezodis, 2005). These measurements are indicative of more efficient motor control and movement. Seemingly small differences in the language of task instructions, shifting focus away from the body and toward movement goals, affect learning and performance across a wide range of tasks.

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.

Phonation and breath are both highly automatized actions applied in speech and breathing, but are approached differently for classical singing. When speaking, a person gives very little thought to inhalation and control of the expulsion of air, or to adjusting the mouth shape to form vowels. Teaching someone to sing requires the teacher to systematically help the learner reshape and adjust these highly automatic actions to a new form of conscious control.

Purpose of the study and research questions

The quality of vocal tone production is a fundamental element of beautiful singing. Producing resonant, ringing vocal tones is a major challenge for aspiring singers at all levels of experience and expertise. Teaching others to produce a beautiful vocal tone is complicated by the fact that much of the machinery of tone production is out of the teacher's view, and even singers themselves are often not aware of the precise ways in which their muscles are engaged as they sing. Thus, vocal pedagogy often relies on metaphors, analogies, physical gestures, and other strategies to shape the production of vocal tone. Yet, these approaches have seldom been subjected to systematic investigation.

The projects in this dissertation were designed to identify the changes in vocal tone production that occur when singers are directed to focus their attention on various aspects of tone production and on external targets. The procedures examined in these investigations were determined following a review of the literature in vocal pedagogy and a thorough examination of the literature in the fields of kinesiology, psychology, and music pertaining to focus of attention and skill learning.

The two investigations included in this report addressed the following question: In what ways and to what extent is the tone quality of trained singers affected by their focus of attention while singing?

CHAPTER 2: REVIEW OF LITERATURE

The following review of literature is organized around three topics that are germane to the experiments in the dissertation: research in motor skill learning, vocal exercises and techniques found in the literature on vocal pedagogy, and the mechanics of the voice and experimental research related to acoustic analysis.

In the first section I describe research on the effects of focus of attention in learning and retention as they relate to age, task, experience, task difficulty, focus distance from the source of movement, feedback, and instructions. In the second section I describe common vocal exercises and techniques that pertain to posture, breath management, tone, vowels, and resonance in singing. I also connect these exercises to the research related to focus of attention. In the final section I review the literature describing the vocal mechanism, vocal acoustics, and acoustic analysis of singing. I describe research that uses acoustic measures of the voice to examine different styles of singing. I also review several assessment tools that measure expert listeners' perceptions of the classical singing voice in a variety of tasks.

FOCUS OF ATTENTION

The acquisition of music performance skills requires learners to attend to the multiple aspects of physical movement that are involved in tone production and to associate various movements with the sounds they produce. The most advantageous places to focus attention often vary as a learner progresses from the beginning stages of skill learning to more advance levels of performance. Teaching learners to sing requires strategically focusing their attention among the many variables that influence performance.

A good deal of instruction intended to develop motor skills focuses learners' attention on correct body positioning and movement, and there are places in the learning process where such focus is entirely appropriate. But recent research has shown that focusing attention away from the physical motions of the body and toward the effects the movements bring about often leads to more efficient skill development and better performance than does focusing attention on movements of the body. The results from numerous studies across a variety of tasks illustrate that in novice and in experienced performers alike, performance is negatively affected by an internal focus of attention (i.e., attention to movements of the body) and that an external focus of attention (i.e., attention to the effects that movements produce) often results in superior performance (Wu, Porter, & Brown, 2012; Wulf, Höß, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999; Wulf et al., 2001; Wulf & Prinz, 2001). Similar results were found for the effects of attentional focus in music learning (Atkins & Duke, 2013; Duke, Cash, & Allen, 2011).

One of the first experiments to compare internal and external focuses of attention in motor skill learning was conducted using a slalom ski machine (Wulf et al., 1998). The results showed that to create a large-amplitude movement quickly, applying force to the platform by focusing on the outermost wheel (external) was more effective than applying force to the platform by focusing on the outermost foot (internal). Participants assigned to one of three groups (internal focus, external focus, or no focus instructions) practiced moving a ski simulator board with as much amplitude and as quickly as possible. The externally focused group performed the best throughout both days of training and on the retention test. The participants who focused on their feet performed more poorly during practice and on the retention test than did those given no instructions.

These results were replicated in a second experiment testing the differences in performances between an external and internal focus of attention in a balance task (Wulf et al., 1998). Participants were asked to look straight ahead as they kept the platform of the stabilometer level. The internal focus of attention group focused on keeping their feet level. The external focus of attention group focused on keeping markers attached to the platform (immediately in front of their feet) level. Although the difference in distance between the markers (external) and feet (internal) was minimal, the external focus group performed better throughout training and on a retention test than did the internal focus group.

Similar results have been found in a golf pitch shot when participants focused on the motion of the golf club rather than on the motion of their arms (Wulf et al., 1999), in a balance task when participants focused on markers affixed to the balance platform rather than on their feet (Wulf et al., 2001), and in several experiments using a jumping task when participants focused on reaching the target rung (external) compared to their fingers touching the rung (internal) (Wulf, Tollner, & Shea, 2007; Wulf, Zachry, Granados, & Dufek, 2007).

Explanatory hypotheses

Several theories have been proposed to explain the effect of attentional focus on motor control: the constrained-action hypothesis (Wulf et al., 2001), and explicit monitoring theories including conscious processing (Beilock, Carr, MacMahon, & Starkes, 2002; Masters, 1992) and reinvestment theory (Masters & Maxwell, 2008). According to the explicit monitoring hypotheses poor performance in a motor skill is explained as an overload on working memory caused by engaging in unnecessary cognitive control of a highly automatized movement. This conscious control may result in a breakdown of performance, especially under pressure (Baumeister, 1984; Beilock et al., 2002).

Beilock et al. (2002, Experiment 2) found that expert soccer players dribbled more slowly with their dominant foot when they had to report aloud at the sound of a tone which side of the foot made contact with the ball (skill-focus) than when they dribbled and were directed to count auditory tones (counting tones) or dribbled with no focus of attention instructions. But when dribbling with their non-dominant foot, expert soccer players showed improved performance under the skill-focus condition compared to the counting condition.

Poolton et al. (2006) examined the putting performance of novice golfers who focused on either the movement of their hands (internal focus) or the movement of the putter (external focus). The authors found no difference in performance between groups, but the external group performed better than the internal group when they putted while also performing a secondary task (counting tones). When interviewed, the participants in both groups reported that, in addition to the focus of attention instructions, they adopted their own focus in an attempt to improve the putt. The authors speculated that the additional focus may have resulted in an overload on attention that disrupted automaticity. To further explore this hypothesis, Poolton et al. conducted a second experiment in which two groups of novices were given either six internal instructions or six external instructions when learning to putt. Both groups' putting performance suffered during secondary task load. The results from the second experiment suggest that explicit rule buildup, whether internal or external, could be a cause of performance breakdown.

Wulf and McNevin designed a study to test further the conscious processing theory. If distracting learners from focusing attention on their movements enhances learning (Masters, 1992), focusing on a non-related secondary task should lead to performance outcomes similar to those obtained when focusing on the effects of movement. Wulf and McNevin (2003) found this was not the case in a balance task. Instead, performing a secondary task (repeating a story aloud) while attempting to keep the platform level resulted in poorer performance in practice and in a retention test (without the secondary task). Adopting an external focus of attention was the only focus of attention condition resulting in learning benefits.

Wulf and McNevin (2003) used a different task, different protocol, and a more difficult secondary task than had the authors of previous studies supporting conscious processing, and demonstrated that simply distracting learners from focusing on their movements did not result in enhanced performance but focusing on the effects of movement often does.

Explicit monitoring theories suggest that novices perform better using skill-related knowledge to perform a new task, an effect that has been demonstrated in golf tasks (Beilock et al., 2002 exp. 1; Perkins-Ceccato, Passmore, & Lee, 2003; Poolton et al., 2006), baseball batting (Castaneda & Gray, 2007), and soccer dribbling (Beilock et al., 2002 exp 2; Beilock & Carr, 2001; Ford, Hodges, & Williams, 2005). Although a benefit of external focus was found among skilled performers, no differences between the external and internal conditions were found in the performance of novices and other less skilled participants.

Another well-documented hypothesis is the constrained-action hypothesis, which asserts that focus on the body negatively affects the execution of well-learned, automated movements, whereas focus away from the body recruits well-learned movements that are implicitly controlled. To date, more than 80 studies have demonstrated an advantage of adopting an external focus of attention for both novices and skilled learners in a variety of tasks (Wulf, 2013). Studies using electromyography (EMG) give support to the constrained action hypothesis by providing evidence that muscles work more efficiently (lower amplitude and higher frequency movements) when participants adopt an external focus compared to an internal focus.

Wulf and colleagues (2001) found that participants focusing externally while balancing on a stabilometer showed higher movement frequency, faster reaction times to a secondary task, and less balance error than did participants who focused internally. Other studies using EMG also showed greater efficiency of muscle movement in addition to improved performance in external focus groups compared to internal focus groups in a vertical jump task (Wulf, Dufek, et al., 2010), a postural stability test (McNevin & Wulf, 2002; Wulf et al., 2004), and a dart throwing task (Lohse et al., 2010). These same results were found when participants lifting a curl bar focused on the movement of the curl bar versus the movement of their arms (Marchant et al., 2008, 2009; Vance, Wulf, et al., 2004) and when participants focused on the basket rather than their wrist motion when shooting free throws (Zachry et al., 2005).

In an isometric muscle task (platform press with a stationary leg), an external focus of attention resulted in decreased movement in the antagonistic muscle compared to an internal focus of attention (Lohse et al., 2011). The higher frequencies and smaller amplitudes of muscle movement in the external groups compared to internal groups are interpreted as more efficient neuromuscular activity; the less thought given to the movement, the better the body performs automatic functions.

External focus of attention instructions also improved muscle endurance in three weight lifting tasks (Marchant, Greig, Bullough, & Hitchen, 2011). Participants performed repetitions to failure on a machine-assisted bench press task, a free-weight bench press task, and a free-weight squat task under a control condition, an internal condition (focus on the arms or legs), and an external condition (focus on the equipment/bar). In the machine-assisted task participants performed more repetitions in the external and control conditions, and fewer repetitions under the internal condition. In both free-weight tasks, participants performed more repetitions under an external focus of attention compared to both the control and internal focus of attention instructions. In all of the studies mentioned above, the participants adopting an external focus of attention performed better on the target goal and moved more efficiently compared to participants who used an internal focus of attention.

Experience level

A wealth of research clearly demonstrates the advantage of an external focus of attention for experienced performers (Perkins-Ceccato et al., 2003; Stoate & Wulf, 2011; Wulf, McConnel, Gärtner, & Schwarz, 2002; Wulf & Su, 2007; Zachry et al., 2005) and novice performers (Southard, 2011; Wulf et al., 1999, 2002; Wulf & Su, 2007) in varying tasks. However, in some studies, novices performed similarly whether using an internal or external focus of attention. This was true in a golf-putting task (Perkins-Ceccato et al., 2003; Poolton et al., 2006), a baseball batting task (Castaneda & Gray, 2007), and a soccer dribbling task (Beilock & Carr, 2001; Ford et al., 2005). These studies reported no differences in novice learners between focusing on body movement (internal) and focusing on the effects of movement (external). When a secondary task was added to the target skill, performance deteriorated more in the internal focus condition compared to the external focus condition. Depending upon the difficulty of the skill, novices may benefit from an internal focus of attention. Wulf (2013) has speculated that when novices receive no instructions about focusing their attention, they in fact focus on the movements of their bodies, whereas experts, when given no focus instructions, focus on their movements' effects.

A few studies have been designed to examine the effect of attentional focus in highly skilled experts performing a variety of tasks, and have produced inconsistent results. Researchers were specifically interested in the effects of an external focus compared to the effects of a control condition in which performers were left to adopt their own focus. Wulf and Su (2007) found that professional golfers performed better in an external focus condition (movement of the club) than in an internal condition (movement of arms) and a condition where the performer was asked to adopt his or her typical focus of attention. In another study, expert swimmers performed better under an external focus (pushing the water back) and a control condition (no specified focus) than when they performed under an internal condition (pulling your hands back). Questionnaire results revealed that most of the swimmers focused externally under the control condition when no specific focus instructions were given (Stoate & Wulf, 2011).

Unlike the participants in the experiments described above, professional acrobats balanced better on an inflatable disk when adopting their own focus of attention than when focusing on an external target (platform) or an internal target (feet) (Wulf, 2008). This is one of the few studies in which participants performed worse when they adopted an external focus of attention compared to a control condition.

Task difficulty

Much of the attentional focus research has been conducted using tasks with a high degree of difficulty, especially for novice learners. In a review of focus of attention studies, Wulf and Prinz (2001) noticed the differing outcomes between the control and internal conditions on a variety of tasks. They hypothesized that if the experimental task is too easy, there will be no observable differences in performance outcomes between internal and external focus of attention conditions.

To test this conjecture, Wulf and colleagues designed a balance task to compare internal and external focus of attention instructions while varying the degree of difficulty (Wulf, Tollner, et al., 2007). No benefits of an external focus of attention were found when participants balanced on a solid surface (control instruction was to stand still; the internal instruction was to exert equal pressure on the feet; and the external instruction was to exert equal pressure on the rectangle on which the participant was standing). When balancing on a foam surface (slightly more difficult task), balance was better in the external condition than in the control condition. There were no differences between the internal condition and the external or between the internal condition and the control condition. When participants balanced on a rubber inflatable disk (high degree of difficulty), balance was better in the external condition than in the internal and control conditions.

Landers, Wulf, Wallmann, and Guadagnoli (2005) found that in patients with Parkinson's disease the benefits of an external focus of attention were only found in the most difficult of three balance tasks tested. Similarly, as task difficulty increased in a series of weight lifting tasks, so did the benefit of an external focus compared to both an internal focus and a control condition with no focus instruction (Marchant et al., 2011). The findings suggest that in these types of tasks, the more complex or difficult the motor skill is for the learner, the more pronounced the benefit of an external focus of attention.

Zentgraf and colleagues (2009) found a difference in neural activations between an external and internal focus of attention in a 16-element key-press task. Participants, assigned to either an external (focus on the keys) or internal group (focus on the fingers), learned and practiced the key-press task using their index, middle, and ring fingers with their eyes closed. The next day, participants repeated the same key-press sequence in a recall test. Then participants repeated the task during neuroimaging without a specified focus, with an assigned focus (internal or external), and while counting tones. No differences among conditions were found in duration or evenness, which could be explained by the large number of repetitions required to successfully complete the task without error. Zentgraf and colleagues found higher activation in the primary somatosensory, motor, and insular cortices in the external condition compared to the internal condition.

There is also evidence that adopting an external focus benefits performance under stress. Totsika and Wulf (2003) found that participants learning to ride a Pedalo (a cycling apparatus that requires balance) using an external focus (pushing the platforms) completed the course more quickly than did participants using an internal focus (pushing the feet). The external group performed faster when asked to ride as fast as possible forward, and in a transfer test, pedaling backward. The external group also outperformed the internal group when counting backward by 3’s (secondary task). These findings suggest that adopting an external focus benefits long-term retention and transfer to similar situations and tasks.

Participant age

The benefits of an external focus of attention are found in populations of various ages. Benefits were found when children adopted an external focus of attention during a bean bag throw, (Chiviacowsky, Wulf, & Ávila, 2012) and a balance task (Thorn, 2006). Likewise, children receiving external focus of attention feedback performed better on a soccer throw-in task (Wulf, Chiviacowsky, Schiller, & Ávila, 2010).

In an experiment comparing adults and children performing a dart-throwing task, novice adults performed better under an external focus of attention condition than under an internal focus, but children performed more accurately under an internal focus of attention than under an external attention (Emanuel, Jarus, & Bart, 2008). Wulf (2013) expressed concern that this study used a different number of instructions in the internal compared to external condition, and that the instructions were not comparable, possibly confounding the results.

The benefits of an external focus of attention have been found in studies of varying tasks performed by older adults. In a study of persons with Parkinson's disease, external focus of attention reduced postural instability when participants stood on a balance platform (Wulf, Landers, Lewthwaite, & Töllner, 2009). In an earlier study, Landers and colleagues found that an external focus benefitted patients who had a history of falling, but only on the most difficult balance task (Landers et al., 2005). Similar benefits of an external focus were found in an object-reaching task in participants who had suffered a stroke and in healthy adults (Fasoli, Trombly, Tickle-Degnen, & Verfaellie, 2002). In addition, aging adults benefitted from an external focus of attention in a balance task (Chiviacowsky, Wulf, & Wally, 2010). These results indicate that instructions that induce an external focus of attention may be beneficial in occupational and physical therapy settings, but may be dependent on the difficulty of the task.

Distal effects

Numerous studies demonstrate the benefits of an external focus of attention in skill learning. For some tasks, these results are evident almost immediately in practice, but for others they are evident only after the completion of training and in tests of retention. Wulf and colleagues noticed that as the distance between the body and the focus of attention was increased, improvement in performance was seen early in practice. In one of the first studies testing this effect, participants stood on a stabilometer and while looking straight ahead focused attention on their feet (internal), on markers placed directly in front of their feet (near external), on more distal markers to the sides of their feet (far outside), or markers in between their feet (far inside) (McNevin, Shea, & Wulf, 2003). The far inside and far outside group (exactly the same distance from the feet) obtained similar benefits. All three external groups outperformed the internal group on a retention test, but the balancing movements of the far outside and far inside groups were higher in frequency and lower in magnitude than were the movements of the other groups. The two groups with the more distal markers performed best overall.

Bell and Hardy (2009) also found a benefit in a more distal focus in a golf task. Skilled golfers performed a pitch shot using an internal focus (motion of the arms), proximal external focus (position of club face through the swing), or a distal external focus (flight of the ball) in both a neutral and anxiety-producing situation (professional evaluation and financial incentive). Replicating results from skilled players performing a baseball task (Castaneda & Gray, 2007), the distal focus group outperformed the proximal focus and internal focus groups, even in the condition that elicited moderate anxiety.

Porter, Anton, and Wu (2012) also found that participants jumped farther in a long jump when they adopted a more distal external focus of attention. Moderately skilled jumpers performed the long jump focusing their attention on jumping as far past the start line as possible (external near), jumping as close to a cone placed 3 m in front of the participant (external far), and jumping to the best of their ability (control). As expected, the participants jumped the greatest distance under both external conditions and performed better under the external far condition than under the external near condition.

The benefits of a distal external focus of attention were also observed in focus of attention studies in music (Atkins & Duke, 2013; Duke et al., 2011). Duke and colleagues (2011) measured the evenness of timing and velocity of a key-stroke sequence performed by pianists and non-pianists focusing on the movement of the fingers (internal), the keys (near external), the hammers (distal external), or the sound produced (far distal external). An external focus of attention increased evenness of timing in nonpianists' keyboard playing. In addition, the farther away from the body the focus, the more evenly the nonpianists played the sequence. Focusing on the sound led to the greatest evenness in timing in the nonpianists. There were no significant effects of focus of attention conditions in skilled pianists, however.

In a study examining the effects of focus of attention on vocal performance in untrained singers, Atkins and Duke (2013) found that performances were ranked higher when participants focused on external targets than when participants focused on internal targets. Singers' performances were ranked lower by expert listeners when participants focused on the vibrations they felt by placing a hand on the throat and were ranked higher when participants focused on directing their sound to their fingertips placed on the mask of the face, to a microphone placed 18 inches in front of the participant, and to a point on the wall 19 feet across the room. Again, the more distal conditions from the vocal source received higher rankings than the conditions closest to the vocal source.

Feedback

Feedback that directs learners to focus on movement goals (external) rather than on their limbs and movements (internal) has been associated with better performance in a basketball free throw (Shojaei & Daneghian, 2010), a balance task (Shea & Wulf, 1999), a tennis-style volleyball serve, and a soccer kick task (Wulf et al., 2002, Experiments 1 and 2). Wulf and colleagues (2002) also compared 33% and 100% feedback frequencies in skilled soccer players and found that external feedback led to better performance than did internal feedback irrespective of feedback frequency. Internal feedback was more effective when given after 33% of the performance trials than when given after 100% of the performance trials. External-focus feedback was clearly more beneficial than internal-focus feedback on performance both during training and in a retention test. In a soccer throw-in task, children ages 10-12 performed better when external feedback was received

100% of the time compared to 33% of the time. No significant differences were found between feedback frequencies under internal feedback conditions (Wulf, Chiviacowsky, et al., 2010).

Porter, Nolan, Ostrowski, and Wulf (2010) tested whether internally- or externally-focused verbal instructions affect running speed on an agility course. All instructions directed participants to run quickly with maximum effort. The external instructions also directed participants to focus on getting to the cone and applying force to the floor on the turn. The internal instructions directed participants to move their legs as fast as possible and to focus on planting one foot on the turn. Participants ran fastest after reading the external instructions, and no difference was found between internal condition and a control condition.

In a review of research on computer-assisted instruction in singing, Hoppe and colleagues reported that real-time visual feedback was beneficial in developing vocal skills (Hoppe, Sadakata, & Desain, 2006), explaining that as singers focus on the visual feedback about their resonance and pitch, they make physical adjustments, sometimes without conscious control, to optimize the quality of their sound. The authors mention that the effects observed may have been a result of singers' external focus of attention, but the research reviewed did not test that proposition.

Evidence from more than a decade of systematic research demonstrates the benefits of an external focus of attention in motor learning. The effects of attentional focus vary somewhat according to the age and skill level of the performer and the nature of the task, but the results of the research conducted to date are highly reliable and robust.

IMPLICIT LEARNING

Implicit learning and explicit learning are in some ways related to external and internal focus of attention. Implicitly controlled movements are initiated and controlled without the conscious attention of the individual performing the action. Much of what we do in life involves implicitly controlled skills: walking, reaching and grasping, driving, and talking. Some skills are learned through explicit instruction and shift to implicit control following much experience and practice. Other skills are learned implicitly. Infants learning the motor control required to crawl do so through trial and error and without conscious awareness of the precise movements that are required for ambulation. Seemingly random movements that create discernible effects become coordinated over time and practice.

A great deal of motor behavior is learned without any explicit instruction whatsoever. In fact, implicit learning strategies, including the use of analogy (Liao & Masters, 2001; Masters, Poolton, Maxwell, & Raab, 2008), are often more effective than explicit strategies (Eves, Masters, & Maxwell, 2000; Green & Flowers, 2003; Masters et al., 2008; Wulf & Weigelt, 1997).

Wulf and Weigelt (1997) compared implicit and explicit strategies in a ski simulator task and found that the participants given explicit instructions (i.e., instructions about when to apply force in a fluid movement) did not perform as well as those who learned the task implicitly (i.e., by focusing on the movement goal without explicit instructions about how to accomplish it). Those who learned the task implicitly also outperformed the explicit group when the task was performed under stress. In a second experiment, participants given explicit instructions after having first learned the skill implicitly showed a drop in their performance and were unable to reach the level of performance they had acquired prior to the explicit instructions.

Similarly, participants given explicit probability information performed more poorly in a video game task than did participants who received no information (Green & Flowers, 2003). All participants showed use of predictive processes to improve their ability to “catch a ball” using a joystick. The results suggest that the explicit conditions (rule application) required greater cognitive involvement that hindered performance.

Liao and Masters (2001) found that the use of analogy with novice table tennis players functioned as an implicit learning strategy. Participants learned to hit a topspin serve to a target area of the table either implicitly (without instruction), through analogy (pretend to draw a right-angled triangle with the paddle), or with explicit instructions. When performing under stress, the analogy group showed an increase in accuracy but the explicit group’s performance declined.

Similar results were found in another study using a topspin shot in table tennis as the target skill (Masters et al., 2008). Masters et al. found that the use of analogy (hit the ball like you are going up the side of a mountain) versus a step-by-step procedure gave novice table tennis players an advantage in high-complexity decision tasks. During a low-complexity task, both implicit and explicit groups continued to improve in accuracy; however, when faced with a high-complexity task, the explicit group’s accuracy declined abruptly. The analogy group showed no degradation in the high complexity task and had more efficient muscle movement, suggesting better use of attentional resources during the high-complexity condition.

CONCLUSION

The majority of the studies described in this section of the review show that automatized movements are inhibited during internal focus conditions, supporting the constrained action hypothesis. Additionally, EMG evidence indicates focusing externally leads to more efficient movement than does focusing internally (Lohse et al., 2010; Lohse, 2012; Marchant et al., 2009, 2006; McNevin & Wulf, 2002; Vance, Wulf, et al., 2004; Wulf, Dufek, et al., 2010; Wulf et al., 2004).

Some studies have shown that novices benefit from adopting an external focus of attention in learning new tasks (Southard, 2011; Wulf et al., 1999, 2002; Wulf & Su, 2007). Other studies, however, have found no differences between internal and external focus of attention in novices (Beilock et al., 2002; Castaneda & Gray, 2007; Perkins-Ceccato et al., 2003). The different results seem attributable to differences among tasks, the ages and experience levels of participants, and learning procedures.

Castaneda and Gray (2007) and Poolton and colleagues (2006) found evidence in support of the conscious processing theory; however, when participants were presented with secondary tasks, the internally focused groups' performance in both studies declined, but the external group remained unaffected. Similarly, participants who received step-by-step instructions performed less well in high-demand situations than did participants who learned implicitly (Liao & Masters, 2001; Masters et al., 2008).

The research on focus of attention demonstrates quite consistently the advantages of focusing attention toward movement goals and away from movements themselves. Of course, great teachers very carefully direct students' focus of attention as they learn, and teachers of singing have developed many instructional strategies that involve focusing singers' attention on external goals. I review these strategies next.

Vocal exercises in singing

Although singing represents controlled motor behavior, precise assessment of the physical movements involved in singing is difficult since most components of the vocal mechanism are not directly observable. A student pulling a bow across a violin string can see and feel the movement of the limbs and bow, but singers cannot feel or see the actions of their vocal folds, for example. As a result, teachers of singing try to create awareness of sensations related to breath and airflow, tone quality, and sound through movement, imagery, and analogy. By doing so, teachers' instructions direct students' attention to the effects of their movement, thereby creating external attentional foci.

Singers' perceptions of their own sounds are different than the perceptions of listeners. For example, a tone that sounds beautiful to an audience may sound overly nasal to the singer. This is a result of several factors that affect singers' perception of their own voices: the location of the mouth opening relative to the ears; the surfaces that reflect the sound wave, which dampen or amplify different component frequencies of the tone; the intracranial vibrations that are conducted through the bones of the head and face.

Teachers, throughout the process of teaching singing, direct students' attention to changes in sound, good and bad, using clear positive feedback when good tone is achieved. Singers must come to associate their teachers' positive feedback with the physical sensations of breath, mouth opening, and shape of the oral cavity in order to produce a beautiful tone consistently.

Of course, there are many different definitions of beautiful tone among individuals and cultures, but one characteristic that singers, listeners, and voice pedagogues most often agree upon is that the voice should sound effortless and free of tension. Beautiful tone of the classically trained voice in Western culture includes a balanced vibrato or spin to the sound, ease of execution, focus, clarity, carrying power, and a warm, rich quality that is not thin, harsh, or strident (Emmons, 2006, p. 106). Alderson agrees that a voice should have a natural tone that is unforced, flowing, and produced easily. The audience is comfortable if the singer sounds and looks comfortable (1979, p. 18).

In the following section I describe different types of exercises in the pedagogical literature pertaining to posture, breath management, vowels, and resonance, making note of how the exercises engage internal and external focus of attention strategies.

POSTURE

Developing a habitual relaxed, tall posture especially in novice singers requires consistent attention on the part of teachers and learners. Simply telling students to relax their bodies and stand tall is clearly insufficient. Teachers can and do directly discuss posture and the alignment of the body using instructions that focus attention internally (directing the learners' focus toward specific parts of the body) using phrases like "feet shoulder-width apart, equal weight on both feet, hands to your sides, and your chest held high." Although directions like this are often repeated in rehearsals with young singers, they may inadvertently cause unwanted tension, especially among students who engage more effort than is necessary to comply with their teachers' instructions.

Teachers employ a variety of physical activities to achieve excellent posture and develop discrimination between good and bad posture. There are also a number of exercises that are intended to relieve tension in an effort to elicit a beautiful tone. I describe these exercises below as they might appear in a typical choral rehearsal. Some common exercises include beginning rehearsal with stretching the body, then massaging the cheeks and neck. Also, students may be directed to tense the entire body from the toes to the nose upon inhalation and then relax while exhaling. These exercises are designed to relieve tension without a specific directive asking students to relax their shoulders or relax the jaw. Students may even be asked to discuss aspects of a piece of music while doing these exercises, thus directing their attention away from their bodies entirely.

Once a relaxed body is achieved, posture exercises are incorporated into the vocal warm-up. For example, posture can be set through large circular arm movements which help straighten the body, prepare the breath, and open the throat (Adams, 1991). In one common exercise singers are directed to bend forward all the way over at the waist and return slowly to an upright position (Apfelstadt, 1985). In another, singers are invited to place an imaginary screw in the top of the head, pull up the body, then slide back down to a tall position.

To find an ideal upper-body position, singers are sometimes directed to take a tense breath with the shoulders raised as high as possible and then to exhale quickly and drop the shoulders without dropping the chest (Powell, 1991). Another exercise directs singers to stand while slumping forward and then rise up slowly to an aligned position. Performing this activity while singing also allows singers to hear the effect posture has on tone (Chagnon, 2001, p. 55), thereby focusing attention on the effect the movement has on sound (external focus).

Setting students' posture at the beginning of singing and throughout rehearsal with a mix of internal and external focus of attention instructions allows posture to be maintained throughout rehearsal with minimal extra tension.

BREATH MANAGEMENT

Breath management is particularly aided by external-focus exercises, as breathing is a well-learned, highly automatized process. When teachers discuss the mechanics of breathing required for singing, students often lift their shoulders upon inhalation resulting in tense, shallow breaths. But directing students to snore or yawn and then sing on their exhale often enables the learner to take a low deep breath without tension in the shoulders or chest. Teachers utilize many different exercises for breathing to focus students' attention on physical sensations created by the effect of correct inhalation (abdomen area moving out), rather than the inhalation itself.

Beautiful tone quality is directly related to the control of breath pressure and airflow, which in turn influences timbre and intensity (Alderson, 1979, p. 68). Breathing is the basis of good tone, and breathing exercises are often done in conjunction with exercises that deal with other aspects of vocal technique. When lying on the back, the abdomen naturally rises and falls with inhalation and exhalation. Students are often directed to sing in this position. This exercise can create a focus on the abdomen (Wis, 1999) especially if a book is placed on the lower abdomen to allow learners to see the result of the expansion of the abdomen during inhalation.

Another exercise used to develop breathing directs students first to stand with good posture with hands at the shoulders, palms facing down. They raise their hands above their heads while inhaling and lower them while exhaling. This is repeated, but with the hands beginning at the waist, resulting in a longer upward movement during inhalation and prompting a deeper breath. Repeating the exercise several times while focusing on the different kinesthetic sensations in the abdomen area between the two hand positions is intended to assist students in discriminating between a shallow and a deep breath.

Telling students to “fill up the big toe with air” and to imagine their lips as the valve stem of a flat tire sitting around their waist are meant to encourage a so-called low breath. Panting like a dog, snoring, yawning, or lifting the eyes while breathing on an “ah” in slow motion are all intended to help students to take a full, low, deep breath (Ehmann & Haasemann, 1982, p. 28).

In addition to becoming aware of breath intake, students must learn to control the expulsion of air. Beginning with the hands hanging relaxed at the side of the body and elevating arms straight out to shoulder height or above the head during inhalation often helps create a deep low breath. Exhaling on a hiss while slowly lowering the arms heightens students’ awareness of air movement and the energy level required to release a steady stream of air. Using this same exercise while singing a musical phrase is intended to reinforce good breath management.

Exercises like “cooling the soup” or “puffing at dandelions” can also assist in creating an awareness of the abdominal activity involved in the expulsion of air. Directing students to hold their hands one on top of the other with palms together and slowly opening vertically during a breath is intended to remind students to take a deep, low breath. The spreading hands represent the expansion of the abdominal area. While singing, the hands draw back together and when the fingers touch, the students take another breath (Bailey, 2007). Students can grasp the concept of changing abdominal pressure to change airflow, but the engagement of the muscles around the larynx and the stiffening of the vocal folds associated with these changes are below conscious awareness. Using different techniques to change the airflow allows the necessary change in the vocal folds to occur, without creating tension (Alderson, 1979, p. 68).

Deeper breathing and controlled exhalation are required for a beautiful tone in singing. Teaching singers to use breath to support the voice is a challenge, but using many different physical movements and analogies can increase awareness and aid in the learning process. As students learn to discriminate between beautiful and poor tone qualities, they become more independent in finding the connections between differing kinesthetic sensations and beautiful sound.

VOWELS

The vowel shape, which is determined by the position of the lips, jaw, and tongue, is the main factor that affects vocal resonance. Developing effective vowels is one of singing teachers' greatest challenges. Choirs achieve their best resonance and intonation through the unified vowel sound (Smith, 1999, p. 138), and choir directors devote a great deal of time establishing tall, relaxed, open mouths when singing.

Vowel formation in human speech is a well-learned automatized function, but the formations learned in speech are not the same as those required for beautiful singing. Simply directing students to open the mouth or drop the jaw is often ineffective and can cause tension or overextension of the jaw.

Many beginning singers do not form enough space in the front of the mouth or achieve a lifted soft palate. Adams recommends having students physically push up on the dome of the mouth with the thumb while cupping the other hand by the ear. This opens the front and back parts of the mouth. She also recommends visualizing an Oreo cookie that is turned vertically in the same space (Adams, 1991). Other exercises intended to open the mouth include having singers lightly push down on the chin with a finger or placing two or three fingers vertically between the teeth. These exercises can cause tension or overextension in the jaw.

Constriction or tightness in any part of the mouth, throat, or larynx is one of the most common problems in singers. Tension in the extrinsic muscles around the vocal folds raises or lowers the larynx from a resting position and closes part of the vocal tract, affecting clarity and freedom in the tone (David, 1995, p. 38). Tension in the jaw and face also cause vowel problems that affect resonance and intonation. Directing singers to locate the hinge of the jaw with their fingers is a procedure intended to open the space in the mouth while remaining relaxed, and often heightens awareness of the arc motion of the jaw. By placing a finger under each ear, students can raise and lower their jaws to feel the space in the hinge. If the hinge is not open when singing, the mouth is not open. Some students, however, over-extend the hinge, causing tension.

There are many exercises that employ kinesthetic and visual references in an effort to establish correct positioning of the articulators (mouth, tongue, jaw, lips, palate). Incorrect vowel formation, directly linked to the lift of the soft palate, causes problems with intonation and timbre. The exercises listed below are intended to change the lift of the soft palate, without the students' thinking specifically about lifting the soft palate, which would likely result in unwanted tension. For example, to describe the "forward-back" approach to the vowel, Powell directs his students to make an inverted U shape with their hand, palms down to represent the roof of the mouth. The tip of the fingers represents the [i] vowel, top of the hand the [α] vowel, and the wrist an [u] vowel (bracketed symbols are from the International Phonetic Alphabet [IPA]). Students are directed to sing through the vowel progression "[i], [e], [α], [o], [u]" until they can "feel" the correct vowel formation (Powell, 1991).

Similarly, Webb developed a system of hand signs to help students visualize and unify correct vowel formation across the ensemble (1993). Each hand sign was specifically designed to imitate the lift of the tongue, lips, and roof of the mouth while creating the desired space. Students are required to memorize the hand signs and use them on command while singing the text of a piece. Webb asserts that as students and conductor sign together they find vowel agreement as they anticipate the next vowel formation and arrive cleanly and with rhythmic precision. Webb states that this technique also assists choir members in moving together on diphthongs and triphthongs.

Bernhardt directs singers to form their hands in the shape of a C and place them on each side of the face with fingers facing the direction that sound travels from the mouth. As the students sing, he has them rotate their hands forward until the opening of the C is facing down, which is intended as a cue to raise the soft palate and as a means of helping students feel the correct placement and sing the correct vowel (Bernhardt, 2001). Cupping and flattening the hands while raising and lowering the soft palate is another gesture that is intended to reinforce the correct sensation (Bailey, 2007).

Similar movements like tracing the soft palate, circling the ear in an upward and forward motion, or holding the hands together, both palms down and lifting the heel of the top hand, are intended to give space to the tone by creating greater space in the oral cavity. Since these techniques are performed while singing, they attempt to focus the students' attention on the change in sound created by the movement, in essence, an external focus of attention on the effects of their movement. As singers gain experience, they learn to modify the shape of the vowels to create smooth transitions between different pitches, registers, and vowels, maintaining a consistently resonant tone throughout.

Vowel modification improves resonance. "When the vowel being sung is compatible with the sung pitch, three advantageous things happen: the singer experiences more comfort, the tone is more beautiful, and the air supply lasts longer" without the use of extra effort or tension (Emmons, 2006, p. 117).

Singing through the *passagio* (passage between registers) requires the use of vowel modification to help the singer achieve a balance between head and chest voice and to move evenly and smoothly between the registers. The failure to achieve this balance results in poor intonation, shrill tone in the high registers, and inaudible, weak sound in the lower registers. Vowels with smaller mouth openings that sit more forward in the mouth allow sopranos, tenors, and basses to achieve this balance in ascending passages. Conversely, a larger mouth opening and vowels that are sung farther back in the mouth allow balance in descending passages (Emmons 2006, pp. 108–9).

Teachers employ many different exercises to correctly position the articulators (mouth, tongue, jaw, palate) for each vowel sound in different ranges. Any extra tension can negatively affect tone quality. The exercises described above are developed to create awareness through kinesthetic sensation or to create a source of feedback not directly linked to the vocal source, and may function as an external focus of attention.

PROJECTION, RESONANCE, AND TONE

Projection, resonance, and tone quality are influenced by breath support and the lift of the soft palate. Since the inside of the vocal tract cannot be observed, resonance can be shaped through a combination of vocal exercises and experimentation with physical positions on each vowel (Phillips, 1992, p. 263). As singers learn to demonstrate the modified vowel shapes required for singing and the proper flow of air, teachers begin working on “placing the tone” (sound) to achieve more resonance and carrying power. “Tone placement or focus is an issue on which singers and voice teachers are sharply divided, not into two or three groups but into many” (David, 1995, p. 70). Voice therapists agree that the majority of voice disorders are caused by low placement of the tone in the laryngopharynx region, which causes tension. High placement into the middle throat and mouth area (oropharynx) and the upper throat and nose area (nasopharynx) allows more flexibility in pitch, loudness, and breathiness. Voice therapists work to lift the focus from the throat.

The teaching of good tone often relies on imagery, including phrases like “place the tone forward,” “direct the tone against the teeth,” and “feel the vowel resonate in the mask” (Reid, 1992, p. 246). The concept of placing the sound in the “mask” refers to directing the sound to the area around and behind the nose. Although not all teachers agree with this technique, the intent of directing students to sing to the mask is to add power, brightness, and clarity to the tone (Pinksterboer, 2002).

Various exercises have been developed to accomplish this conceptual goal by creating an awareness of the sensation of the vibration in this area. When placing the hands along the bony sides of the nose (zygomatic arch), for example, students are asked to think of spoken and sung sounds as buzzing through the fingers. Directing students to focus on the sensation in the mask area while singing exercises or musical passages on lip buzzes, lip trills, syllables beginning with “f,” “v,” “th,” “z,” “l,” or “n,” the word “sing,” and on French nasal sounds helps develop resonance (Smith, 1999, p. 123).

Some teachers recommend having singers massage their foreheads or raise and lower their eyebrows to direct attention to the mask area when singing. In addition, directing students to bend at the waist and sing "upside down" (forehead facing their knees) provides a sensation of pressure in the top of the head and mask area. While continuing to sing, the student is directed to place the fingertips in the mask area and "send" the voice to their fingertips while slowly rising to a standing position. The intended effect is increased resonance in the sound. Similarly, Adams directs her students to place their hands on the temples, across the forehead, and under the eyes in an effort to focus attention on the vibrations created by increased resonance (Adams, 1991). Many teachers have singers point to different parts of the head and body to change where the tone is placed, and doing so is often effective in improving tone among students who sing too far back in the throat, too much in the chest, or produce a breathy sound.

There are many exercises that are intended to help achieve correct placement and resonance. The examples most commonly found in the literature attempt to direct singers' attention to physical sensations that occur away from the vocal source, and may be functioning as an external focus of attention.

PHYSICAL MOVEMENT

In addition to introducing metaphorical ideas and calling singers' attention to different physical sensations that occur while singing, teachers also incorporate physical movement and gestures to improve tone. For example, choral directors often request that singers produce sound that is more like a laser beam than a flashlight; having students sing with their arms extended to their sides and then moving them slowly together to a point is believed to promote a more focused tone (Eichenberger, 2001). To help achieve a more forward tone placement, teachers sometimes ask singers to gesture as if they are throwing a Frisbee, imagining the sound traveling out with the Frisbee. Directing singers to move as if throwing leaves up from the ground and slowly bringing the arms down to their sides while singing is thought to result in improved tone as well. A throwing motion is believed to create a more energized and focused sound from the choir. These movements create a perception of energy and effort for singers, with the intent that they sing with more energy.

Various pedagogues recommend having singers position their bodies and move as if they are holding and throwing different sized objects as a way to influence tone production: imagining throwing a garbage can lid rather than a Frisbee, with the intent of achieving a darker tone; imagining holding a beach ball or a tennis ball or a paper clip as metaphors for rounder or more pointed tones (Chagnon, 2001, pp. 56, 80). Directing singers to clap close to and away from their bodies while singing an [α] vowel is intended to affect tone production: clapping close is intended to produce a more settled sound, whereas clapping away (with arms extended) is intended to produce a sound that is more aggressive. All of these exercises are designed to create a perception of increased energy through physical movement.

Effective teachers of singing routinely focus students’ attention on various aspects of their physical behavior in ways that are meant to improve sound by focusing attention advantageously. Since much of the movements of the vocal mechanism are neither seen nor felt by the singer, activities and exercises that focus attention away from the vocal mechanism are designed to produce changes in sound without creating physical tension. Even breathing, which of course involves highly automatized movements, requires specific attention, as there are few human activities that require the sustained, even exhalation of breath that is required for singing. Although the effectiveness of most of the strategies I describe above has not been studied systematically, the fact that so many singing teachers and choir directors create, write about, share, and employ these types of exercises and activities is evidence of a general agreement among practitioners that they are useful tools of vocal pedagogy.

Empirical research on the vocal mechanism

Although many voice teachers and choir directors develop and use exercises to improve tone quality, much of their decision making about these procedures is more or less intuitive, and the determination of techniques “that work” often does not include a deep understanding of the mechanics of the vocal mechanism. Many voice teachers and choral directors have completed one or more courses in vocal pedagogy during their undergraduate degree programs, but it seems that the mechanics of the voice are rarely discussed with novice singers. Of course, this seems entirely appropriate, since it is unnecessary for singers to understand the particulars of the structures and movements that produce vocal tone. It does seem important, however, that *teachers* understand those particulars, especially as that knowledge may guide their instruction.

THE VOICE SOURCE

The human voice is capable of imitating a wide range of sounds, including the voices of other people. Even though talented impersonators can convincingly mimic the sound of another’s voice, no two voices are exactly the same, because no two people are exactly the same in terms of their physical characteristics (including vocal mechanism). Yet, humans are able to change the size and shape of their instrument, and tone quality is affected by variations in air pressure, along with resonance changes caused by conscious and unconscious movement of the articulators (the mouth, lips, tongue, jaw, cheeks, teeth, larynx, and soft palate).

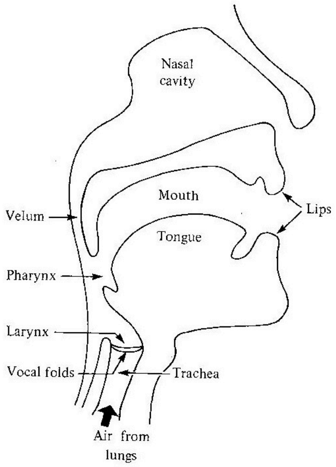


Figure 2.1. “Principle features of the voice organ” (Campbell & Greated, 1988, p. 472).

A source of energy is needed to generate sound. In singing, the generation of energy begins when the lungs are first filled with air and when air is then compressed into the trachea, moving it to the larynx, which then opens into the pharynx (throat). At the bottom of the larynx is the glottis or vocal folds (See figure 2.1). In normal breathing, the vocal folds remain open to permit the free flow of air. When speaking or singing, the muscles attached to the arytenoid cartilage bring the vocal folds together, in turn, creating a change in air pressure on either side of the glottal opening. The greater air pressure on the bottom of the glottis forces the airstream through the closed vocal folds and sets the folds into vibration. This effect is called *Bernoulli* force or the *Bernoulli* effect. This effect (change in air pressure that sets the folds into motion) regenerates as the vocal folds begin to close, allowing the folds to continue vibrating by drawing energy from the air supplied by the lungs. These vibrations can be compared to the buzzing of the lips on a brass instrument or the oscillation of the reed on a woodwind instrument.

The pitch of a sung note is determined by the tension of the area of the vocal folds that is vibrating and their thickness or mass. The thickness of male vocal folds is greater than that of female vocal folds, the result of which is the difference in pitch between genders. When the voice produces low pitches, almost the entire area of the vocal folds vibrate and they are fairly relaxed. When the voice produces higher pitches, the tension increases in the folds, making them longer and thinner. At the very highest notes, only a small area near the edge of the fold vibrates.

Although listeners perceive a given sung tone as a single pitch, each sung tone is actually made up of a series of partials (whole number multiples of the fundamental frequency), commonly referred to as the overtone series. If the vocal folds were vibrated without a resonator (outside the body), the energy (dB) in each partial would decrease as the frequency (Hz) increased (higher partials). When attached to the resonating chambers of the human body (vocal tract, which includes the mouth and nasal passages), individual partials of the complex vocal tone are amplified or attenuated by the resonators. The shape, length, and hardness of the resonating cavity determine which frequencies are amplified or attenuated, and result in the different tone qualities among vocal sounds (see Figure 2.2).

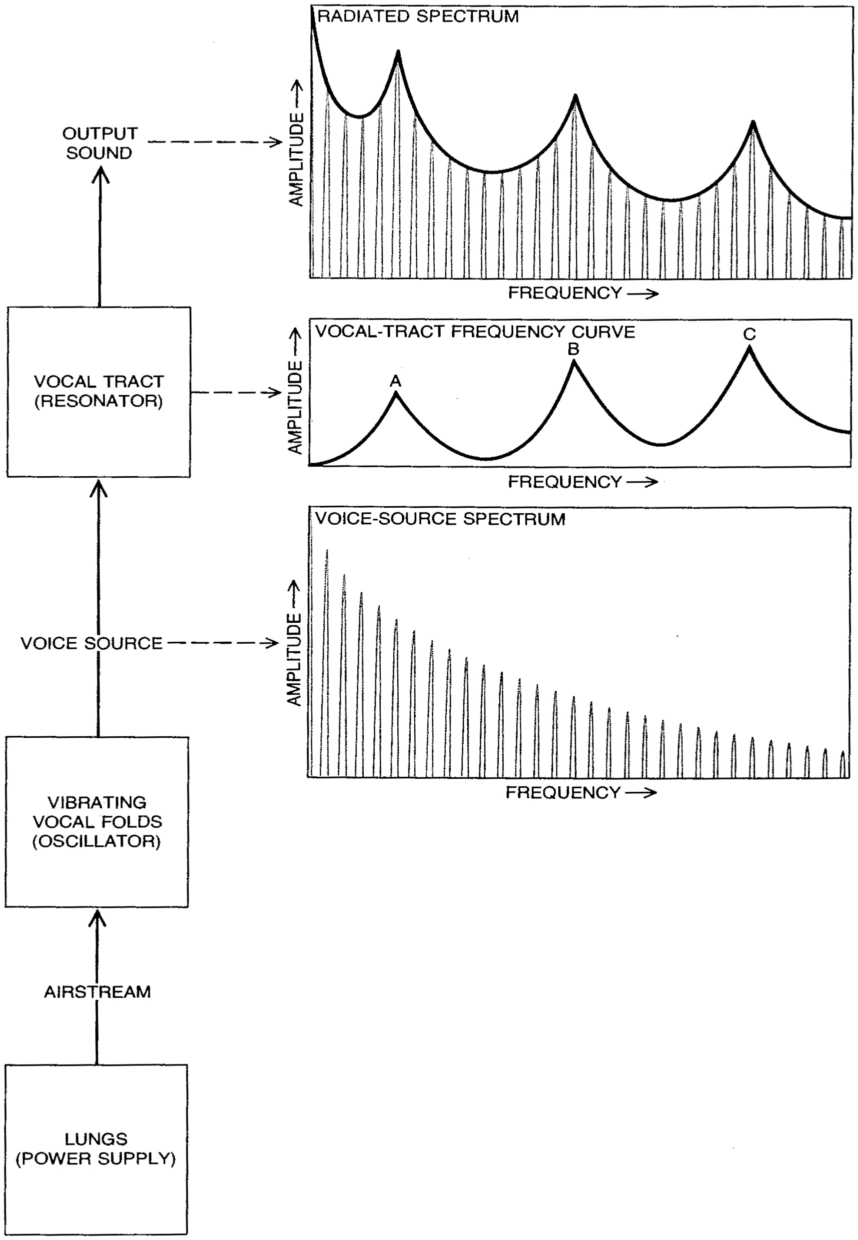


Figure 2.2. The voice source. Air supplied by the lungs activates the vocal folds, which vibrate in periodic cycles. A complex tone results in which the fundamental frequency vibrates with the greatest amplitude and amplitudes decrease in successively higher partials. Changes in the articulators redefine the dimensions of the vocal tract, thus changing the ranges in which the resonance is attenuated or amplified (from Sundberg, 1977, p. 108).

FORMANTS

A range of frequency in which partials resonate with increased amplitude (broad spectral peaks) is called a formant (see Figure 2.2) (Fant, 1970, p. 20). Changes in the articulators redefine the dimensions of the vocal tract, thus changing the ranges in which the resonance of various partials is attenuated or amplified.

If the male vocal tract were a perfectly cylindrical 17 cm tube closed at one end, the formants (frequency regions of high amplitude) would occur at around 500 Hz (Formant 1), 1500 Hz (Formant 2), 2500 Hz (Formant 3), 3500 Hz (Formant 4), and 4500 Hz (Formant 5) (Sundberg, 1977). When a partial of a complex tone lies close to one of these frequencies, a resonance occurs that accentuates that harmonic, changing the resultant tone quality or timbre. Females and children have shorter vocal tracts than males; thus, the formant frequencies are approximately 3 semitones higher in females and 4 semitones higher in children (Campbell & Greated, 1988, p. 483).

Vowel sounds are determined by the positions of the articulators. The first two formants (Formant 1 and Formant 2) are the main contributors to vowel recognition in speech and singing. Formant 1 (F1) is affected by the jaw opening. Closing the jaw lowers the formant frequency, and opening the jaw raises the formant frequency. The shape of the body of the tongue affects Formant 2 (F2). The changes in position of the jaw and tongue constrict and expand the size of the vocal tract, causing changes in the length and width of the vocal tract.

Again using a 17 cm closed cylindrical tube as an analog for the male vocal tract, the sound of a sung [u] vowel is characterized by formant peaks around 300 Hz, 800 Hz, and 2500 Hz in the spectral envelope. An [i] vowel sounds bright because it accentuates higher overtones: F2 moves above the 1500Hz range; F1 moves below the 500Hz range. Figure 2.3 shows which harmonics are emphasized as a baritone, singing C3, changes from an [a] to an [u] and back. Figure 2.4 shows the formant frequencies related to each vowel in comparison to the average formants (dotted lines) as sung by a tenor.

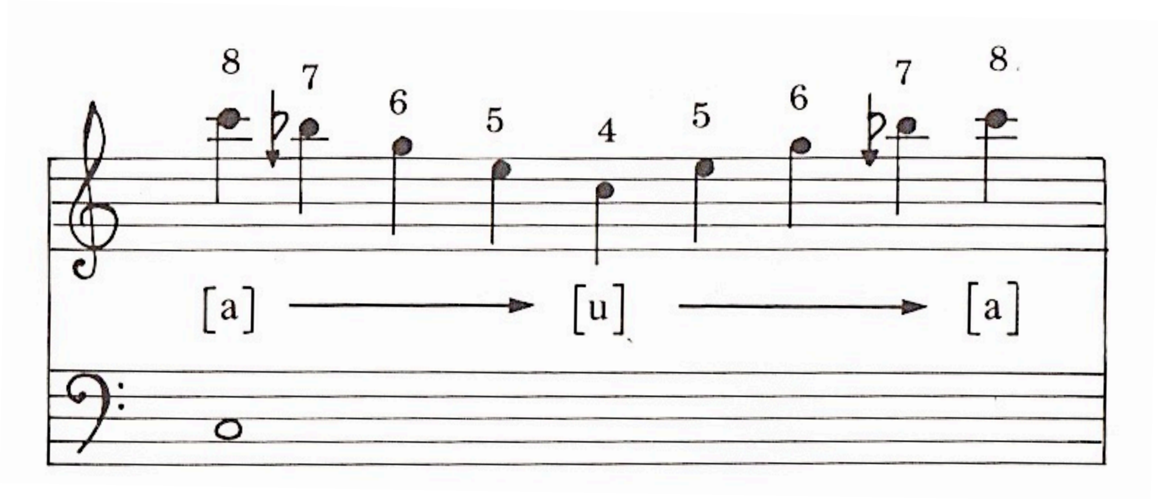


Figure 2.3. The harmonics (shown as musical notes) that are emphasized as a baritone changes from an [a] to [u] when singing a C below middle C (from Campbell & Greated, 1988, p. 482).

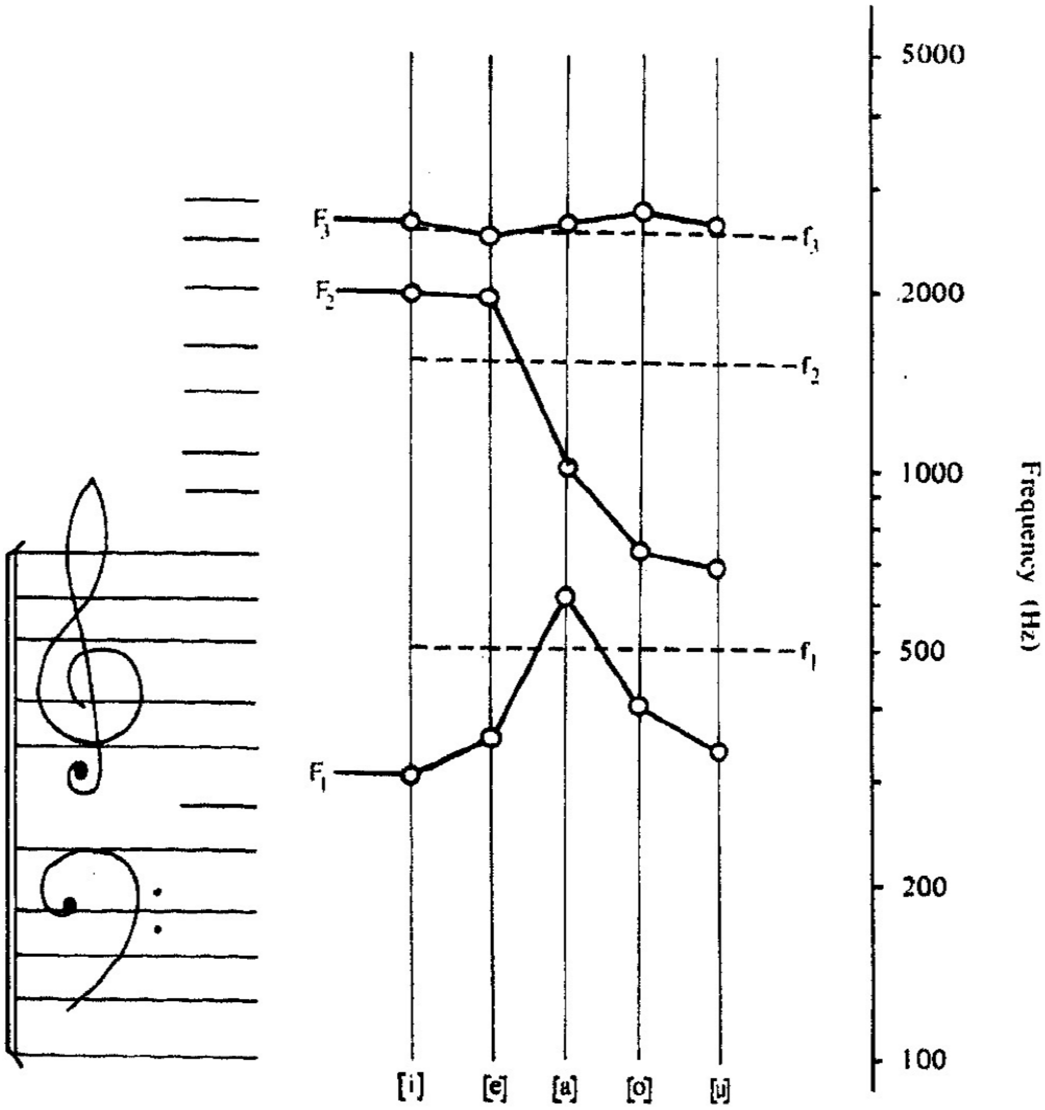


Figure 2.4. F1, F2, F3 of tenor singing [i], [e], [a], [o], [u] vowels. Cylindrical model frequencies shown as dotted line (from Campbell & Greated, 1988, p. 483).

Classically trained singers produce a clear formant peak around 3000 Hz (2800-3400 Hz for males) by modifying the shape and length of the vocal tract through movement of the articulators. One of the earliest observations of this peak came in a study of the speaking and singing voice in Western-style classical male singers

(Bartholomew, 1934). Bartholomew noticed an increase in the amplitudes of the partials between "2800-2900 cycles, regardless of whether produced by a tenor or baritone, a good voice or a poor one, and regardless of the fundamental pitch, the vowel or the intensity" (1934, p. 28). He attributed this phenomenon to an expansion of the throat and the lowering of the larynx in singing compared to speaking.

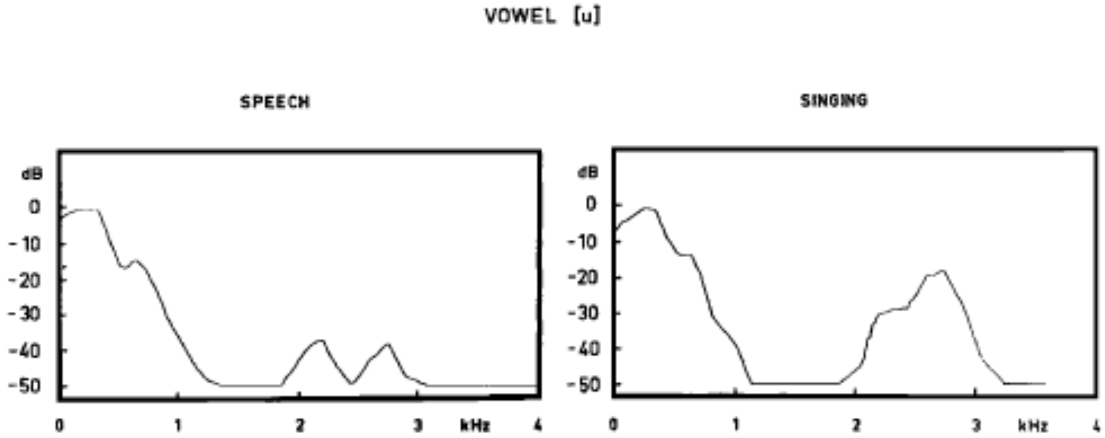


Figure 2.5. Spoken (left) and sung (right) of a male singer on an [u] vowel (from Sundberg, 1974, p. 838). Notice on the left in speech, the two formant peaks at approximately 2200 Hz and 2800 Hz. The example on the right displays one format peak around 2800 Hz. This one peak has been termed the "singer's formant."

Sundberg (1974) coined the term for this area of increased amplitude around 3000 Hz as the "singer's formant," explained as a clustering of F3, F4, and F5 into one broad spectral region (see Figure 2.5). As he began to explore the articulatory movements through X-rays and photos taken during singing and speaking, Sundberg observed a lowered larynx, a wider opening of the jaw, a more forward tip of the tongue in the back vowels (versions of [a], [u], [o]), and more protruded lips in the front vowels (versions of [i], [e]) during singing compared to speaking. He proposed that the larynx tube, unaffected by movement of the articulators, might act as a separate resonator. Articulatory movement in classical singing results in a lowering (relaxation) of the larynx, which widens the pharynx cavity at the laryngeal tube opening, resulting in the increased amplitudes in the singer's formant range (Sundberg, 1974).

The exact location of the singer's formant peak varies based on individual voice type, vocal range, and physiological factors, and also varies based on the vowel, pitch, and amplitude of the sung note. Many authors have reported the presence of the singer's formant in male classical singers (Bartholomew, 1934; Cleveland, 1977; Johnson & Kempster, 2011; Sundberg, 1974), but the spectral location of a singer's formant in classically trained females, especially sopranos, has much more variability than the formants observed in males (Joliveau, Smith, & Wolfe, 2004; Kenny & Mitchell, 2006; Weiss, Brown, Moris, & others, 2001). Spectral analysis has shown that sopranos do not typically show a single peak around 3 kHz (in the approximate range of 2.8-3.2 kHz) compared to altos and male singers (Bloothooft & Plomp, 1986; Seidner, Schutte, Wendler, & Rauhut, 1983). Depending on pitch, some sopranos show either two peaks, one in the 2500-3200 Hz range and another around 3300-4200 Hz, or a broad range of reinforcement with no clear peak between 2600 and 4600 Hz, especially evident on lower pitches (Weiss et al., 2001).

The orchestra's peak amplitude is generated in the frequency range of around 500 Hz. Since sopranos' fundamental pitch is often higher than 500 Hz, they can already be heard over the orchestra. Using the special technique of lowering (relaxing) the larynx to create amplitude in the singer's formant area could result in a very harsh tone quality in sopranos. Therefore, sopranos use vowel modification and other techniques to increase their carrying power. Female voices generally produce a lower amplitude in the singer's formant than do males, and sopranos produce a lower amplitude than do altos (Bloothooft & Plomp, 1986; Seidner et al., 1983).

BREATH

Efficient use of the breath has a large impact on tone quality, resonance, and singing technique. A singer can control (though somewhat unconsciously) the muscles in the larynx that affect the spacing and tension of the vocal folds. If the folds are too slack, the sound is very breathy and there is excess airflow. Conversely, increasing the subglottal pressure by over-tightening the vocal folds creates unsteady airflow and varying amplitudes throughout the sung phrase (Campbell & Greated, 1988, p. 476). These changes in breath efficiency also affect the resonance in the singer's formant.

Several studies show differences in sound pressure level (SPL) due to differences in vocal style. Rossing, Sundberg, and Ternström (1986b), for example, found that basses changed their SPL output between the choral style and solo style. In choral singing, singers produced a lower SPL in the singer's formant region compared to solo singing.

Various styles of singing (pop, belt, classical chest, Broadway, opera) also affect the closed-quotient ratio (ratio of the closed glottal time to the period measured by EGG) and subglottal pressure (Cleveland, Sundberg, & Prokop, 2003; Schutte & Miller, 1993). The major differences among styles of singing were changes in larynx positioning, the percentage of time in the closed phase in a periodic cycle, and the level of subglottal pressure. Belt style (chest voice) was characterized by a closed quotient ratio greater than 50%, high subglottal pressure, and a very high larynx position, resulting in a more tense sound compared to a relaxed larynx and moderate subglottal pressure in the classical and Broadway style. Pop style resulted in a medium to high larynx position and moderate subglottal pressure.

USES OF LONG TERM AVERAGE SPECTRUM (LTAS)

As previously discussed, the amplitude and frequency of the formants are affected by the voice source (periodicity, duration of glottal closure, and breath pressure) and vocal tract resonance, which is affected by shape and length of the vocal tract. Long-term average spectrum (LTAS) reports the formant frequency ranges for singing and speaking as an average power of the component sine waves (dB) across time. Several measurements related to vocal quality in singing are based on LTAS data, including the difference between F4 and F3, the difference between F5 and F3, and other measurements related to peak amplitudes. These measurements are associated with the perception of ring or resonance in vocal tone.

Researchers have explored the use of LTAS to distinguish voice classifications (e.g., bass, baritone, tenor) of classical singers. Expert voice teachers' classifications of male voices (Cleveland, 1977; Ekholm, Papagiannis, & Chagnon, 1998) and singers' self-classifications (Johnson & Kempster, 2011) are highly correlated with the formant frequency averages and ranges obtained using LTAS.

When tenors sing in the high part of their range, and when basses sing in the low part of their range, the amplitude of the singer's formant increases (Sundberg, 1977). Johnson and Kempster (2011) found that the strength of the correlation between classification and formant frequency averages increased with the duration of the singing sample. The authors speculated that this was due to a more even representation of a full range of notes and phonetic content in longer samples.

Researchers agree that years of classical voice training increase the amplitude of the singer's formant region (Magill & Jacobson, 1978; Mendes, Rothman, Sapienza, & Brown, 2003; Vurma & Ross, 2004). Magill and Jacobson found a singer's formant in all classical voice types, and noted that professional singers with more than 5 years of training had a much stronger singer's formant than did student singers. Trained sopranos in this study, compared to other trained voice classifications, had much lower amplitudes in the singer's formant range, and student sopranos evidenced no singer's formant. Similar results have been obtained in other studies (Bloothooft & Plomp, 1986; Mendes et al., 2003; Seidner et al., 1983; Weiss et al., 2001).

There are differences in formant frequency ranges between the singing and speaking voices of trained actors, singers, and typical speakers. The speaking formant range for trained actors is between 3000-4000 Hz. By practicing speaking exercises, actors can increase the energy level in this range (Leino, Laukkanen, & Radolf, 2011). The range of the speaker's formant is slightly higher than the range of the singer's formant (2800-3200 Hz).

Although there is evidence that classically trained singers have more spectral energy than do non-singers in the singers/speaker's formant (around 3000 Hz) when speaking and singing (Barrichelo, Heuer, Dean, & Sataloff, 2001; Mendes, Brown, Rothman, & Sapienza, 2004). Brown and colleagues (2000) found that undergraduate audiology and speech pathology students were able to perceive the difference between trained and untrained singers only when they sang, but not when they spoke. The only differences found between the correctly-identified singers' singing and speaking passages and the incorrectly-identified singers' and non-singers' passages were variations of intonation and the durations of vowel sounds (Brown et al., 2000; Rothman, Brown, Sapienza, Morris, & others, 2001).

The areas of reinforcement in the upper partials vary with the style of singing. The singer's formant range that is typically found in classically trained singers is not found in other professional styles and modes of singing. For example, Country and Western singers show similar formant profiles when they sing and when they speak (Cleveland, Sundberg, & Stone, 2001). Similarly, no singer's formant was found in the Croatian Klapa folk style, though an area of greater amplitude was found at 3000-3800 Hz in the Croatian Dozivački folk style, which can be attributed to the much louder, shouting style in this type of music (Kovačić, Boersma, & Domitrović, 2003).

LTAS values also differ between choral singing and classical solo singing. In a study that compared the LTAS readings in choral and solo singing by eight professional basses, Rossing et al. (1986b) found that the basses showed more energy (higher amplitude) in the first formant and less energy (lower amplitude) in the singer's formant area in choral singing compared to solo singing. Conversely, in solo singing, basses showed more energy in the singer's formant area and less energy in the fundamental compared to choral singing. Similar results were found in studies of soprano singers (Rossing, Sundberg, & Ternström, 1986a), and amateur bass singers (Goodwin, 1980; Rossing, et al., 1986b). One possible contributing factor to the variation in formant structure between solo and choral singing is the lower average SPL used to achieve blend in a choir.

Singing Power Ratio (SPR), the difference between the highest singing power peak (SPP) in the 0-2 kHz range and the highest SPP in the 2-4 kHz range, is correlated with listeners' perceptions of ring in the singing voice (Omari, Kacker, Carroll, Riley, & Blaugrund, 1996). The smaller the difference between these peaks, the more resonance/ring is present in the tone as heard by expert listeners. This effect has been observed with trained and untrained voices (Omari et al., 1996) and talented and "nontalented" untrained singers (Watts, Barnes-Burroughs, Estis, & Blanton, 2006).

Another measurement using LTAS information to assess ring is the Energy Ratio (ER). This measurement is very similar to SPR except it compares the difference between the overall average energy (rather than peak) between 0-2 kHz and 2-4 kHz. A low ER value represents greater amplitude in the 2-4 kHz range, and a high ER value represents greater amplitude in the 0-2 kHz range (Thorpe, Cala, Chapman, & Davis, 2001). Thorpe and colleagues found increased energy (using ER) in the singer's formant and a decrease in exhalatory flow when singers were asked to project their voices.

Kenny and Mitchell (2006) evaluated the effects of pedagogical strategies on overall vocal performance and found that expert listeners rated professional singers more favorably when they sang with a more open throat than when they sang with a less open throat. But Kenny and Mitchell found SPR and ER values did not correspond to the perceptual ratings.

Callinan-Robertson, Mitchell, and Kenny (2006) found that expert listeners also rated singers more favorably when they sang while imagining a halo around their head than when they sang without the use of halo imagery. Again, the perceptual ratings did not correspond to the acoustic measurements from LTAS, SPR, and ER, nor were there significant differences between conditions in terms of the acoustic measurements (Callinan-Robertson, Mitchell, & Kenny, 2006). Though differences were perceived by expert listeners, they were not observable in the SPR or ER measurements.

TONE QUALITY EVALUATION

Singing teachers judge the quality of singing voices for auditions, entrance into college programs, competitions, and other performances. Many different terms are used for evaluating voices, and the definitions of many of these terms are unclear. There are few reliable assessment tools for evaluating singing.

Researchers agree that accurate intonation is one of the most important contributors to evaluations of overall voice quality, both in trained and untrained singers (Cao, Li, Liu, & Yan, 2008; Ekholm et al., 1998; Madsen & Geringer, 1999; Wapnick & Ekholm, 1997; Watts, Barnes-Burroughs, Andrianopoulos, & Carr, 2003). Other aspects of singing found to have strong correlations with overall quality ratings and have high intra- and inter-judge reliability include rhythmic accuracy (Cao et al., 2008), appropriate vibrato, timbre/brightness, resonance/ring (Cao et al., 2008; Ekholm et al., 1998; Oates, Bain, Davis, Chapman, & Kenny, 2006; Wapnick & Ekholm, 1997), vocal clarity (Cao et al., 2008; Ekholm et al., 1998; Wapnick & Ekholm, 1997), color/warmth (Ekholm et al., 1998; Wapnick & Ekholm, 1997), and evenness throughout range (Oates et al., 2006; Wapnick & Ekholm, 1997). Many of these terms can be linked to acoustic measurements of vocal tone.

Harmonic-to-noise ratio (HNR) is the amount of harmonicity in a vocal tone compared to amount of noise caused by the aperiodicity of the glottal closure. The term *vocal clarity* was found to be correlated to HNR (Cao et al., 2008) in untrained singers. *Timbre/brightness* and *resonance/ring* were strongly related to the amplitude of frequencies in the 2.5 kHz range (Cao et al., 2008) and the vowel formant in trained singers (Ekholm et al., 1998). High rankings in *resonance/ring* had higher energy (dB) and less noise (HNR) in the vowel formant range. Higher ratings for *color/warmth* were correlated to presence of vibrato, vibrato that began at tone onset, and higher energy in the singer's formant range (Ekholm et al., 1998).

Several researchers have attempted to create rating scales that consolidate and define terminology (Cao et al., 2008; Ekholm et al., 1998; Oates et al., 2006; Wapnick & Ekholm, 1997). Wapnick and Ekholm (1997) created a rating scale with moderately high inter- and intra-judge reliability. They found that judges' ratings were primarily influenced by the singer's execution (legato line, intonation accuracy, efficient breath management, freedom, evenness and flexibility) and the quality of the singer's voice (intensity, dynamic range, resonance/ring, color/warmth, and appropriate vibrato).

Oates et al. (2006) found that the use of an 11-point equal-appearing interval scale produced better reliability than did a visual analog scale, and higher reliability ratings than the scale used in the Wapnick and Ekholm study. Oates et al. used fewer evaluation criteria (overall voice quality, appropriate vibrato, ring, pitch accuracy, evenness throughout the range, and strain) and more consistent listening conditions than did Wapnick and Ekholm, which may explain the better reliability.

Singing professionals have worked for many years to develop a consensus regarding terms used to describe the classical singing voice (Van den Berg & Vennard, 1959). As research continues, knowledge of the physiological and acoustic factors that affect timbre and overall vocal quality is increasing. Yet, few studies have been conducted to connect the instructional strategies of singing with systematic evaluations of vocal quality, nor has singing been studied in relation to other human motor behavior. Studies of this nature would not only provide valuable information about how singers learn, but may also aid in the development of effective pedagogical strategies for creating a beautiful singing tone.

CHAPTER 3: EXPERIMENT 1

Results of a previous study (Atkins & Duke, 2013) revealed that directing untrained singers' attentional focus to targets that were away from the vocal apparatus resulted in better tone production than did directing their focus internally, to the vibrations of their vocal chords. Specifically, participants' overall vocal quality was better when they focused on directing their sound to their fingertips placed on the mask of the face, to a microphone positioned 18 inches in front of them, and to a point on the wall across the room; overall vocal quality was worse in a baseline condition (no focus instructions) and when they focused on feeling the vibration in their throat with their hand. Assessments were based on within-subject rankings of overall tone quality, and not evaluations of specific aspects of vocal tone.

Many questions remain regarding the effects of attentional focus on vocal tone production, including whether the effects observed in untrained singers are also present in more experienced singers with more extensive training. In the study described in this chapter, I sought to identify which aspects of vocal tone are affected by attentional focus. I was particularly interested in expert listeners' descriptions of the changes in vocal tone that may result from different attentional foci. The study was designed to answer the following question: In what ways and to what extent is the tone quality of trained singers affected by their focus of attention while singing?

METHOD

Participants were 12 trained singers (2 baritones, 3 tenors, 5 sopranos, 2 mezzos) ranging in age between 18 and 31 years old (*M* = 20 years, *Mdn* = 19 years). Due to problems with the recording equipment, one soprano was excluded from the analysis. At the time of the study, participants were attending a Summer Opera Workshop at The University of Texas at Austin. Six participants were incoming undergraduate voice performance majors, one participant was a doctoral voice performance major, and the remaining 5 participants were sophomore and junior voice performance majors.

The experimental procedure met all of the requirements for human subjects participation concerning confidentiality and informed consent. All participants volunteered to take part in the study, and they received no compensation for their participation.

Each participant selected a convenient 15-minute appointment time between 11:00 AM and 4:30 PM on the days they were on campus for the workshop. Prior to singing, each participant signed a consent form and provided information about their background and experiences in music.

Average duration of choir participation by the participants was 10.3 years (*Mdn* = 8 years) and ranged from 5 to 21 years. Average duration of private instruction in voice was 5.0 years (*Mdn* = 5 years) and ranged from 0 to 11 years.

Instrumental training also varied. Three of the vocalists played no other instrument. The remaining eight participants all played piano. One was self-taught and the remaining had an average duration of private study of 2.6 years (*Mdn* = 2 years), ranging from 0 to 10 years. One of the pianists had also played trumpet for 6 years.

Recording took place in a large classroom using a Sony PCM-D50 digital audio recorder (96kHz/24 bit) and its on-board microphones. The recorder was mounted on a tripod and positioned approximately18 inches in front of the participant at mouth height. Using the recorder's recommended specifications for solo singing, I placed the recorder face up with the two unidirectional microphones in a horizontal plane angled at 90 degrees toward each other and toward the singer's mouth. The limiter and low cut filter switches were set in the off position.

In light of the fact that the study would focus on within-subject comparisons, the recording level was adjusted for each individual while they practiced the singing tasks prior to beginning the experiment. The recording volume was set so that the peak level did not indicate distortion; the signal was centered around -24 decibels (dB) on the onboard VU meter of the device. Recording levels were between 4.5 and 6 on the dial of the recorder for all participants. Recording was continuous throughout each participant's session; the gain (record level) remained constant across all conditions. Participants were instructed to face the microphone during recording. I made a separate video recording to document the procedures.

Each participant performed two different singing tasks, one after the other, under six different focus of attention conditions. In the first task, participants sang a three-note sequence that began on E♭, ascended to F, and then returned to E♭. The octave (range) was selected to match each participant's vocal range. The sequence was sung a cappella using a continuous [ɑ] vowel at a tempo of approximately 120 beats per minute. Participants were instructed to sustain the final tone for approximately 8 beats or until they ran out of air. In the second task, participants sang the first one or two phrases of a solo piece that they could perform from memory (enough of the piece to generate a minimum of 7-8 s of singing).

For each of the conditions, participants first listened to the 3-note pattern played in tempo on the piano and then sang the sequence three times in a row. Following the 3-note pattern, I repeated the focus of attention instruction and played the starting pitch for the solo piece on the piano. Participants then sang the beginning of the solo piece a cappella.

Singers first performed both tasks in a baseline condition in which no focus of attention instructions were given. After completing both singing tasks in the baseline condition, they reported how their attention was focused while singing. Participants then performed the remaining five conditions in randomized order. I asked singers to focus their attention on (i.e., to think about) one of the following targets: the position of the soft palate, keeping their vibrato steady, directing their sound to the microphone 18 inches in front of them at mouth height (near distance), directing their sound to a music stand approximately 9 feet across the room at a height of approximately 4 feet (middle distance), and directing their sound toward a circle, 4 inches in diameter, drawn on a white board approximately 19 feet across the room and 6 feet above the floor (far distance).

Preparation of recordings for analyses

I listened to the each participant's 3-note trials through Bose QuietComfort2 Acoustic Noise Cancelling Headphones to determine the level of consistency among the three trials in each condition. As might have been expected, each singer's three trials in each condition were highly similar; most were indistinguishable from one another. I chose to use the first trial of the three in subsequent analyses in light of the fact that it was performed immediately following the focus of attention instructions.

I analyzed only the final, sustained pitch of the 3-note E♭-F-E♭ sequence, thus limiting variations in intonation, tone onset, and movement between pitches. Using the acoustical software Praat (Boersma & Weenink, 2011), I isolated and extracted a 2-s excerpt from the final pitch of every participant's first 3-note trial in each condition. I also extracted the recording of the solo piece performed under each condition and saved each as an individual WAV file. Thus, there were six 2-s [ɑ] vowel trials and six solo piece trials per subject: 132 total WAV files. The specific details of the procedure using Praat software are given in the Appendix.

Expert listeners' descriptions of recordings

I first evaluated all 2-s [ɑ] vowel trials and all solo piece excerpts for all 11 participants and made notes describing the vocal aspects of the performance. I especially focused on describing the differences I heard among conditions for each participant.

I identified five participants whose [ɑ] vowel and song trials were, in my perception, the most clearly affected by focus condition. I then asked one DMA teaching assistant (20 years of teaching experience) and one university voice professor (15 years of teaching experience) to describe the differences they heard among the six conditions on both singing tasks for these five participants (60 total WAV files). I was most interested in learning about the language experts use to describe differences in vocal tone quality and the specific aspects of tone that seemed to them affected by condition.

I met with each listener individually in a quiet classroom for one 75-m listening session. Using the same pair of Bose QuietComfort2 Acoustic Noise Cancelling Headphones connected to the headphone jack of a 15-inch MacBook Pro computer (2.2 GHz Intel Core i7, Mac OS X version 10.7.5) running QuickTime software (version 10.1 501.29), each listener first heard the first participant's six 2-s [ɑ] vowel trials one after another in the same order (recall that order for each participant following baseline was randomized). Listeners were blind to the experimental condition associated with each recording. During this initial listening the experts made no comments about what they heard. Then, each expert listener was invited to play the examples again in any order as many times as they wished by clicking on each WAV file icon. While they replayed the examples, they described aloud the differences they heard among the performances in the baseline and the five focus conditions for each participant.

I did not provide any guidelines to follow, but invited the experts to speak freely about what they heard. I typed all verbalizations as they were spoken, and I made no comments about the experts' stated perceptions other than asking for clarification or asking them to repeat a comment I did not understand. After completing the evaluations of the [ɑ] vowel recordings for a given participant, we followed the same procedure for the solo piece WAV files for the same participant. We repeated the entire listening procedure for the remaining four participants' recordings. I also audiotaped the entire session to use for future reference if needed.

I then compiled the descriptions from the transcriptions of expert listeners and my own descriptions, identifying language that described various aspects of vocal performance. In the expert listeners' descriptions of vocal performance for the five participants' [α] vowel and solo pieces, groupings emerged describing tone quality, color, intonation, vowels, consistency of vibrato, consistency of resonance, and consistency of air flow. Understandably, given the brevity of the [α] vowel recordings, descriptions pertaining to vowels, intonation, consistency of resonance, and consistency of air flow were not used to describe the 2-s [α] vowel recordings, but were used only when describing the solo piece performances.

Expert listeners' descriptions typically indicated either a positive or negative assessment (e.g., "lots of ring" or "pushed"). The words *bright* and *dark* in reference to tone color and vowel sound were at various times associated with either a negative, neutral, or positive assessment. When expert listeners used descriptions discussing color or vowels, I asked them to clarify whether their description was intended to be positive, negative, or neutral.

I briefly consulted with each of expert listeners again individually during a second session to review the list of descriptors I had compiled during the listening sessions, to clarify positive, neutral, and negative descriptions of color, and to ascertain their agreement with the categories that emerged. Based on these discussions, I made minor changes to the categories pertaining to specific descriptors. For example, *breathy* was originally in the same category as was *undersupported*; however, we all agreed that it was possible for a tone to be both supported and breathy. I created a separate category for *breathy* and *less breathy*. In addition, the word *thin* was originally in the category with *tight*, but based on our discussions I moved it to the category containing *no deep overtones*. What follows is a compilation of the vocabulary the two expert listeners and I used to describe the performances of the 2-s [α] vowel trials and the solo piece recordings. Each grouping under a bolded heading includes words that describe the same characteristic. The symbols (+), (-), and (n) represent positive, negative, or neutral statements in the 2-s [α] vowel and solo piece performances. Asterisks denote the vocabulary not used in the 2-s [α] vowel.

Resonance/ring
good ring (+)
more ring (+)
warmth (+)
resonance (+)
balanced tone (+)
full voice (+)
energized (+)
supported (+)
round (+)
some ring (n)
no deep overtones (-)
no firm tone (-)
thin (-)
less resonance (-)
less ring (-)
consistent (+)*
inconsistent (-)*

Intonation
consistent (+)
good (+)
problems (-)
sharp (-)
flat (-)
wobble (-)
scooping (-)
inconsistent (-)

Freedom
open (+)
relaxed (+)
natural (+)
free (+)
strident (-)
tight (-)
nasal (-)
pressed (-)
forced (-)
pushed (-)
harsh (-)

Support
undersupported (-)
less supported (-)
weak (-)
tentative (-)
softer (-)

Breathiness
less breathy (+)
breathy (-)

Noise
less noise (+)
less buzz (+)
gravelly (-)
hiss (-)
noisy (-)
scratchy (-)
less clear tone (-)
buzz (-)

Air Flow*
consistent (+)
inconsistent (-)
wavery (-)

Expression*
legato (+)
nice line (+)
choppy line (-)

Vibrato
consistent (+)
inconsistent (-)
straight tone (-)

Color
bright (+)
over bright (-)
less bright (+)
bright (n)
dark (n)
dark (+)
darker (-)
swallowed (-)
hollow (-)
over-covered (-)
dropped soft palate (-)

Diction
consistent vowel (+)
good vowel (+)
dark vowel (+, -, n)
bright vowel (+, -, n)
over-bright (-)
elongated vowels *(+)
over-enunciated* (-)
vowel problems* (-)
vowels pop out* (-)
shadow vowels* (-)

Each expert met with me again individually for another 75-m session to evaluate the remaining six participants' recordings. Using the same procedure as the first session, I asked the participants to describe aloud the changes heard between the conditions for the remaining participant's [ɑ] vowel. Before we began, I asked them to read through the list I had compiled from the first session in an effort to direct them to use more succinct descriptions. I again invited them to speak freely, but asked them to refrain from diagnosing and explaining how to correct negative aspects of singing. Recall that the expert listeners had already described the participants whose tone quality, in my perception, were most affected by conditions. In the remaining six participants' WAV files there were fewer audible differences among the conditions.

After completing all of the [ɑ] vowel trials, we spent the remaining time assessing the solo pieces. At the end of the second session, we had not completed the evaluation of four of the participants' solo pieces (B, D, E, and H). We met for one more 45-m session to complete the remaining participants' solo pieces.

RESULTS OF EXPERT LISTENERS' DESCRIPTIONS

I was interested in summarizing the descriptors the expert listeners used to describe performances in each condition. I found that, in addition to the musical descriptions, listeners often reported whether they liked or disliked a WAV file, made comparative statements among WAV files, and diagnosed the possible causes of a poor tone quality. Table 3.1 reports the number of musical descriptions given by each of the three experts (the voice faculty member, the DMA student, and myself).

Table 3.1

Frequency of descriptors reported by each expert listener for individual WAV files (66 WAV files per singing task)

Number of descriptors per example	Expert 1**		Expert 2		Expert 3	
	[ɑ]	solo	[ɑ]	solo	[ɑ]	solo
1 descriptor	21	18	17	18	0	4
2 descriptors	26	30	21	23	15	10
3 descriptors	15	14	12	17	13	22
4 descriptors	1	2	5	4	19	18
5 descriptors	1	1	1	2	4	9
6 descriptors	0	0	1	0	1	3
7 descriptors	0	0	0	0	1	0
No descriptor*	2	1	9	2	13	0

*Rather than describing aspects of the tone, the listener stated only that the performance trial was similar to one or more other trials by that participant.

** Myself

Expert 1 and Expert 2 were very similar in the number of descriptions reported per WAV file. Expert 3 described WAV files with four descriptors more often than did Experts 1 and 2, and rarely used only one descriptor to assess a WAV file.

The [ɑ] vowel performances

To examine the reliability among the expert listeners in their descriptions of each WAV file, I first compared the listeners' descriptions of the [ɑ] vowel performances. In 23 of the 66 WAV files, all three listeners identified at least one aspect of singing in common. In 38 of the 66 WAV files, two listeners identified at least one aspect of singing in common. In only 5 of the 66 WAV files did no two listeners describe the same aspects of tone quality. In four of these instances listeners were unanimous in their assessment of the tone as either good or poor, or unanimously stated that the condition sounded the same as another condition.

Positive, neutral, and negative descriptions of the [ɑ] vowel performances

I examined the listener comments and counted the total number of positive, neutral, and negative comments made by all three listeners for every participant in every condition (see Table 3.2). Neutral descriptions consisted of comments describing similarities between two or more conditions, or a diagnosis for a negative tone quality (e.g., pulling down on the back of the tongue). Line 1 shows that Participant *A* received six positive comments, one neutral comment, and four negative comments in the Baseline condition. In the Vibrato condition, Participant *A* received no positive comments, one neutral comment, and seven negative comments.

Table 3.2 provides a general indication of the prevailing valence of the listeners' assessments of each recording. I examined the content of listeners' verbal descriptions and made an overall determination about whether the descriptions for each file were predominantly positive, predominantly negative, or neither. I made my decisions based not only on the numbers of positive and negative statements pertaining to each recording, but also on the content of the statements. Boxes in Table 3.2 indicate the WAV files in which the assessments of overall tone production were predominantly positive; shadowed boxes indicate the WAV files in which the assessments of overall tone production were predominantly negative. Numbers only (no box) indicate the WAV files in which the listeners' assessments were neither predominately positive nor predominantly negative.

Table 3.2
Number of positive, neutral, and negative descriptors in each condition for every participant in the [ɑ] *vowel performances*

	Baseline			Vibrato			Soft Palate			Mic (near)			Stand (middle)			Point (far)		
Participant	+	N	-	+	N	-	+	N	-	+	N	-	+	N	-	+	N	-
A	6	1	4	0	1	7	5	0	3	4	2	1	1	1	6	3	1	4
B	3	0	2	4	0	5	3	2	3	0	2	5	2	2	3	0	2	10
C	1	0	4	1	1	3	0	1	4	2	0	4	4	0	2	2	1	3
D*	0	2	5	2	0	5	3	1	6	2	0	8	2	3	4	2	3	5
E*	8	3	2	4	3	1	3	3	3	0	3	5	0	3	5	2	3	4
F*	0	1	7	7	1	6	2	2	4	3	3	1	3	3	4	2	3	2
H*	2	2	4	1	2	6	3	2	3	1	2	5	5	3	2	7	3	1
I	3	0	8	0	1	5	1	0	7	0	1	3	8	0	1	4	0	1
J	2	1	5	2	2	1	0	0	5	7	2	2	3	1	3	0	0	4
K	2	3	5	3	0	5	1	2	5	0	4	5	5	0	2	2	2	3
L	0	1	9	1	2	6	8	0	1	2	1	7	2	0	4	3	0	5

*Listeners commented that performances in all conditions were highly similar. Boxes indicate predominately positive assessments in overall tone production. Shadowed boxes indicate predominately negative assessments in overall tone production. Numbers only (no boxes) indicate the WAV files in which the listeners' assessments were not predominately positive or negative.

According to the listeners' descriptions of the [ɑ] vowel performances, more participants performed poorly in the Baseline (7), Vibrato (7), Soft Palate (5), and Microphone (7) conditions, than in the Stand (2), and Point Conditions (2). Four of 11 participants were assessed positively in the Stand condition, three in the Microphone condition, two in the Point and Soft Palate conditions, one in the Vibrato and Baseline conditions, and none in the Vibrato condition.

The information in Table 3.2 also shows that focus of attention conditions did not affect all participants in the same ways. For example, Participant *L* seemed to perform best in the Soft Palate condition compared to all their other conditions. Participant *I* performed better in the Stand and Point conditions than in the other conditions.

Descriptors applied to the [ɑ] vowel performances

I was interested in learning which aspects of singing were most affected by condition. Table 3.3 shows the number of musical descriptors (98 total) identified by two or more of the expert listeners when evaluating the [ɑ] vowel performances.

Line 1 of Table 3.3, for example, indicates the number of participants whose performances were described as having resonance/ring in each condition: no participants' performances in the Baseline, one participant's performance in the Vibrato condition, one participant's performance in the Soft Palate condition, two participants' performances in the Microphone condition, seven participants' performances in the Stand condition, and five participants' performances in the Point condition were described as having resonance/ring. Descriptions of negative aspects of tone quality (n = 71) outnumbered positive descriptions (n = 27) by more than two to one.

Table 3.3

Numbers of instances in which positive and negative terms were used to describe the 11 [ɑ] vowel recordings in each condition

		Internal Focus		External Focus		
Tone Quality Descriptor	Baseline	Vibrato	Soft Palate	Mic (near)	Stand (middle)	Point (far)
Positive Descriptors						
resonance/ring	0	1	1	2	7	5
free	1	0	0	0	0	0
less breathy	0	0	2	0	0	0
consistent air flow	0	0	0	0	1	0
consistent vibrato	1	0	1	1	2	0
clearer vowel	0	0	1	0	0	0
bright tone	0	1	0	0	0	0
Total Positive (n = 27)	2	2	5	3	10	5
Negative Descriptors						
tight/strident/pushed	1	0	1	3	1	3
buzz/noise	0	0	1	0	0	1
breathy	2	3	1	2	1	0
less resonance/ring	4	1	1	0	1	0
undersupported	3	4	2	3	0	0
darker/swallowed	0	3	4	0	0	1
over-bright	1	0	1	2	1	0
inconsistent intonation	1	2	1	1	2	0
inconsistent vibrato/straight	3	3	2	1	3	0
inconsistent air flow	0	0	1	0	0	0
Total Negative (n = 71)	15	16	15	11	9	5

Generally, the two internal conditions (Vibrato and Soft Palate) and the Microphone condition were described with a greater number of negative than positive assessments. The Baseline performance (no instruction) was also described with more negative comments than positive. The Stand condition resulted in the greatest number of positive descriptors. The two conditions with the fewest negative comments were the Stand and Point conditions.

More comments were made about resonance/ring than about any other aspect of tone. Seven participants in the Stand condition and four participants in the Point condition were described as having good resonance/ring, and four participants in the Baseline condition were described as having less resonance/ring.

Inconsistent vibrato and lack of support were the most frequently applied negative descriptors. No participants' performances were described as undersupported in the Stand and Point condition, but there were a number of unsupported performances in the Vibrato (4), Baseline (3), Microphone (3), and Soft Palate (2) conditions. Listeners also used negative descriptors related to Color, especially the darker/swallowed description. Four performances in the Soft Palate condition, and three in the Vibrato condition were described as too far back in the throat and swallowed.

The solo piece performances

I compiled the same information for the performances of the solo pieces. In 30 of the 66 WAV files all three listeners identified at least one aspect of singing in common; in 31 of the 66 files two listeners identified at least one aspect of singing in common; and in only 5 of the 66 WAV files did no two listeners describe the same aspects of tone quality, though in all of these instances, listeners were unanimous in their assessment of the tone as either good or poor.

Positive, neutral, and negative descriptions of the solo piece performances

I examined the listener comments for the solo piece and counted the total number of positive, neutral, and negative comments made by all three listeners for every participant in every condition (see Table 3.4). Line 1 shows that Participant *A* received three positive comments, two neutral comments, and one negative comment in the Baseline condition. In the Vibrato condition, Participant *A* received three positive comments, one neutral comment, and one negative comment.

Like the presentation in Table 3.2, boxes in Table 3.4 indicate the WAV files in which the assessments of overall tone production were predominantly positive; shadowed boxes indicate the WAV files in which the assessments of overall tone production were predominantly negative. Numbers only (no boxes) indicate the WAV files in which the listeners' assessments were not predominately positive or negative.

Table 3.4

Number of positive, neutral, and negative descriptors in each condition for every participant in the solo piece performances

	Baseline			Vibrato			Soft Palate			Mic (near)			Stand (middle)			Point (far)		
Participant	+	N	-	+	N	-	+	N	-	+	N	-	+	N	-	+	N	-
A*	3	2	1	3	1	2	1	3	1	2	3	4	5	2	0	6	1	2
B	8	4	2	2	1	5	3	1	2	3	2	6	8	1	0	2	1	4
C	2	1	5	9	0	0	4	0	2	4	0	4	1	1	6	0	2	5
D	1	2	6	5	2	2	7	3	1	2	1	3	2	1	9	2	1	6
E	2	0	6	0	0	6	6	0	2	3	1	3	6	1	4	10	1	3
F*	1	1	7	0	1	5	3	2	4	4	2	4	4	3	2	5	0	2
H*	0	3	7	1	1	8	3	0	4	3	3	3	3	1	1	10	1	0
I	1	0	7	2	0	5	8	0	1	1	1	6	3	1	4	2	1	3
J	4	3	3	1	2	3	1	1	6	8	0	3	3	2	3	2	0	6
K	1	2	6	5	0	2	2	1	7	0	0	6	4	1	2	7	1	0
L	2	1	4	1	1	5	5	0	4	0	0	7	8	1	1	5	0	3

*Listeners commented that performances in all conditions were highly similar. Boxes indicate predominately positive assessments in overall tone production. Shadowed boxes indicate predominately negative assessments in overall tone production. Numbers only (no boxes) indicate the WAV files in which the listeners' assessments were not predominately positive or negative.

More participants sang with poor tone in the Baseline (7) and Vibrato (6) conditions than in the Soft Palate (3), Microphone (4), Stand (2) and Point (3) conditions. Listeners more often assessed participants' overall tone production positively in the Point

(6) and Stand (6) conditions than in the Soft Palate (3), Vibrato (3), Microphone (1), and Baseline (1) conditions.

The focus of attention conditions did not affect all singers in the same ways, however. For example, Participant *D* performed well in the Vibrato and Soft Palate conditions, but performed poorly in the Baseline, Stand, and Point conditions. Participant *E* performed poorly in the Baseline and Vibrato conditions, but performed well in the Soft Palate, Stand, and Point Conditions. Participant *B* performed well in the Baseline and Stand conditions, but poorly in the Vibrato condition and Microphone conditions.

Descriptors applied to the solo piece performances

Table 3.5 shows the number of musical descriptors (109 total) identified by two or more of the expert listeners when evaluating the solo piece performances.

Line 1 of Table 3.5, for example, indicates the number of participants whose performances were described as having resonance/ring in each condition: one participant's performance was described as having resonance/ring in the Baseline condition, four in the Vibrato condition, one in the Soft Palate condition, two in the Microphone condition, four in the Stand condition, and eight in the Point condition. As with the descriptions of the [ɑ] vowel performances, negative descriptors (n = 65) outnumbered the positive descriptors (n = 44).

Table 3.5

Numbers of instances in which positive and negative terms were used to describe the 11 solo piece recordings in each condition

		Internal Focus		External Focus		
Tone Quality Descriptor	Baseline	Vibrato	Soft Palate	Mic (near)	Stand (middle)	Point (far)
Positive Descriptors						
resonance/ring	1	4	1	2	4	8
free	1	0	0	0	1	0
less breathy	0	0	1	0	0	0
better supported	0	0	1	0	0	0
consistent air flow	0	0	0	0	3	0
consistent vibrato	0	1	1	0	1	2
elongated vowels/legato	0	1	2	2	2	2
balanced	1	0	2	0	1	0
Total Positives (*n* = 44)	3	6	8	4	12	12
Negative Descriptors						
tight/strident/pushed	2	2	1	3	2	4
buzz noise	0	0	0	1	0	0
breathy	3	0	0	0	0	0
less resonance/ring	3	1	1	1	0	0
undersupported	1	0	3	2	0	0
darker/swallowed	2	2	2	2	0	0
over-bright	1	2	0	1	0	1
inconsistent intonation	3	1	1	1	0	0
inconsistent vibrato/straight	2	1	1	1	1	0
inconsistent air flow	0	0	0	2	0	0
inconsistent resonance	2	0	1	1	1	0
choppy/non-legato	0	0	0	0	0	1
overarticulated	0	1	0	0	0	1
Total Negatives (*n* = 65)	19	10	10	15	4	7

Table 3.5 summarizes the expert listeners' descriptions of the solo piece performances. Results were similar to the results in the [α] vowel. The Stand and Point

conditions (external) obtained the highest number of positive comments and the lowest number of negative comments. The Baseline condition obtained the highest number of negative comments and the lowest number of positive comments. The Soft Palate, Vibrato, and Microphone conditions were described with more negative descriptors than positive.

Consistent with the [α] vowel description results, resonance/ring was the most often mentioned aspect of singing among the positive comments. The descriptors tight/strident/pushed, lack of ring, undersupported, and issues with color and resonance were the most often used negative descriptors.

The most frequently mentioned descriptor applied to all of the performances in both singing tasks was resonance/ring. Singers performed with less resonance/ring in the Baseline, Vibrato, Soft Palate, and Microphone conditions, and with greater resonance/ring in the Stand and Point conditions.

Although singers' performances showed clear evidence that focus of attention affected tone quality, not all singers were affected by the focus of attention instructions in the same ways. My original intent in this study was to assess the changes in vocal performance through a panel of expert listeners' descriptions. I was interested in determining which aspects of vocal production are most affected by focus of attention.

The expert panel described changes in a free operant with no guidelines. Not only was this a time consuming task for the listeners, some had difficulty only describing the sound rather than explaining how the sound should be improved. I also found that listeners did not always discuss the same aspects of vocal production in each performance, making it more difficult to clearly identify and report the effects of condition on tone quality.

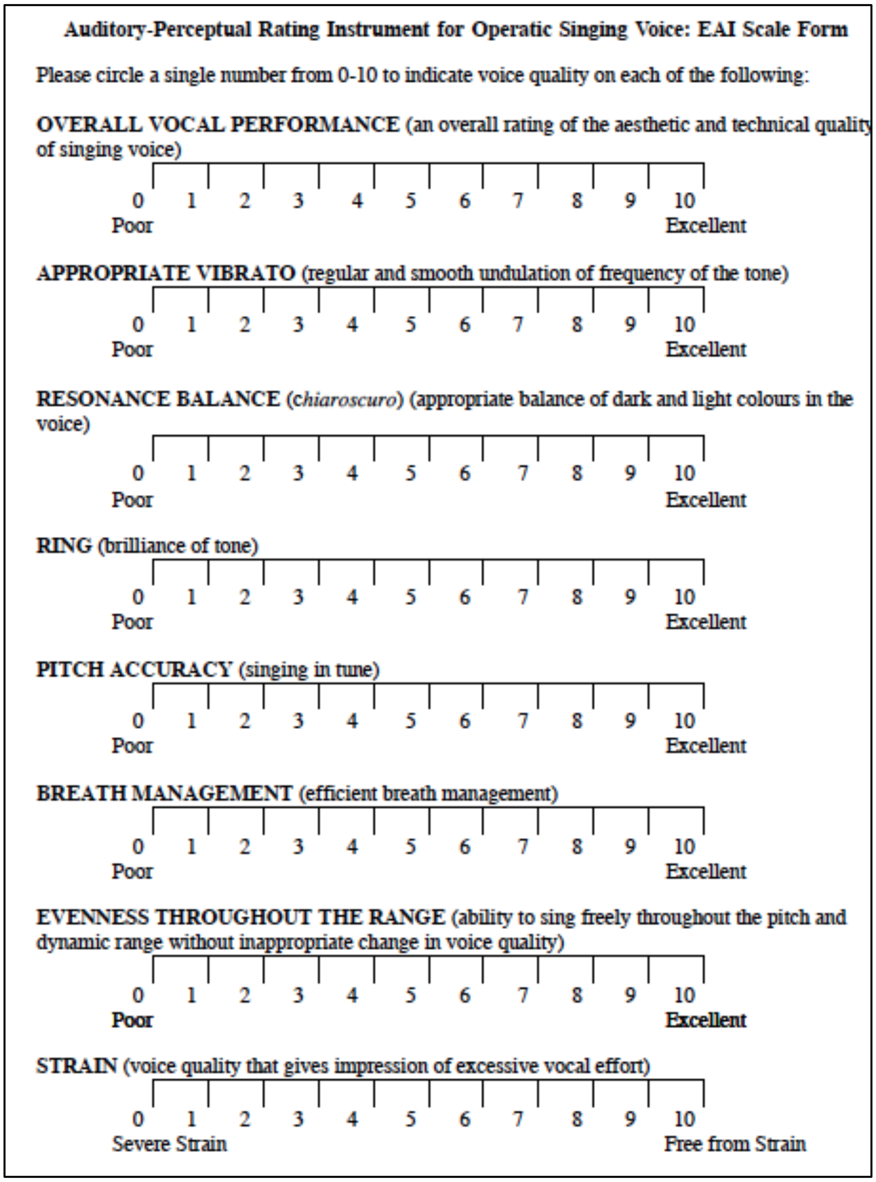
These preliminary results led me to construct an assessment instrument for rating the most important aspects of tone quality using numerical scales. A description of that instrument follows.

DEVELOPMENT OF AN ASSESSMENT INSTRUMENT

Researchers over many decades have attempted to clarify and consolidate terms used to describe and evaluate vocal tone quality (Van den Berg & Vennard, 1959). As I described in Chapter 2, a number of rating scales have been developed, some of which have been associated with acoustic data (Cao et al., 2008; Ekholm et al., 1998). Several of these scales have moderately high to high intra- and inter-reliability (Ekholm et al., 1998; Oates et al., 2006; Wapnick & Ekholm, 1997).

Oates et al. (2006) developed the "Auditory-perceptual 11-point rating instrument" to assess operatic singers. Oates' instrument obtained high reliability, and the rating categories included in the instrument are similar to the descriptions used by the expert listeners' in the current study.

In constructing an evaluation instrument, I used Oates et al.'s evaluation instrument (see Figure 3.1) as a starting point, and applied what I learned from analyzing the expert listeners' descriptions to modify the scale in ways that more effectively matched experts' language in describing tone quality. I found that the 11-point scales of Oates et al.'s instrument seemed unwieldy, so I used 5-point scales for each of the descriptors in my modified instrument. I also used descriptive terms as anchors of each rating scale, rather than simply “poor” and “excellent.” Other differences between Oates et al.’s instrument and the instrument I developed for this study are illustrated in the figures below.



Auditory-Perceptual Rating Instrument for Operatic Singing Voice: EAI Scale Form

Please circle a single number from 0-10 to indicate voice quality on each of the following:

OVERALL VOCAL PERFORMANCE (an overall rating of the aesthetic and technical quality of singing voice)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

APPROPRIATE VIBRATO (regular and smooth undulation of frequency of the tone)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

RESONANCE BALANCE (*chiaroscuro*) (appropriate balance of dark and light colours in the voice)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

RING (brilliance of tone)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

PITCH ACCURACY (singing in tune)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

BREATH MANAGEMENT (efficient breath management)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

EVENNESS THROUGHOUT THE RANGE (ability to sing freely throughout the pitch and dynamic range without inappropriate change in voice quality)

0 1 2 3 4 5 6 7 8 9 10
Poor Excellent

STRAIN (voice quality that gives impression of excessive vocal effort)

0 1 2 3 4 5 6 7 8 9 10
Severe Strain Free from Strain

Figure 3.1. Auditory-perceptual rating instrument designed by Oates et al. (2006) to assess operatic singers.

Figure 3.2 shows the rating instrument I created from the expert listeners descriptions in this experiment. Instead of poor and excellent to represent the range of the ratings, I used specific comparative descriptors as the anchors for each scale. For example, the expert panel used comparative adjectives when describing Ring, so I assigned 1 as “no ring” and 5 as “nice ring.” I changed the word Strain from the Oates et al. scale to Freedom of Tone (referred to as *Freedom*). With this change, the rating of 1 was designated “pushed/pressed” and the rating of 5 as “free/natural.” I changed the term Pitch Accuracy to Intonation with 1 designated as “inconsistent intonation,” and 5 as “consistent intonation.” I added the category Breathiness in which 1 was designated as “breathy/noisy” and 5 as “not breathy/clear.” And I added the category Support/Energy in which 1 was designated “undersupported/weak” and 5 as “supported/energized.”

Because expert listeners often mentioned color in their descriptions of the differences they heard between conditions, I added Color as a category in the new instrument. On this scale, a rating of 3 described a “good, balanced” color, 4 was “bright”, and 5 was “over-bright,” 2 was “dark,” and 1 was “over-dark/swallowed.”

Ring (brilliance of tone)

1	2	3	4	5
no ring				nice ring

Evenness throughout the range (ability to sing freely throughout the pitch and dynamic range without inappropriate change in voice quality) **SOLO PIECES ONLY**

1	2	3	4	5
uneven air/resonance				even air/resonance

***Support/Energy**

1	2	3	4	5
undersupported/weak				supported/energized

Freedom of Tone (voice quality that is free and natural, without strain)

1	2	3	4	5
pressed/pushed				natural/free

Color

1(-)	2	3 (+)	4	5 (-)
over-dark/covered	dark	balanced	bright	over-bright

Intonation (singing in tune) **SOLO PIECES ONLY**

1	2	3	4	5
inconsistent				consistent

Vibrato (regular and smooth undulation of frequency of the tone)

1	2	3	4	5
inconsistent				consistent

***Breathiness**

1	2	3	4	5
breathy/noisy				clear/not breathy

Overall Vocal Quality (an overall rating of the aesthetic and technical quality compared to the other conditions – there may be ties)

1	2	3	4	5
poor				superior

Figure 3.2. Evaluation instrument created from expert listeners' descriptions. Asterisks indicate scales that were deleted after pilot testing. Parenthetical descriptions are from the instrument developed by Oates et al. (2006).

To pilot test the scale and establish reliability, two expert listeners (one singer and one instrumentalist, both music professors in the Butler School of Music) and I used the instrument to assess vocal quality in 20% of the recordings. After an orientation to the task and the form, each expert listener independently rated three randomly selected participants' six solo piece performances. The experts then rated a different three participants' six [ɑ] vowel performances. Thus, the experts listened to 36 of the 132 WAV files.

Listeners opened each WAV file in QuickTime on a MacBook and listened through Bose QuietComfort2 Acoustic Noise Cancelling Headphones. I instructed the listeners to listen to all 6 conditions for the participant one time before evaluating each condition. Then, the expert listeners were invited to play the examples again in any order as many times as they wished by clicking on each WAV file icon as they determined ratings for the different evaluation variables. After completing the first participant's six conditions, they followed the same procedure for the remaining participants. The expert listeners were blind to the conditions, though I was not.

In individual follow up meetings, I asked the listeners to reflect on their use of the rating instrument. One of the expert listeners (singer) had also participated as an expert listener in the free-operant sessions. I was especially interested in her comparison of the two types of assessments (free operant compared to the rating sheet). Both expert listeners and I agreed that use of the rating scale was a somewhat time-consuming task, but the expert listener who had participated in both assessments and I agreed that the rating sheet was no more time consuming than were the free-operant descriptions. We also agreed that the rating scale was much better at focusing the expert listeners on specific aspects of singing.

Discussions with the two reliability evaluators revealed that the scales for *Breathiness* and *Support/Energy* were the least useful and most difficult to evaluate among the nine scales. In an effort make the instrument as efficient as possible, I deleted those two scales from the form. Asterisks in Figure 3.2 indicate the deleted scales.

I assessed the extent to which each listener agreed with my ratings of vocal quality. Thus, I obtained two reliability estimates, one for each reliability observer for each scale. I defined reliability as the percentage of ratings that were within ±1 point of my ratings. The reliability between my ratings and the ratings by the expert singer was .78 for all categories and singing tasks combined. The lowest reliability was .67 for *Evenness* (this variable was rated only in the song performances), and the highest score was .89 for *Intonation* (this variable was rated only in the song performances).

The reliability between my ratings and the ratings by the instrumentalist was .76 for all categories and singing tasks combined. The lowest reliability score of .61 was for *Freedom of Tone* (combined [α] vowel and song), and the highest score was .89 for *Color* (combined [α] vowel and song). I considered these reliabilities acceptable.

After assessing reliability, I rated all remaining participants' [α] vowel WAV files using the rating scales for the terms *Ring, Freedom, Color, Vibrato* and *Overall*. I rated all remaining participants' solo piece using the terms *Ring, Evenness, Freedom, Color, Intonation, Vibrato,* and *Overall* (See Figure 3.2 for the rating instrument).

LISTENER RATINGS

Using my ratings for all 66 recordings on the [α] vowel for 11 subjects, I constructed a matrix of bivariate correlations among the 5 assessment variables: *Overall*, *Ring, Freedom, Vibrato,* and *Color* (see Table 3.6). The evaluation variable *Overall* was significantly and positively correlated with all other variables, and the strongest correlation was between *Overall* and *Ring*. *Ring* was positively correlated with *Color* and *Vibrato*. *Vibrato* was also positively correlated with *Freedom*.

Table 3.6
Bivariate correlations among five assessment variables for the [α] vowel performances

	Overall	Ring	Freedom	Vibrato	Color
Overall	1				
Ring	0.57*	1			
Freedom	0.38*	0.02	1		
Vibrato	0.38*	0.37*	0.30*	1	
Color	0.35*	0.24*	0.04	0.23	1

Pearson's r, * $p < .05$

I applied the same procedure to the ratings of the 66 solo piece performances, this time with the seven assessment variables: *Overall, Ring, Freedom, Vibrato, Color, Intonation,* and *Evenness* (see Table 3.7). As expected, I found significant positive correlations between *Overall* and all evaluation variables except *Color*. The strongest correlation was between *Overall* and *Evenness*. *Evenness* was also strongly correlated with *Vibrato*. *Intonation* was weakly correlated with *Freedom* and *Evenness*. The ratings of *Color* were moderately correlated with *Ring*. Brighter tone quality (*Color*) was associated with greater *Ring*. In addition, the ratings for *Ring* and *Vibrato* were not significantly correlated with *Intonation* in the solo piece performance.

Table 3.7
Bivariate correlations among seven assessment variables for the solo piece performances

	Overall	Ring	Freedom	Vibrato	Color	Intonation	Evenness
Overall	1						
Ring	0.44*	1					
Freedom	0.57*	0.07	1				
Vibrato	0.57*	0.41*	0.36*	1			
Color	0.22	0.36*	0.10	0.22	1		
Intonation	0.26*	0.16	0.29*	0.14	0.04	1	
Evenness	0.65*	0.31*	0.40*	0.57*	0.01	0.27*	1

Pearson's r, * $p < .05$

Rating results for the [α] vowel performances

I conducted a one-way repeated-measures ANOVA for each evaluation variable (*Overall, Ring, Vibrato, Freedom,* and *Color)* for the [α] vowel performances, comparing listener ratings for all participants among the six performance conditions: Baseline, Vibrato, Soft Palate, Microphone (near), Stand (middle), Point (far).

The number of participants relative to the number of evaluation variables obviated the use of multivariate analysis of variance (MANOVA). In the interest of being conservative in my application of statistics, I used a Bonferroni correction procedure to adjust the p-values in the univariate F-tests. In the univariate ANOVAs of the five evaluation variables in the [ɑ] vowel performances, I considered p-values lower than .01 statistically significant. Table 3.8 reports the means and ±1 standard deviation for the evaluation variables in the [ɑ] vowel performances.

Table 3.8
Means and standard deviations for the evaluation variables in the [ɑ] vowel performances

	Overall*		Ring*		Vibrato		Freedom		Color	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Baseline	3.00	.63	2.91	.70	3.36	.81	4.18	.70	3.09	.83
Vibrato	3.36	.92	3.18	.87	3.64	1.03	4.36	.50	3.09	.94
Soft Palate	2.45	.82	3.27	.79	3.45	.93	3.73	.79	2.27	1.10
Mic (near)	3.55	.93	3.91	.83	3.82	.75	4.00	1.00	2.82	.87
Stand (middle)	3.82	.98	4.36	.67	3.82	.41	3.91	.94	3.18	.98
Point (far)	3.82	.98	4.45	.52	3.64	.51	3.82	.75	3.09	1.04

*Significant evaluation variable, $p < .01$.

Performance condition significantly affected the ratings for *Ring*, $F(3.39, 33.93)^{*} = 8.86$, $p < .001$; pairwise comparisons (with Bonferroni correction) revealed significant differences between the Baseline and Stand (middle) conditions, $p = .04$, and between the Baseline and the Point (far) conditions, $p = .001$. There were no other significant differences among the means of the six conditions for *Ring* revealed in the pairwise tests (see Figure 3.3).

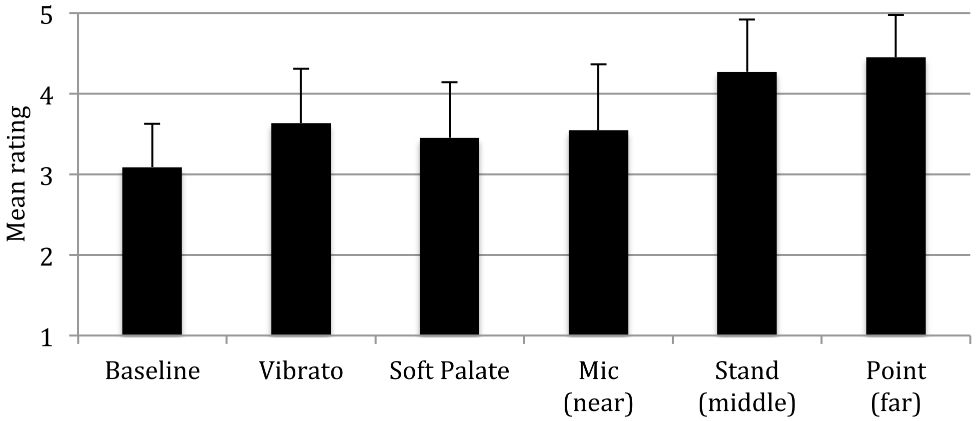


Figure 3.3. Mean [ɑ] vowel performance ratings for *Ring* in the 6 focus of attention conditions. Error bars represent ±1 standard deviation. Scale anchors: 1 = no ring, 5 = nice ring.

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[*] Greenhouse-Geisser adjusted degrees of freedom

I also found a significant effect of condition on the ratings of *Overall Vocal Quality*, $F(5, 50) = 3.85, p = .005$; in pairwise comparisons (with Bonferroni correction) a difference between the means approached significance between the Soft Palate and the Point conditions, $p < .08$ (see Figure 3.4). The Soft Palate condition had lower ratings for *Overall* than all other conditions.

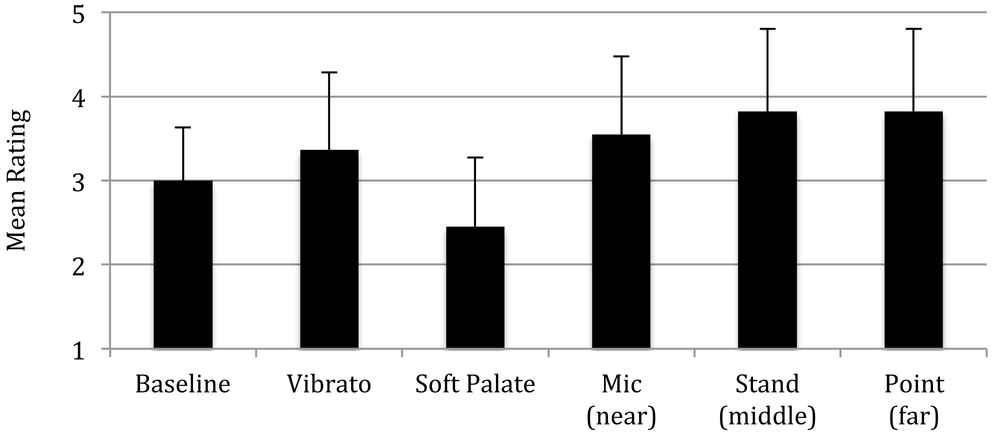

Figure 3.4. Mean [ɑ] vowel performance ratings for *Overall* in the 6 focus of attention conditions. Error bars represent ± 1standard deviation. Scale anchors: 1 = poor, 5 = superior.

I found no significant effects of condition in terms of the remaining evaluation variables: *Freedom*, $F(3.15, 31.52)^{*} = 1.28, p = .30$, *Vibrato*, $F(5, 50) = 0.88, p = .50$, or *Color*, $F(5, 50) = 1.75, p = .14$.

Rating results for the solo piece performances

Following the same procedure for the solo piece, I conducted a one-way repeated-measures ANOVA for each evaluation variable (*Overall, Ring, Evenness, Vibrato,*

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[*] Greenhouse-Geisser adjusted degrees of freedom.

Freedom, Intonation, and *Color)*, comparing listener ratings for all participants among the six performance conditions, Baseline, Vibrato, Soft Palate, Microphone (near), Stand (middle), Point (far).

Again, the number of participants relative to the number of evaluation variables obviated the use of multivariate analysis of variance (MANOVA). I again used a Bonferroni correction procedure to adjust the p-values in the univariate F-tests. In the univariate ANOVAs of the seven evaluation variables in the solo piece performances, I considered p-values lower than .01 statistically significant. Table 3.9 shows the means and ±1 standard deviation for the solo piece performances.

Table 3.9

Means and standard deviations for the evaluation variables in the solo piece performances

	Overall*		Ring*		Evenness		Vibrato		Freedom		Intonation*		Color	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Baseline	2.91	.70	3.09	.54	3.27	.65	3.36	.51	3.64	1.12	4.00	.45	2.82	.60
Vibrato	2.82	.75	3.64	.67	3.27	.65	3.45	.52	3.18	1.08	3.54	.69	3.00	1.18
Soft Palate	2.91	1.14	3.45	.69	3.72	.65	3.55	.52	3.45	.93	4.00	.45	2.64	.92
Mic (near)	3.36	.67	3.55	.82	3.72	.47	3.55	.82	3.55	1.04	4.00	.45	3.27	.91
Stand (middle)	3.91	.94	4.27	.65	4.00	.77	4.00	.63	3.91	.94	4.09	.54	3.36	.67
Point (far)	3.73	.65	4.45	.52	3.82	.60	3.73	.65	3.64	.92	4.09	.30	3.27	.65

*Significant evaluation variable, $p < .01$.

As with the [ɑ] vowel performances, focus condition significantly affected expert ratings of *Ring* in the solo piece performances, $F(2.35, 23.51)^*$ = 8.06, p = .001. Pairwise

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[*] Greenhouse-Geisser adjusted degrees of freedom

comparisons (with Bonferroni correction) revealed significant differences in the means for *Ring* between the Stand (middle) condition performances and the Baseline, $p = .001$, and Microphone, $p = .006$, conditions. There were also significant differences between the means for the Point (far) condition and Baseline, $p < .001$, Vibrato, $p = .07$, and Soft Palate, $p = .06$, conditions. The middle and far external conditions had higher ratings in *Ring* than Baseline, Soft Palate, Vibrato, and Microphone conditions (see Figure 3.5).

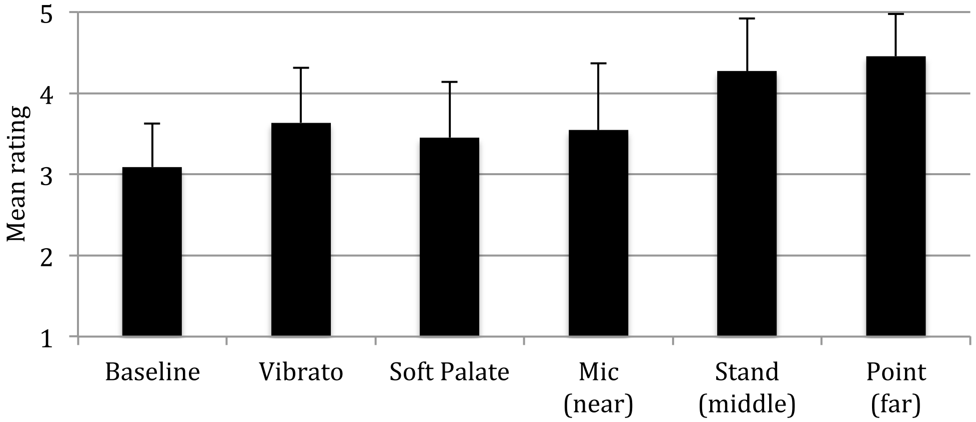

Figure 3.5. Mean solo piece performance ratings for *Ring* in the 6 focus of attention conditions. Errors bars represent ±1 standard deviation. Scale anchors: 1 = no ring, 5 = nice ring.

Focus condition significantly affected ratings of *Overall Vocal Quality, F*(5, 50) = 3.56, *p* = .008. Pairwise tests (with Bonferonni correction) revealed no significant differences between the means for *Overall*. The pairwise comparisons with the lowest probability values were between the Baseline condition and the Stand (*p* = .12) and Point (*p* = .16) conditions. The mean ratings for *Overall* were higher in the Stand (middle) condition than all other conditions including the Point condition in the solo piece (see Figure 3.6).

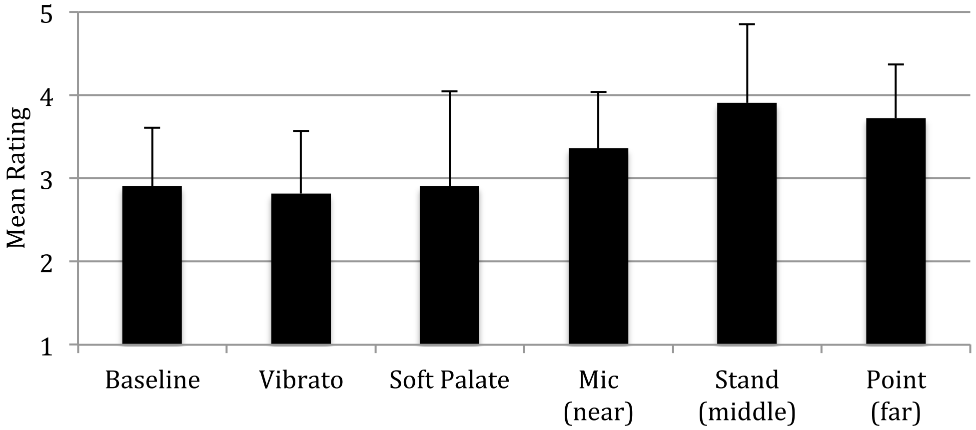

Figure 3.6. Mean solo piece performance ratings for *Overall* in the 6 focus of attention conditions. Errors bars represent ±1 standard. Scale anchors: 1 = poor, 5 = superior.

The ANOVA revealed that focus condition significantly affected expert ratings of *Intonation,* $F(5, 50) = 3.23$, $p = .01$, but there were no significant pairwise comparisons (with Bonferroni correction) among the means for the evaluation variable *Intonation*. Figure 3.7 presents the means for *Intonation*.

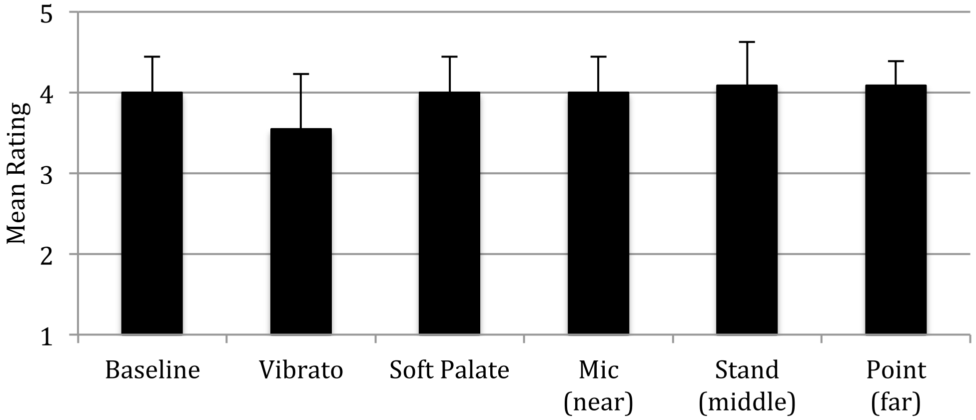

Figure 3.7. Mean solo piece performance ratings for *Intonation* in the 6 focus of attention conditions. Errors bars represent ±1 standard deviation. Scale anchors: 1 = inconsistent, 5 = consistent.

No significant effects of condition were found in the ratings of *Evenness,* $F(5, 50) = 2.17$, $p = .03$, *Vibrato*, $F(5, 50) = 1.69$, $p = .15$, *Freedom*, $F(2.83, 28.28)^{*} = 0.96$, $p = .42$, or *Color,* $F(2.90, 29.02)^{*} = 1.40$, $p = .26$.

Acoustic analyses

There were many audible differences identified by expert listeners among the six focus conditions in both singing tasks. I sought to determine whether the differences

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[*] Greenhouse-Geisser adjusted degrees of freedom

among singers' performances could also be identified through acoustic evaluation. For each [ɑ] vowel and solo piece performance, I used Praat acoustic software to determine the mean harmonic-to-noise ratio, intensity, and formant frequencies (F1-F5) from the long-term average spectrum (LTAS) of each sound file. I applied one-way repeated measures ANOVAs to test the effects of condition on the mean values of harmonic-to-noise ratio and intensity. I also ran one-way repeated measure ANOVAs on three acoustic measurements associated with resonance/ring: the difference in Hz between F4 and F3, the difference in Hz between F5 and F3, and the Singing Power Ratio (SPR).

Acoustic results for the [ɑ] vowel performances

Harmonic-to-noise ratio is the ratio of the amplitudes of periodic components to aperiodic components in a complex tone and reflects the proportion of noise in the tone.

I found no significant effects of condition in the [ɑ] vowel performance for harmonic-to-noise ratio, $F(5, 50) = 1.32$, $p = .27$.

Analysis of the intensity measure for the [ɑ] vowel revealed a significant effect of conditions on Intensity, $F(5, 50) = 5.71$, $p < .001$; pairwise comparisons (using Bonferroni correction) revealed differences among the means between the Baseline and Point condition, $p = .05$, and between the Vibrato condition and the Soft Palate, $p = .05$, and Stand, $p = .01$, conditions. Figure 3.8 shows the intensity levels in each condition for the [ɑ] vowel. The lowest mean Intensity level was found in the Vibrato condition (67.41 dB) and the highest intensity was found in the Point condition (69.97 dB), a difference of 2.56 dB.

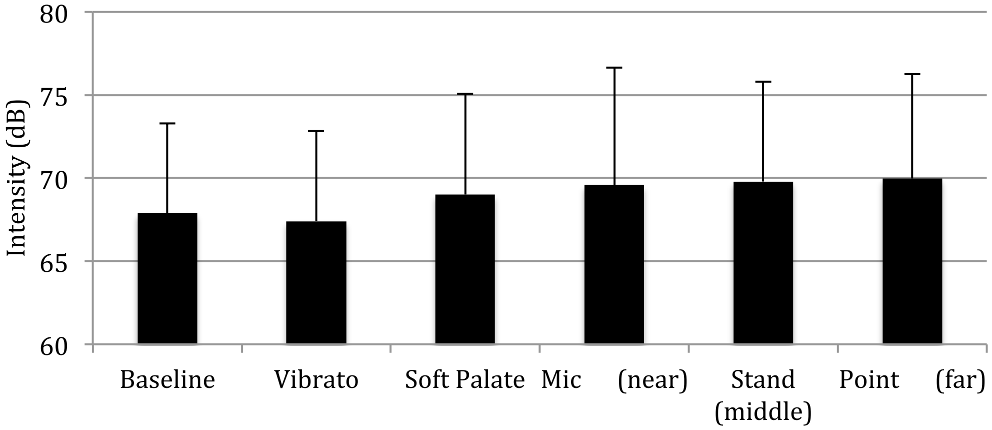

Figure 3.8. Mean [ɑ] vowel performance Intensity levels in the 6 focus of attention conditions. Errors bars represent ±1 standard deviation.

I also examined individuals' intensity level differences among conditions and found differences ranging from 2.45 to 8.36 dBs. The smallest within-subject difference was found between the Microphone (68.50 dB) and Soft Palate (71.17 dB) conditions in the performances of Participant *D*. The largest within-subject difference was found between the Vibrato (70.04 dB) and Point (78.39 dB) condition performances of Participant *A*.

Recall that in terms of expert ratings of tone quality, the variable most affected by condition was the tonal characteristic labeled *Ring*. Increased ring or resonance is a result of singers' adjusting the articulators in a way that increases the amplitudes of the partials around 3000 Hz, the so-called singer's formant (Sundberg, 1974).

Using the formant frequency information, I calculated the difference in Hz between F4 and F3 in each performance. A one-way repeated measures ANOVA revealed no significant effects of condition in the [ɑ] vowel performance for the difference between F4 and F3, $F(5, 50) = 0.70, p = .63$.

Another common measurement associated with listener perceptions of *Ring* is the difference in Hz between F5 and F3. Again, I found no significant effect of condition for the difference between F5 and F3 in the [ɑ] vowel performance, $F(1.37, 13.67)^{*} = 1.16, p = .34$.

I also calculated the SPR, another measurement associated with resonance/ring, for each performance. SPR is the difference in amplitude between the highest peak (greatest amplitude of single partial) in the 2-4 kHz range and the highest peak in the 0-2 kHz range. Previous research has shown that SPR values are inversely proportional to perceptions of ring (Omari et al., 1996).

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[*] Greenhouse-Geisser adjusted degrees of freedom

I found a significant effect of condition in the [ɑ] vowel performances for SPR, $F(2.81, 28.05)^{*} = 3.26$, $p = .04$. In pairwise comparisons (with Bonferroni correction), a difference of the means that approached significance was found between the Microphone and Point conditions, $p = .11$ (see Figure 3.9).

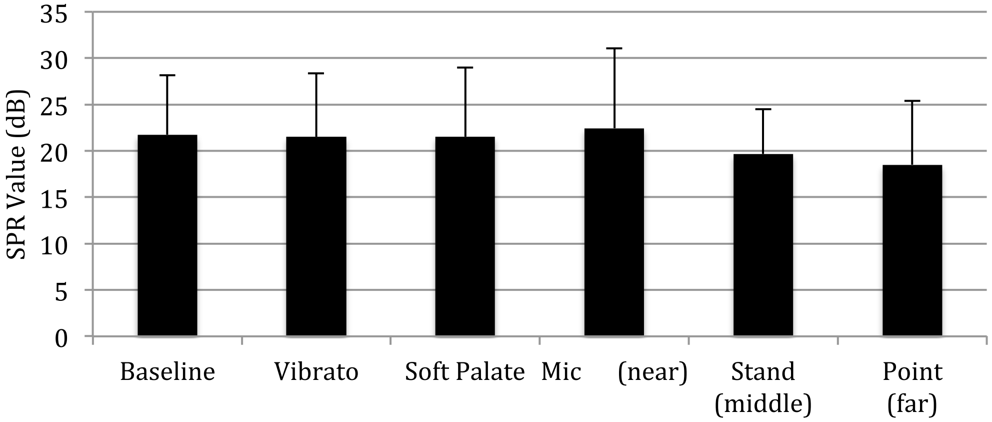

Figure 3.9. Mean [ɑ] vowel performances for SPR in the 6 focus of attention conditions.

Acoustic analysis of the solo performance

Using acoustic data from the recordings of the solo pieces, I applied one-way repeated measure ANOVAs to the measurements of harmonic-to-noise ratio, intensity, and the three measurements associated with resonance/ring (difference between F5 and F3, the difference between F4 and F3, and SPR).

I found no significant effects of condition attributable to harmonic-to-noise ratio, $F(5, 50) = 0.98$, $p = .44$, or Intensity, $F(5, 50) = 0.98$, $p = .44$, in the solo piece performances. I also found no significant effect of condition for the measurements associated with resonance/ring in the solo piece performances: difference between F5 and

F3, $F(2.64, 26.35)^* = 0.93, p = .47$, difference between F4 and F3, $F(2.22, 22.21)^* = 0.49$, $p = .78$, and SPR, $F(5, 50) = 1.28, p = .29$.

These results indicate that the effects of condition on vocal tone that were evident to human listeners were not easily detectable in terms of acoustic measurements of the variables that I assessed. Only Intensity and SPR measurements of the [α] vowel performances revealed significant differences among conditions, and given the number of ANOVAs that I performed on the data, these results must be considered with some caution.

Self-reports of attentional focus

After participants performed the baseline condition, I asked them to describe what they had focused attention on during the performance. Responses varied widely and unsystematically; that is, I found no relationships among these responses and the tone of singers' Baseline performances. Three participants reported thinking about emotions, character, or how their voice related to the orchestration of the piece. Two participants reported focusing on the space in the room and filling the room or letting the voice bounce off the back wall. Three participants reported thinking about technical aspects of singing like keeping the abdomen relaxed, breathing, and maintaining balance between head and chest voice. Two focused on their own vocal tiredness or that the [α] vowel was positioned at their vocal break, and one focused on what their professor would say about their performance if in the room.

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[*] Greenhouse-Geisser adjusted degrees of freedom

DISCUSSION

My purpose in this study was to determine whether the vocal tone quality of experienced singers is affected by directing their attention to different aspects of their singing. The results are consistent with those observed in other motor tasks.

In a previous pilot experiment (Atkins & Duke, 2013), an expert listener ranked 30 untrained singers' performances of the same [α] vowel task used in the study described in this chapter under five different focus of attention conditions. The untrained singers performed best when focusing on directing their sound to a microphone located 18 inches in front of them, to a more distal point on the wall, and when directing the sound to their fingertips placed on the mask of the face.

In the current study, I analyzed three expert judges' descriptions of vocal tone quality in two singing tasks to determine which aspects of vocal tone were affected by focus of attention conditions. In 122 of 132 sound files, at least two expert listeners identified the same vocal characteristics, a level of agreement that seems particularly notable given that the listeners responded freely and were given no guidelines about what to listen for. As might be expected, I found that even though judges often agreed in their descriptions, they often did not discuss the same aspects of vocal tone with respect to each recorded performance, making it more difficult to clearly identify and report the effects of the condition on tone quality.

I created an evaluation instrument based on previous research and the expert listeners' descriptions. The "Auditory-perceptual rating instrument for operatic singing voice" developed by Oates and colleagues (2006) included many of the aspects of singing cited by expert listeners in the current study. I used this instrument as a starting point to develop an evaluation tool specific to this experiment. Compared to the free-operant descriptions, the evaluation instrument I created focused on specific aspects of singing, thus providing more interpretable results.

Results of the expert ratings revealed a significant effect of focus condition on *Ring* and *Overall Vocal Quality* in performances of the [α] vowel, and on *Ring*, *Overall Vocal Quality,* and *Intonation* in the solo piece performances. Ratings for *Ring* were highest in the more distal focus conditions both in the [α] vowel performances and in the solo piece performances.

Baseline condition

I had expected that the Baseline condition would be performed well by the trained singers who participated in this experiment, but listeners assessed 7 of 11 participants' performances of the [α] vowel negatively in terms of tone production. The Baseline condition was often rated lowest in terms of *Overall*, *Ring*, and *Vibrato* (refer to Table 3.8).

Similar results occurred in the participants' solo piece performances in the Baseline condition. Expert listeners described 7 of the 11 participants' solo piece performance negatively, and mean ratings for *Ring* and *Vibrato* were lowest in the Baseline condition.

Six of the performers in this study had just graduated high school and had been involved in the opera camp for just a few weeks. Their lack of experience may account for the negative evaluations of tone production in the Baseline condition. The Baseline condition was always performed first, and although the two singing tasks were practiced briefly before recording began, the lower ratings of the baseline performances may be at least partially attributable to presentation order.

Internal conditions

I defined the Soft Palate and Vibrato conditions as internal focuses of attention. Placement of the soft palate is of course a physical aspect of vocal production and attending to vibrato prompts attention to the physical sensations in the mouth and larynx. I had hypothesized that participants would perform less well in these two conditions than in the conditions prompting a more distal focus of attention. I found in both the listeners' descriptions and in the ratings, when considered together, that the Soft Palate and Vibrato conditions were generally evaluated less positively than the external conditions.

In terms of their verbal descriptions of tone quality in particular, expert listeners' described 5 of the 11 participants' [α] vowel performances in the Soft Palate condition negatively overall and only 2 participants' performances positively. Expert listeners' described 6 of 11 participants [α] vowel performance in the Vibrato condition negatively. No participant's Vibrato condition was described positively in the [α] vowel performance.

Expert listeners described 3 of the 11 participants' solo piece performance in the Soft Palate condition negatively overall, and 3 participants' performances positively. In the Vibrato condition, expert listeners described 6 of 11 participants' solo piece performances negatively, and 3 participants' performance positively.

In terms of the evaluation variables that were most influenced by focus of attention conditions, ratings of *Ring* and *Overall Vocal Quality,* were lower in the Soft Palate and Vibrato conditions than in the most distal external conditions.

External focus of attention conditions

I had expected the Microphone condition to result in more positive effects on tone quality compared to the Baseline, Vibrato, and Soft Palate conditions, especially in light of the fact that untrained singers performed well in the Microphone condition in a previous experiment (Atkins & Duke, 2013). In describing performances in the Microphone condition in the current study, expert listeners described 7 of 11 singers' [α] vowel performances and 4 singers' solo piece performances negatively. The participants in the present study may have "held back" a bit in light of the microphone's proximity. One participant mentioned at the end of the experiment that he was worried he would distort the recording in this condition because the microphone was so close.

Performances in the Stand and Point conditions were described more positively overall than were the performances in the other conditions. There was less of an observable effect in the verbal descriptions for the [α] vowel performances, however. In terms of their verbal descriptions of tone quality in the Stand condition, expert listeners described 4 participants' [α] vowel performance in the Stand condition positively, and 2 participants' negatively. In the [ɑ] vowel performances in the Point condition, listeners described 2 participants positively and 2 participants negatively.

The effect was more pronounced in the descriptions of the solo piece performances. Expert listeners described 6 of 11 participants' solo piece performances in the Stand condition positively and 3 participants' solo piece performances negatively. Similar results were found for the Point condition. Listeners described 6 of 11 singers solo performances positively in the Point condition, and only 3 participants' solo performances negatively.

Performances in the Stand and Point conditions also obtained the highest mean ratings among the six conditions on every evaluation variable compared to the ratings in all other conditions in both the [ɑ] vowel performances and the solo piece performances.

The Stand and Point conditions resulted in the most positive effects on the majority of singers in this study, especially in terms of resonance/ring. Resonance/ring was the positive descriptor identified most often by expert listeners in these conditions.

Distal effects

I was also interested to learn whether focusing at different distances from the vocal source affects tone quality. In the focus of attention literature, superior physical performances have been associated with distal focus conditions in a balance task (McNevin et al., 2003), a golf pitch shot (Bell & Hardy, 2009), a long jump (Porter, Anton, & Wu, 2012), and a piano keyboard sequence task (Duke et al., 2011), among others. Depending on the difficulty of the task and level of expertise, the farther away the participant's focus from the source of the movement, the more positive the target outcomes.

In the current study, participants directed their sound to a microphone 18 inches in front of them (near), a music stand approximately 9 feet in front of them (middle), and a point on the wall approximately 19 feet in front of them (far). Pairwise comparisons revealed significant differences in ratings of *Ring* among the three distances in both singing tasks. The Microphone condition (near) resulted in lower ratings for *Ring* than did the Stand condition (middle) and Point (far) conditions. In the current study, the farther from the vocal mechanism singers directed their sound, the better the ratings for *Ring*.

Acoustic measurements

To date, no studies comparing the effects of various vocal techniques have found reliable differences in acoustic measures of tone. Expert listeners in two previous experiments identified tone quality differences through ratings of *Overall Vocal Quality, Richness,* and *Vibrato*, and in rankings of two contrasting singing tasks, yet no differences were found in acoustic measurements of resonance (SPR, ER) (Callinan-Robertson et al., 2006; Kenny & Mitchell, 2006).

In the current study, I found that focus conditions significantly affected measures of SPR values and intensity (dB) in performances of the [α] vowel, but not in the solo piece performances. Recall that the [α] vowel performances were only 2 s in duration. I extracted the recordings from performances of a brief 3-note pattern; thus, the recordings

I analyzed were devoid of note onsets. Although I found a significant effect of focus of attention condition on intensity, the [α] vowel sound sample was quite limited, and the acoustic results should be interpreted with caution. In light of the fact that no other studies have shown significant effects of condition on acoustic measurements associated with tone quality, it seems that expert listeners' assessments of vocal tone may be the most beneficial and reliable means of evaluating vocal tone.

Of course, all participants were able to hear the sounds of their own voices during the experiment, and trained singers have learned to make adjustments in their singing based on auditory feedback. Yet, few participants reported focusing on the sound of their voice when they sang the baseline performances (with no focus instructions). The self-report of "letting the tone bounce off the back wall" was the only self-report focus related to auditory feedback.

Further research is warranted to explore the relationships between these and other singing tasks with singers of varying ages and experience levels, and with varied singing tasks. A replication of this experiment is recommended with a larger sample to test the generalization of these results for a similar population.

Both teachers and students alike work to efficiently improve vocal performance and carrying power in Western classical singing. The results of the present study, together with results in many other motor learning investigations, show focus of attention affects performance outcomes and that external focus conditions are often associated with superior performance (for a review see Wulf, 2013).

Singing teachers rely on a variety of techniques acquired through observations and trial and error to improve performance. Very few studies have tested these techniques systematically. This study provides a protocol and evaluation tool to enable researchers to further test current vocal practices. Through a replication of this study and continued research comparing the effectiveness of specific vocal tasks, music researchers may continue to provide further insight into the processes of music learning.

CHAPTER 4: EXPERIMENT 2

Results from the experiment reported in the previous chapter revealed that trained singers produced better resonance/ring when they focused their attention on distal points in the room (Stand and Point) than when they focused on the position of the Soft Palate, keeping the Vibrato steady, directing the sound to a Microphone (near), and when they had no focus instructions. I found significant effects of focus condition on the ratings of *Ring* in recorded performances of a single [α] vowel and in recorded performances of excerpts of solo repertoire. Again, ratings were highest when singers focused their attention on distal targets (Stand and Point).

I present in this chapter a modified replication of the experiment described in Chapter 3, designed to test the effects of focus of attention with a larger sample singing multiple tasks in a large performance space. I recorded college voice majors in an acoustically live 175-seat recital hall in the Sarah and Ernest Butler School of Music at The University of Texas at Austin. I added to the focus instructions from the previous experiment another condition in which I asked participants to focus on “filling the room with your sound,” an instruction often given to vocalists singing in large performance spaces.

I changed the placement of the microphone and used in its place an empty tripod as a focus target. In the previous study, the Microphone condition resulted in the greatest variability among all of the conditions on all evaluation variables. Some participants reported in that experiment that the microphone seemed “too close” and that they felt awkward directing their sound toward a microphone is such close proximity. In order to accommodate this concern, I repositioned the microphone and replaced it as a focus target with an empty tripod.

I asked the singers to perform the first phrase of “My Country ’Tis Of Thee” in addition to the tasks from the previous experiment. I was interested in finding out whether a well-known, but not well-practiced, melody would lead to similar results. To determine whether the focus effects were influenced by vocal register, I also asked participants to sing the [α] vowel pattern in two different registers.

In the study reported in Chapter 3 and in an earlier study (Atkins & Duke, 2013), I found no reliably measurable effects of focus condition in terms of acoustic variables (H-to-N ratio, F4-F3, F5-F3, and SPR). Other vocal studies comparing similar vocal tasks also produced no significant effects in terms of acoustic measurements (SPR, ER), even when expert listeners reported effects through ratings and rankings (Callinan-Robertson et al., 2006; Kenny & Mitchell, 2006). Therefore, I did not analyze acoustic data in the current experiment.

Like the previous experiment, the experiment in this chapter was designed to answer the following question: In what ways and to what extent is the tone quality of trained singers affected by their focus of attention while singing?

METHOD

Participants were 22 trained singers (8 sopranos, 5 alto/mezzos, 3 tenors, 4 baritones, and 2 basses) enrolled in various degree programs in the Sarah and Ernest Butler School of Music at The University of Texas at Austin. Participants’ ages ranged from 18-25 years old (*M* = 21 years old, *Mdn* = 21 years old). Due to technical difficulties (incomplete recordings), 1 mezzo (participant L) and 1 baritone (participant O) were not included in the analyses.

Participants were recorded individually in 30-min sessions. Prior to singing, participants answered questions pertaining to age, voice classification, the degree they were pursuing, the number of years experience performing with a choir, the number of years of private voice lessons, other instruments played, and the number of years of private lessons on those instruments.

The experimental procedure met all of the requirements for human subjects participation concerning confidentiality and informed consent. All participants volunteered to take part in the study, and they received no compensation for their participation.

Of the 20 participants, 18 were undergraduate students studying vocal performance (6), music studies (9), music business (2), and biomedical engineering (1). One soprano was earning a doctor of musical arts degree and another a master's degree in opera performance. All participants reported taking private voice lessons and singing with choirs. Average duration of choir participation was 9 years (*Mdn* = 6 years) and ranged from 4 to 17 years. The average duration reported for private voice instruction was 6 years (*Mdn* = 4 years), ranging from 1 to 8 years. Fourteen participants also reported playing other instruments, including double bass, clarinet, French horn, guitar, mandolin, piano, trumpet, and ukulele. Of those 14, seven had enrolled in private piano instruction (*M* = 6.7 years, *Mdn* = 7 years) ranging from 2 to 11 years.

Recording procedures were nearly identical to those described in Chapter 3. The experimental sessions were held in a 175-seat recital hall. I recorded all performances with the same Sony PCM-D50 digital audio recorder (96kHz/24 bit) and its on-board microphone used in the previous experiment. The empty recital hall was acoustically a somewhat live performance space. I checked recording levels prior to the start of each participant's recording session using Bose QuietComfort2 Acoustic Noise Cancelling Headphones. I set all record levels between 3.5 or 4.0 to accommodate for the individual singers' loudness levels and to avoid undesired reverberation or feedback. Recording was continuous throughout each participant's session; the gain (recording level) remained constant across all conditions. A separate video recording was also made to document the procedures.

I oriented the singers to four singing tasks as I set the microphone levels. In each focus of attention condition, participants first sang two 3-note patterns on an [α] vowel, each pattern starting on a different pitch. The participants performed a low-pitch [α] vowel pattern in the octave (range) appropriate to each participant's vocal range immediately followed by a high-pitch [α] vowel pattern. Sopranos and tenors sang the low-pitch [α] vowel pattern beginning on G, ascending to A, and then returning to G, immediately followed by a high-pitch [α] vowel pattern beginning on D, ascending to E, and returning to D. Altos and basses sang the low-pitch [α] vowel pattern beginning on C, ascending to D, and returning to C, immediately followed by the high-pitch [α] vowel pattern beginning on G, ascending to A, and returning to G.

Participants then performed a cappella the first full phrase of “My Country ’Tis Of Thee” through the words “of thee I sing.” Sopranos and tenors performed in the key of G. Altos, baritones, and basses performed in the key of E♭. Finally, I asked participants to choose a well-known solo piece and to sing the first one or two phrases from memory (enough of the piece to generate a minimum of 7-8 s of singing). I provided the starting pitch for this performance in the key in which the piece had been learned.

These four tasks (low-pitch [α] vowel, high-pitch [α] vowel, “My Country ’Tis Of Thee,” and solo piece) were performed one after the other under seven different conditions. Following a baseline condition, participants performed the six directed focus of attention conditions arranged in a different random order for each participant.

As in Experiment 1, each condition directed singers to focus their attention on a different target: focusing their attention to the position of their soft palate (Soft Palate), focusing their attention on keeping their vibrato steady and consistent (Vibrato), directing their sound to a tripod 18 inches in front of them at mouth height (Tripod - near), directing their sound to a chair in the center of the performance hall, approximately 24 feet directly in front of the singer (marked with a piece of paper) (Chair - middle), directing their sound to a piece of paper on the back wall of the performance hall approximately 40 feet from the singer and approximately 8 feet above the level of the microphone (Point - far), and thinking about filling the room with their sound (Fill).

All participants started with the baseline condition (no focus of attention instructions). After singers performed the two 3-note [α] vowel patterns, I asked them to describe what they had focused their attention on while singing. They next performed the first full phrase of “My Country ’Tis Of Thee,” and following their performance described again what they had focused their attention on while singing. The final task was the performance of the first one or two phrases of a well-known solo piece. After completing the solo piece performance, they described their focus of attention.

Each participant then performed the same tasks in the remaining six conditions. The six focus of attention conditions were arranged in a separate random order for each subject (determined using a random number generator). Again, participants first sang the 3-note [α] vowel pattern on two different pitches. When finished, I asked them if their focus had remained on the target that I had directed them to focus on. Participants then performed the first phrase of “My Country ’Tis Of Thee” and again reported whether they had focused their attention as directed. This was followed by the performance of the excerpt of the solo piece, after which participants again reported whether they had focused their attention as directed.

In the few instances when the response to the focus of attention question was No, I asked the participants to identify what they had focused attention on during the performance.

After all singing tasks were completed under all seven conditions, I asked the participants the following questions:

1. Which of the focus of attention instructions were like or unlike what your voice teacher asks you to do?
2. Were there any instructions that made you feel awkward and uncomfortable?

3. Were there any instructions that made you feel especially comfortable or made it easier to sing?
4. Which instructions do you feel affected your sound the most, either positively or negatively?

Preparation of recordings for analyses

Using the same procedures described in Chapter 3, I isolated and extracted a 2-s excerpt from the last note of both 3-note [ɑ] vowel patterns in each condition and saved each pitch in a separate WAV file (2 pitch levels in 7 conditions for each of 20 participants = 280 WAV files). I extracted the middle portion of the phrase from "My Country 'Tis Of Thee" (the words "sweet land of liberty") for each participant in each condition and saved each as a separate WAV file. One participant (T) did not sing "My Country 'Tis Of Thee" in one condition (experimenter error) and was not included in the analysis for that singing task (7 conditions for each of 19 participants = 133 WAV files). I also extracted the recording of the solo piece performed under each condition and saved each as a WAV file (7 conditions for each of 20 participants = 140 WAV files). I used 553 WAV files in the analyses reported below.

As I extracted the singing samples from the continuous recording, I transcribed the negative responses to the question, "While you were performing the 3-note pattern/'My Country 'Tis Of Thee'/solo piece, did you maintain your focus on directing the sound to the Soft Palate/Vibrato/Tripod/Chair/Point/Fill condition?"

Rating/listening procedures

Using the rating sheet developed in the previous experiment (see Figure 4.1), I rated and described all examples in a quiet, distraction-free room while listening to the recordings through Bose QuietComfort2 Acoustic Noise Cancelling Headphones connected to the headphone jack of an Apple MacBook Pro computer. To reduce fatigue I listened in 1½-hour sessions (with a 5-minute break at 45 minutes) every other day until all 553 WAV files were rated (approximately 6 sessions). As I rated, I made brief notes for every condition of the most obvious differences I heard between conditions.

I was blind to the focus condition associated with each WAV file except for the baseline condition. I rated the recordings of the solo pieces sung by all 20 participants first, followed by all participants' recordings of "My Country 'Tis Of Thee." I then rated the first participant's low-pitch [ɑ] vowel and high-pitch [ɑ] vowel. I repeated this procedure for the remaining participants.

To rate the recordings, I opened the seven WAV files (7 conditions) for one task sung by one participant (either solo piece, "My Country 'Tis Of Thee," or vowels) using QuickTime software on a MacBook Pro. I first listened to the seven recordings one after the other, without recording any ratings or notes. After I listened to the recordings of one task one time, I replayed the recordings as many times as needed to rate and briefly take notes about differences among the performances. I rated the recordings of the solo pieces and the recordings of "My Country 'Tis Of Thee" in terms of *Ring, Evenness, Freedom of Tone (Freedom), Color, Intonation, Vibrato,* and *Overall Vocal Quality (Overall).* I rated the recordings of the [ɑ] vowels in terms of *Ring, Freedom, Color, Vibrato,* and

Overall Vocal Quality.

Ring (brilliance of tone)

1	2	3	4	5
no ring				nice ring

Evenness throughout the range (ability to sing freely throughout the pitch and dynamic range without inappropriate change in voice quality) **SOLO PIECES ONLY**

1	2	3	4	5
uneven air/resonance				even air/resonance

Freedom of Tone (voice quality that is free and natural, without strain)

1	2	3	4	5
pressed/pushed				natural/free

Color

1(-)	2	3 (+)	4	5 (-)
over-dark/covered	dark	balanced	bright	over-bright

Intonation (singing in tune) **SOLO PIECES ONLY**

1	2	3	4	5
inconsistent				consistent

Vibrato (regular and smooth undulation of frequency of the tone)

1	2	3	4	5
inconsistent				consistent

Overall Vocal Quality (an overall rating of the aesthetic and technical quality compared to the other conditions – there may be ties.)

1	2	3	4	5
poor				superior

Figure 4.1. Rating instrument.

Reliability

An independent expert listener (a voice professor with more than 20 years experience who had participated in the study reported in Chapter 3) rated and described approximately 23% of the WAV files. I randomly selected (using a random number generator) the following WAV files to be evaluated by the listener: five participants' solo piece recordings in each of the seven conditions; five participants' recordings of "My Country 'Tis Of Thee" from each condition; four participants' low-pitch [α] vowel recordings from each condition; and four participants' high-pitch [α] vowel recordings from each condition. Thus, the expert listener rated 126 of the 553 WAV files, following the same procedure that I had used.

I assessed the extent of agreement between my ratings and those of the independent expert listener. I defined reliability as the percentage of ratings that were within ±1 point of my ratings on each scale. The reliability between my ratings and the ratings by the expert listener was .89 for all categories in ratings of "My Country 'Tis Of Thee" and the solo piece performances combined. The lowest reliability score was .72 for *Freedom*, and the highest score was 1.00 for *Color* followed by .96 for *Ring*.

In the combined low- and high-pitch [α] vowel recordings, the reliability between my ratings and the ratings by the expert listener was .77 for all categories combined. The lowest reliability score of .63 was for *Freedom*, and the highest score was .88 for *Overall*. I considered these reliabilities acceptable.

RESULTS

Using my ratings for the low- and high-pitch [ɑ] vowel recordings for 20 subjects (140 low, 140 high), I constructed a matrix of bivariate correlations for both the low- and high-pitch [ɑ] vowel conditions among the five assessment variables: *Overall, Ring, Freedom, Vibrato,* and *Color* (see Table 4.1 and 4.2). The *Overall* evaluation variable was positively correlated with *Ring, Freedom*, and *Color* on both the low-pitch and high-pitch [ɑ] vowel. Color was also positively correlated with *Ring* and *Freedom*. *Color* had the strongest correlations with the other evaluation variables. Brighter tone (*Color*) was associated with higher ratings for *Ring* and *Overall* on the high-pitch [ɑ] vowel, and higher ratings for *Ring* and *Freedom* on the low-pitch [ɑ] vowel.

Table 4.1
Bivariate correlations among five assessment variables for the low-pitch [ɑ] vowel performances

	Overall	Ring	Freedom	Vibrato	Color
Overall	1				
Ring	0.33**	1			
Freedom	0.43**	-0.07	1		
Vibrato	-0.02	0.05	0.14*	1	
Color	0.59**	0.33**	0.53**	0.12	1

Pearson's r, $^{**}p < .05$, $^{*}p < .10$

Table 4.2

Bivariate correlations among five assessment variables for the high-pitch [ɑ] vowel performances

	Overall	Ring	Freedom	Vibrato	Color
Overall	1				
Ring	0.30**	1			
Freedom	0.36**	-0.02	1		
Vibrato	-0.05	0.07	0.14*	1	
Color	0.50**	0.62**	0.33**	0.07	1

Pearson's r, **$p < .05$, *$p < .10$

Using the same procedure for the solo piece (140 WAV files) and "My Country 'Tis Of Thee" (133 Wav files), I constructed a matrix of bivariate correlations for each task with the seven assessment variables of *Overall, Ring, Freedom, Vibrato, Color, Intonation,* and *Evenness* (see Table 4.3 solo piece and Table 4.4 "My Country 'Tis Of Thee").

For the solo piece, the *Overall* evaluation variable was positively correlated with all other evaluation variables, and the strongest correlations were with *Ring*, *Vibrato,* and *Evenness*. *Vibrato* and *Evenness* were also moderately correlated. There were no significant correlations between *Ring* and *Freedom*, *Color* and *Intonation*, and *Ring* and *Vibrato*. C*olor* was negatively correlated with *Freedom* and *Evenness*; as *Evenness* and *Freedom* were rated lower, the sound was perceived to be darker.

Table 4.3
Bivariate correlations among seven assessment variables for the solo piece performances

	Overall	Ring	Freedom	Vibrato	Color	Intonation	Evenness
Overall	1						
Ring	0.59**	1					
Freedom	0.48**	0.10	1				
Vibrato	0.66**	0.47**	0.46**	1			
Color	-0.22**	-0.12	-0.31**	-0.09	1		
Intonation	0.48**	0.14*	0.40**	0.47**	-0.13	1	
Evenness	0.59**	0.45**	0.39**	0.57**	-0.20**	0.32**	1

Pearson's *r,* $^{**}p < .05$, $^{*}p < .10$

The correlations among the evaluation variables in the recordings of "My Country 'Tis Of Thee" (Table 4.4) were similar to the results in the solo piece. The only differences in correlations were between *Color* and *Freedom*. *Color* was not significantly correlated with *Overall* or with *Evenness* in "My Country 'Tis Of Thee." *Freedom* and *Ring* were also positively correlated. The strongest correlations were between the evaluation variable *Overall* and the evaluation variables *Vibrato, Ring, Freedom*, and *Evenness*. *Ring* was also moderately correlated with *Evenness*.

Table 4.4
Bivariate correlations among seven assessment variables for "My Country 'Tis of Thee" performances

	Overall	Ring	Freedom	Vibrato	Color	Intonation	Evenness
Overall	1						
Ring	0.57**	1					
Freedom	0.61**	0.37**	1				
Vibrato	0.57**	0.50**	0.36**	1			
Color	-0.06	0.04	0.18**	0.05	1		
Intonation	0.52**	0.38***	0.40**	0.38**	0.18**	1	
Evenness	0.67**	0.58*	0.52**	0.50**	-0.01	0.51**	1

Pearson's r, $^{**}p < .05$

One-way multivariate analyses of variance (MANOVA) were performed to examine the effect of condition on the evaluation variables in each of the four singing tasks. Prior to the MANOVA, sphericity was tested for all evaluation variables. When sphericity was not satisfied, I applied the Greenhouse-Geisser adjusted degrees of freedom procedure.

Rating results for the [α] vowel

I found a significant effect of condition on the combined evaluation variables in both the low-pitch [α] vowel performances, Pillai's Trace = .663, $F(30, 570) = 2.91$, $p < .001$, and in the high-pitch [α] vowel performances, Pillai's Trace = .651, $F(30, 570) = 2.84$, $p < .001$. See Table 4.5 for and 4.6 for the means and standard deviations for the low-pitch and high-pitch [α] vowel performances. It is interesting to note that the mean ratings are very similar between the two different pitches across evaluation variables.

Table 4.5
Means and standard deviations for the evaluation variables in the low-pitch [ɑ] vowel performances

	Overall*		Ring*		Vibrato		Freedom		Color	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Baseline	3.05	.60	2.95	.60	3.45	.69	3.90	.72	3.45	.60
Vibrato	3.20	.83	2.85	.93	3.45	.89	3.90	.79	3.30	.66
Soft Palate	3.60	.88	3.45	.94	3.50	.76	3.70	.73	3.15	.81
Tripod (near)	3.10	.79	3.05	.94	3.25	.91	3.50	.89	3.40	.68
Chair (middle)	3.55	.89	3.45	.94	3.60	.68	3.65	.88	3.25	.85
Point (far)	3.45	.83	3.95	.51	3.45	.69	3.40	.75	3.30	.86
Fill	4.10	.91	4.70	.47	3.70	.86	3.40	.75	3.60	.60

*Significant evaluation variable, $p < .05$.

Table 4.6
Means and standard deviations for the evaluation variables in the high-pitch [ɑ] vowel performances

	Overall*		Ring*		Vibrato		Freedom		Color	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Baseline	3.00	.55	2.95	.59	3.45	.67	3.90	.70	3.45	.59
Vibrato	3.15	.79	2.85	.91	3.45	.86	3.90	.77	3.30	.64
Soft Palate	3.50	.87	3.45	.92	3.50	.74	3.70	.71	3.15	.79
Tripod (near)	3.00	.77	3.05	.92	3.25	.89	3.50	.87	3.40	.66
Chair (middle)	3.55	.86	3.45	.92	3.60	.66	3.65	.85	3.25	.83
Point (far)	3.50	.87	3.95	.50	3.45	.67	3.40	.73	3.30	.84
Fill	4.10	.94	4.70	.46	3.70	.84	3.40	.73	3.60	.58

*Significant evaluation variable, $p < .05$.

Univariate tests revealed significant effects of condition on ratings of *Ring* in both the low-pitch [α] vowel performances, $F(6, 114) = 17.3$, $p < .001$, and high-pitch [α] vowel performances, $F(6, 114) = 17.3$, $p < .001$. In both the low-pitch and high-pitch [α] vowel performances, pairwise comparisons revealed differences in the means for *Ring* between the Fill condition and all other conditions: Baseline, $p < .001$, Vibrato, $p < .001$, Soft Palate, $p < .001$, Tripod, $p < .001$, Chair, $p = .002$, and Point, $p = .001$. Differences were also revealed between the Point condition and the Baseline, $p < .001$, Vibrato, $p = .003$, and Tripod conditions, $p = .028$. *Ring* was rated highest when singers focused on directing their sound to a point on the wall and when they focused on filling the room with their sound (see Figure 4.2).

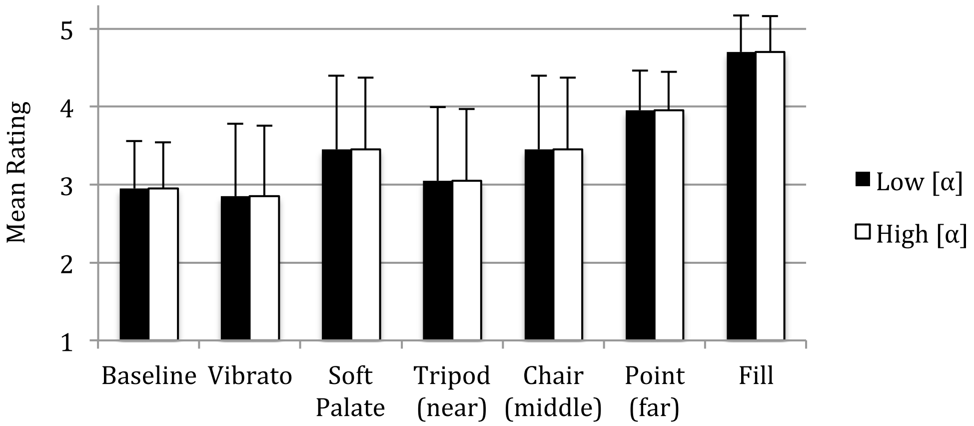

Figure 4.2. Mean low- and high-pitch [α] vowel performance ratings for *Ring* in the 7 focus of attention instructions. Error bars represent ±1standard deviation. Scale anchors: 1 = no ring, 5 = nice ring.

Univariate tests revealed significant effects of condition on ratings of *Overall Vocal Quality* for both the low-pitch [α] vowel performances, $F(6, 114) = 4.33$, $p = .001$, and the high-pitch [ɑ] vowel performances, *F*(6, 114) = 4.63, $p < .001$. There were significant differences between the Fill and the Baseline conditions in the low-pitch [ɑ] vowel performances, $p = .018$, and in the high-pitch [ɑ] vowel performances, $p = .014$. Ratings of the Fill and Tripod conditions were significantly different in both sets of recordings, $p = .004$. Ratings of *Overall Vocal Quality* were highest when singers focused on filling the room with their sound (see Figure 4.3).

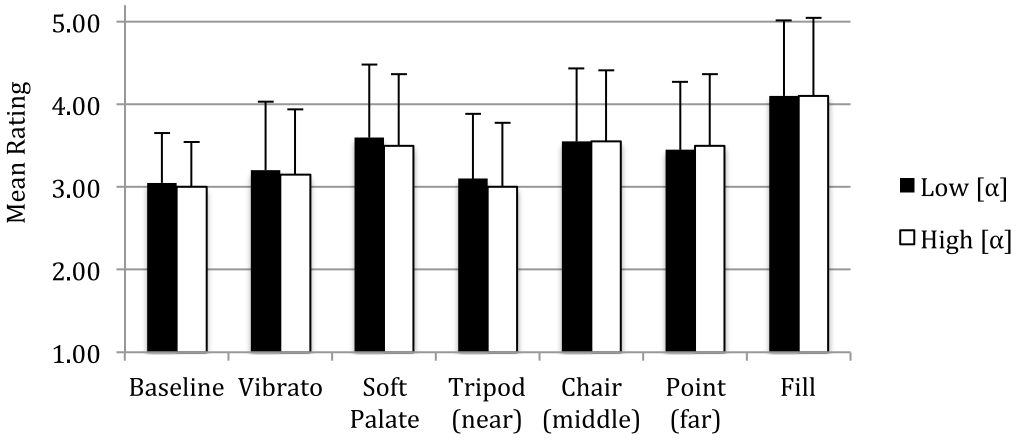

Figure 4.3. Mean low- and high-pitch [ɑ] vowel performance ratings for *Overall* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = poor, 5 = superior.

In ratings of the low-pitch [ɑ] vowel recordings, no significant effects of condition were found for *Freedom*, *F*(6, 114) = 1.76, $p = .11$, *Vibrato*, *F*(6, 114) = 0.95, $p = .46$, or *Color*, *F*(3.96, 75.28)[*] = 1.22, $p = .30$. Likewise on the high-pitch [ɑ] vowel

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[*] Greenhouse-Geisser adjusted degrees of freedom

recordings, no significant effects of condition were found for *Freedom*, $F(6, 114) = 1.76$, $p = .11$, *Vibrato*, $F(6, 114) = 0.95$, $p = .46$, or *Color*, $F(3.96, 75.28)^{*} = 1.22$, $p = .31$.

Rating results of the solo piece

I followed the same procedure for the solo piece. MANOVA indicated that the dependent variables were significantly affected by condition, Pillai's Trace = .57, $F(42, 678) = 1.70$, $p = .004$. See Table 4.7 for the means and standard deviation of all evaluation variables in the solo piece performances.

Table 4.7

Means and standard deviations for the evaluation variables in the solo piece performances

	Overall*		Ring*		Evenness*		Vibrato*		Freedom		Intonation		Color	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Baseline	3.35	.67	3.55	.60	3.65	.59	3.50	.51	3.95	.76	3.75	.72	3.50	.61
Vibrato	3.75	.97	3.80	.70	4.15	.75	3.85	.88	4.15	.93	3.85	.67	3.45	.76
Soft Palate	3.55	.76	3.75	.72	3.70	.73	3.80	.70	3.70	.86	3.95	.60	3.40	.50
Tripod (near)	3.55	.94	3.75	.64	3.70	.92	3.65	.67	3.80	1.06	3.85	.67	3.45	.76
Chair (middle)	3.80	.89	3.90	.45	4.10	.64	3.85	.49	3.90	.91	3.95	.69	3.30	.73
Point (far)	3.75	.72	4.15	.59	3.80	.62	3.65	.81	3.60	1.05	3.80	.52	3.50	.69
Fill	4.20	.89	4.75	.44	4.30	.73	4.10	.72	3.80	.95	3.95	.89	3.25	.85

*Significant univariate effects, $p < .05$.

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* Greenhouse-Geisser adjusted degrees of freedom

Univariate ANOVA revealed a significant effect of condition on ratings of *Ring*, *F*(6, 114) = 9.32, *p* <.001 for the solo piece performances. Pairwise comparisons (with Bonferroni correction) revealed significant differences between Fill and all other focus of attention conditions: Baseline, *p* < .001, Soft Palate, *p* < .001, Vibrato, *p* = .005, Tripod, *p* < .001, Chair, *p* < .001, and Point, *p* = .018. There was also a significant difference between the means for the Baseline and Point conditions, *p* = .02. Performances in the Fill condition were rated highest among the seven conditions in terms of *Ring* (see Figure 4.4).

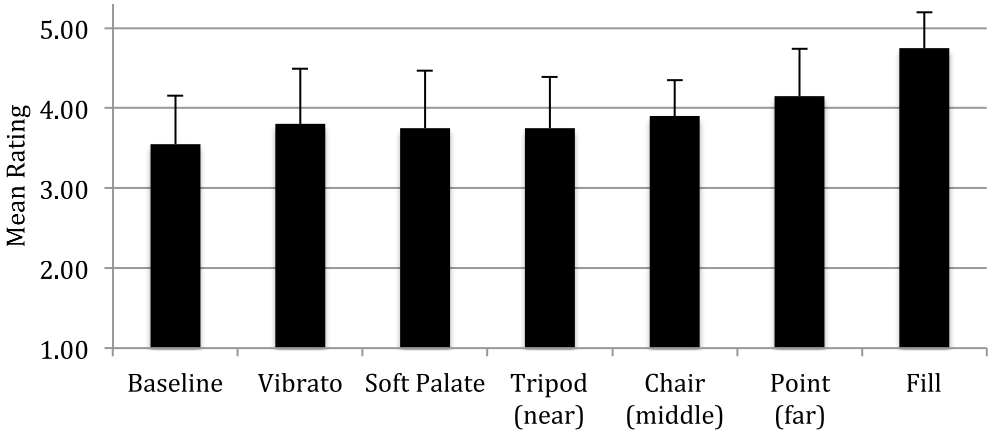

Figure 4.4. Mean solo piece performance ratings for *Ring* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = no ring, 5 = nice ring.

Univariate ANOVA revealed a significant effect of condition on ratings of *Overall Vocal Quality,* *F*(6,114) = .70, *p* = .033. Only a difference among the means between the Soft Palate and Fill conditions approached significance in pairwise tests (with Bonferroni correction), *p* = .08 (see Figure 4.5).

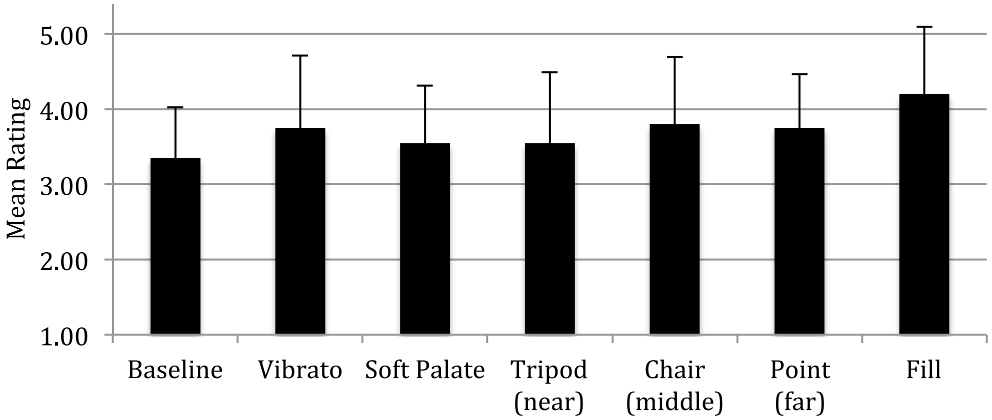

Figure 4.5. Mean solo piece performance ratings for *Overall* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = poor, 5 = superior.

Univariate ANOVA revealed a significant effect of condition on ratings of *Vibrato, F*(6, 114) = 2.17, *p* =.05. There were no significant pairwise comparisons revealed when a Bonferroni correction was applied. Only the difference between the Baseline and Fill conditions approached significance, *p* = .14 (see Figure 4.6).

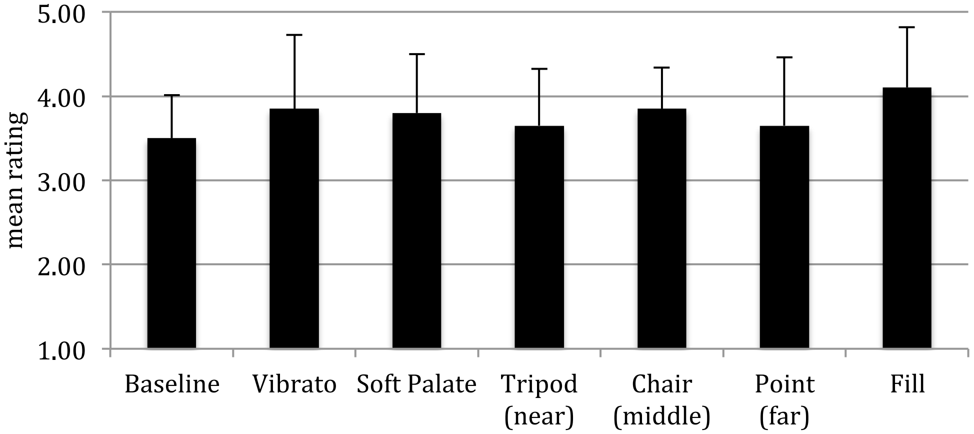

Figure 4.6. Mean solo piece performance ratings for *Vibrato* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = inconsistent vibrato, 5 = consistent vibrato.

Univariate ANOVA revealed a significant effect of condition on ratings of *Evenness*, $F(6, 114) = 3.12, p = .007$. Pairwise comparisons (with Bonferroni correction) revealed a significant difference between the means for the Tripod and Fill conditions, p = .044. The difference between the Baseline and Fill conditions approached significance, $p = .12$ (see Figure 4.7).

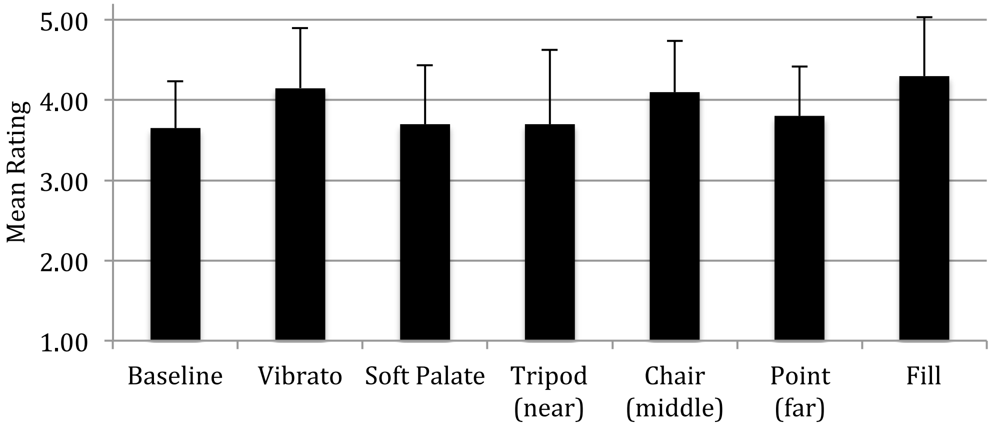

Figure 4.7. Mean solo piece performance ratings *for Evenness* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = uneven air/resonance, 5 = even air/resonance.

Univariate ANOVAs revealed no significant effects of condition for the evaluation variables *Freedom*, $F(6, 114) = 1.39, p = .23$, *Color*, $F(3.30, 62.72)^{*} = 0.70, p = .65$, and *Intonation*, $F(3.95, 75)^{*} = 0.41, p = .87$, in the solo piece performances.

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[*] Greenhouse-Geisser adjusted degrees of freedom

Rating results for “My Country ’Tis Of Thee”

I followed the same procedures in analyzing the ratings of the performances of “My Country ’Tis Of Thee.” MANOVA indicated that the dependent variables were significantly affected by condition, Pillai’s Trace = .782, $F(42, 642) = 2.48$, $p < .001$. Means and standard deviations for all evaluation variables are presented in Table 4.8.

Table 4.8
Means and standard deviations for the evaluation variables in “My Country ’Tis of Thee” performances

	Overall*		Ring*		Evenness		Vibrato*		Freedom		Intonation*		Color*	
	Mean	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*	*Mean*	*SD*
Baseline	2.95	.52	3.47	.51	3.47	.51	2.79	.54	3.74	.87	3.58	.61	3.26	.56
Vibrato	3.32	.95	3.68	.82	3.79	.98	3.89	.74	3.58	.96	3.84	.87	3.05	.71
Soft Palate	3.32	.89	4.11	.74	3.74	.87	3.68	.75	3.58	.77	3.63	.68	2.74	1.15
Tripod (near)	3.42	.69	3.84	.83	3.68	.75	3.47	.51	3.74	.65	3.79	.63	3.26	.65
Chair (middle)	3.21	.79	4.00	.88	3.79	.98	3.53	.84	3.53	1.07	3.74	.45	3.21	.98
Point (far)	3.63	.76	4.32	.48	3.74	.73	3.74	.65	3.68	.89	3.89	.57	3.42	.84
Fill	4.05	.78	4.68	.48	4.16	.90	4.00	.75	4.16	1.01	4.11	.46	3.05	.85

*Significant univariate effects, $p < .05$.

Univariate ANOVA revealed a significant effect of condition on the evaluation variable *Ring*, *F*(6, 108) = 9.38, *p* <. 001. Pairwise comparisons (with Bonferroni correction) revealed differences between the Fill condition and Baseline, *p* < .001, Vibrato, *p* = .001, Soft Palate, *p* = .04, Tripod, p = .02, and Chair, p = .07. The mean rating in the Fill condition was not significantly different than the mean rating in the Point condition.

There were also significant differences in the means for *Ring* between Baseline and Soft Palate, *p* = .04, between Baseline and Point, *p* < .001, and between Vibrato and Point, p = .04 (see Figure 4.8).

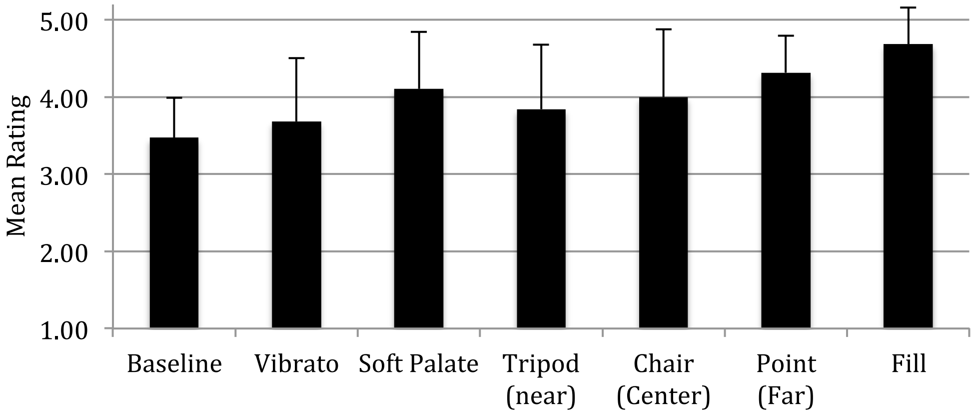

Figure 4.8. Mean “My Country ’Tis Of Thee” performance ratings *for Ring* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = no ring, 5 = nice ring.

Univariate ANOVA revealed a significant effect of condition on ratings of *Overall Vocal Quality*, *F*(6, 108) = 4.14, *p* = .001. Pairwise comparisons (with Bonferroni correction) revealed differences between the Baseline and Point conditions, *p* = .04, between the Baseline and Fill conditions, *p* = .001, and between the Chair and Point conditions, *p* = .04. Performances in the Fill and Point conditions were rated highest in terms of *Overall Vocal Quality* (see Figure 4.9).

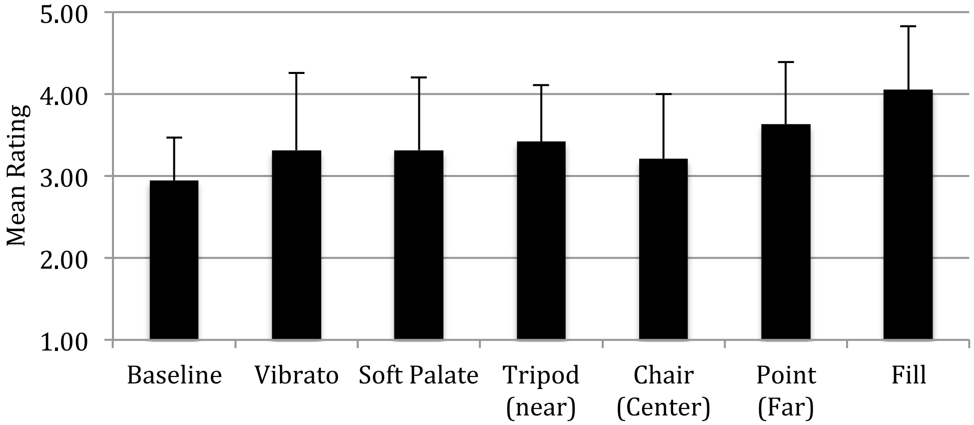

Figure 4.9. Mean "My Country 'Tis Of Thee" performance rating for *Overall* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = poor, 5 = superior.

Univariate ANOVA revealed a significant effect of condition on ratings of *Vibrato*, $F(4.45, 72.68)^{*} = 1.31$, $p < .001$. In pairwise comparisons (with Bonferroni correction), I found significant differences in the ratings of *Vibrato* between Baseline and all other conditions: Vibrato, $p < .001$, Soft Palate, $p < .001$, Tripod, $p = .002$, Chair, p = .095, Point, $p = .001$, and Fill, $p < .001$ (see Figure 4.10).

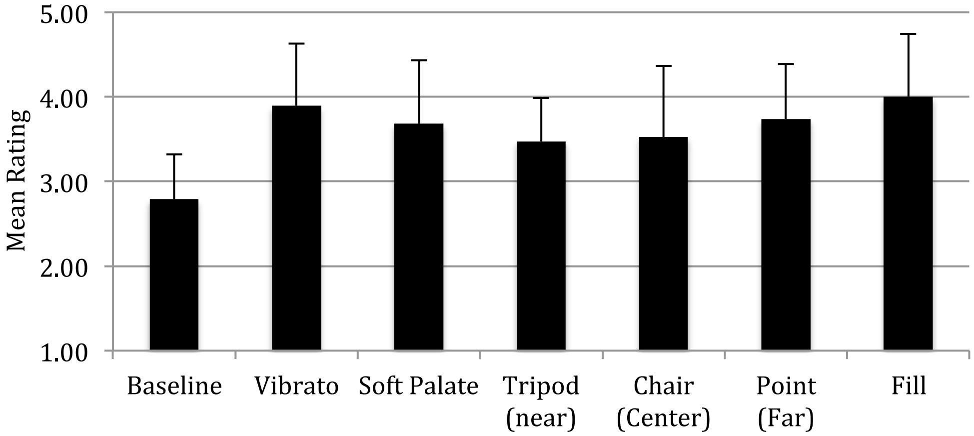

Figure 4.10. Mean "My Country 'Tis Of Thee" performance ratings *for Vibrato* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = inconsistent vibrato, 5 = consistent vibrato.

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[*] Greenhouse-Geisser adjusted degrees of freedom

Univariate ANOVA revealed a significant effect of condition on ratings of *Intonation,* $F(6, 108) = 2.10$, $p = .059$. In pairwise comparisons the difference between the means for the Baseline and the Fill conditions approached significance, $p = .085$ (see Figure 4.11).

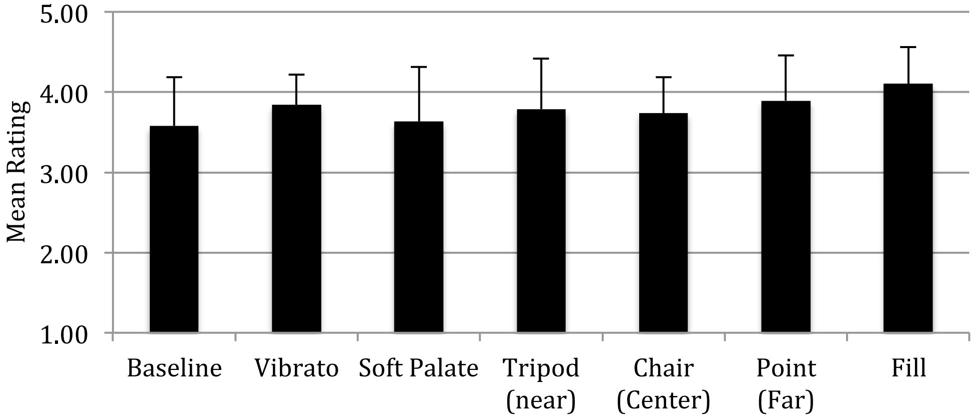

Figure 4.11. Mean "My Country 'Tis Of Thee" performance ratings *for Intonation* in the 7 focus of attention instructions. Error bars represent ±1 standard deviation. Scale anchors: 1 = inconsistent intonation, 5 = consistent intonation.

Univariate ANOVA revealed a significant effect of condition on ratings of *Color*, *F*(6, 108) = 2.51, *p* = .026. No significant pairwise differences between means were found for *Color*. The difference between the Soft Palate and Point conditions obtained the lowest *p*-value, *p* = .17 (see Figure 4.12).

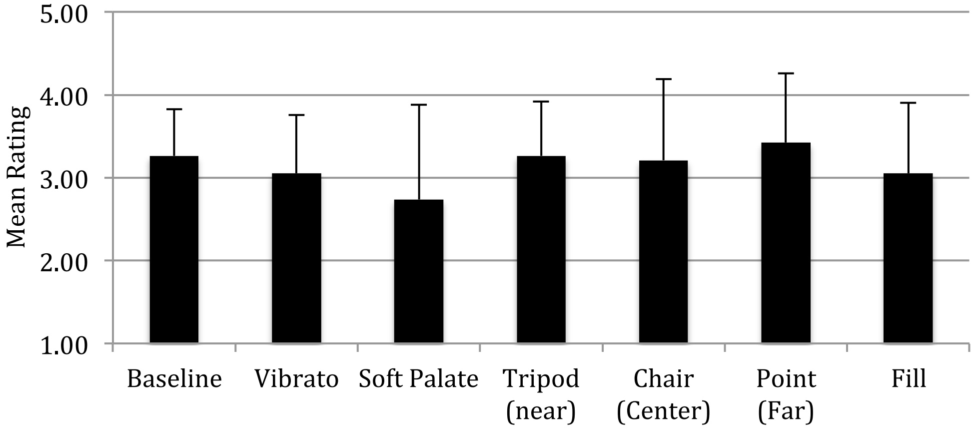

Figure 4.12. Mean "My Country 'Tis of Thee" performance ratings *for Color* in the 7 focus of attention instructions. Error bars represent ±1standard deviation. Scale anchors: 1 = overdark, 3 = balanced (+), 5 = overbright.

Univariate ANOVAs revealed no significant effects of condition on the ratings of *Freedom*, *F*(6, 108) = 1.31, *p* = .26, and *Evenness*, *F*(6, 108) = 1.30, *p* = .27, in the "My Country 'Tis Of Thee" performances.

Self-report of attentional focus

Recall that I asked each participant after each singing task whether they maintained the attentional focus that I had directed. I asked the question 18 times per participant (six times following the two [ɑ] vowel performances [*N* = 20], six times following the “My Country ’Tis Of Thee” performances [*N* = 19], and six times following the solo piece performances [*N* = 20] for a total of 354 responses. In only seven instances (five different participants) did a participant respond that he or she had not followed the focus instructions.

Recall that I also asked participants what they focused their attention on as they sang each Baseline performance ([α] vowels, “My Country ’Tis Of Thee,” and solo piece). Participants thought about different aspects of singing, and there seemed to be no systematic relationship that I could discern between what was focused on during the Baseline performances and the quality of singing. Responses most often related to breath management, resonance, musicality, diction, and text.

Self-report of the relationship between voice lesson and experimental directives

Following the final singing task, I asked each participant to answer four questions related to voice lessons. After a brief reminder of the different focus of attention instructions (Vibrato, Soft Palate, Tripod, Chair, Point, Fill), I asked the first question: “Which of the focus of attention instructions were like or unlike what your voice teacher asks you to do?” Table 4.9 shows the number of participants who described the focus targets in the present study as like or unlike directions typically given by their voice teachers. Directing the sound to a point on the back wall and filling the room with sound were most often identified as the kind of instructions their teacher had given.

Table 4.9
Participant responses to the question "Which instructions were like or unlike what your voice teacher asks you to do?"

	Vibrato	Soft Palate	Tripod	Chair	Point	Fill
Like	8	9	4	6	11	14
Unlike	5	8	13	10	5	4

I examined whether the responses to these questions were related to the quality of participants' performances in the various conditions. I did not find any discernible relationships. For example, nine participants reported working on the placement of the Soft Palate in lessons, but none of them performed the majority of the four singing tasks well in the Soft Palate conditions compared to their other conditions.

I also asked the participants, "Were there any instructions that made you feel awkward and uncomfortable?" Eight participants reported that thinking about keeping the vibrato steady and consistent felt awkward. Of those eight participants, four explained that vibrato in their lessons is normally approached through other aspects of singing like breath, filling the room, and resonance. One person said, "Thinking about vibrato made it more difficult to have a healthy vibrato."

Six participants responded that the Tripod condition was awkward. One participant stated that if the tripod were a person, he was afraid she would be blown away by the sound of his voice.

Three participants reported that the Soft Palate condition was awkward. One participant reported that singing to the paper on the back wall was awkward, and one reported that filling the room with her sound was uncomfortable.

I also asked participants the question, “Were there any instructions that made you feel especially comfortable or made it easier to sing?” Twelve participants reported that it was easy to sing in the Fill condition; nine participants reported that it was easy to sing in the Point condition; and six participants reported that it was comfortable to sing in the Soft Palate condition. Few participants reported that it was comfortable to sing in the Vibrato condition (2), the Tripod condition (2), or the Chair condition (3).

Participants’ responses to the question “Which instructions do you feel affected your sound the most, either positively or negatively?” are presented in Table 4.8. Nine participants reported that the Vibrato condition affected their sound negatively. Eight participants reported that the Soft Palate, Point, and Fill Conditions affected their sound positively.

Table 4.10
Participant responses to the question "Which instructions affected your sound the most, either positively or negatively?"

	Vibrato	Soft Palate	Tripod	Chair	Point	Fill
Positively	2	8	1	3	8	8
Negatively	9	4	3	0	1	3

I compared the above responses to the actual performance outcomes. Only one participant who reported that the Fill condition affected her tone positively actually performed best in the Fill condition in all four singing tasks; only two participants performed best in this condition in three of the four tasks. I found in the remaining five participants no relationship between their report of a positive effect on tone and their actual performance.

No participants who identified the other conditions as having a positive effect on their singing actually performed best in those conditions. It appears that the singers in this study were unable to assess accurately the effect of condition on their tone quality.

DISCUSSION

My purpose in this study was to determine the extent to which trained singers' tone quality is affected by focus of attention. The results are consistent with the results from the experiment reported in Chapter 3 and with the results of other focus of attention literature. Ratings for *Overall Vocal Performance* and *Ring* were higher when performers directed their sound to a point on the back wall and filled the room with their sound than when performers focused on internal targets and directed their sound to near and middle distances. Ratings for *Ring* and *Overall* were not as high when singers focused on the position of the soft palate, focused on keeping the vibrato steady, focused on directing their sound to a tripod (near) and chair (middle), and when singing with no focus instructions. For *Ring*, differences were revealed between the Fill condition and all conditions except Point, and between the Point condition and the Vibrato and Baseline conditions.

In the present experiment, singers performed in a medium-size recital hall two 3-note patterns, a prepared solo piece, and a song they knew ("My Country 'Tis Of Thee") but had not practiced. In all four singing tasks I found a significant effect of condition on the evaluation variables for *Ring* and *Overall Vocal Quality*. I also found significant effects of condition in the performances of "My Country 'Tis Of Thee" for *Vibrato, Color*, and *Intonation,* and significant effects of condition in performances of the solo piece for *Vibrato* and *Evenness*. Focusing on directing the sound to a point on the back wall and on filling the room resulted in better-perceived tone quality in all four singing tasks.

Research in motor skill learning has demonstrated that the performance of physical skills often improves as distance from the source of movement is increased. Duke et al., for example, found that novice pianists performed a keyboard sequence with more even timing as the assigned focus of attention moved from the piano keys (near) to the hammers (mid) and finally to the sound (distal) (Duke et al., 2011). Similar results were found in numerous other tasks, including balancing (McNevin et al., 2003), golf putting (Bell & Hardy, 2009; Castaneda & Gray, 2007), and long-jumping (Porter et al., 2012).

The external focus of attention conditions in this study were the Tripod (near) Chair (middle), Point on the back wall (far), and Fill the room with sound. The ratings for *Ring* were highest for the two most distal external targets (Point, Fill) and univariate tests revealed a significant effect of condition for *Ring* on all singing tasks. Figure 4.13 shows the mean rating in all singing tasks for *Ring*.

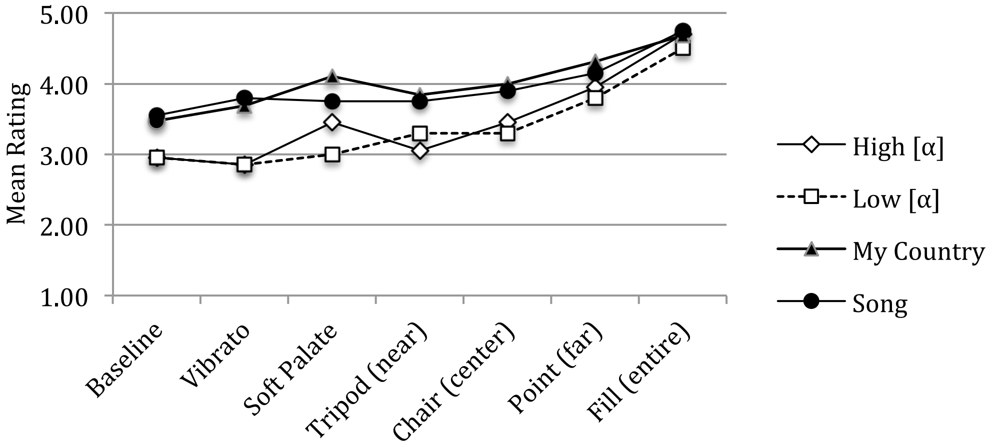

Figure 4.13. Mean ratings for *Ring* in all singing tasks.

I found a significant effect of condition on tone quality ratings. *Ring* was rated higher in the external conditions compared to baseline and the internal conditions. In addition, the amount of *Ring* detected by listeners increased as the distance of focus increased from the vocal source. Focusing on filling the room with sound resulted in the highest mean ratings for all evaluation variables. This condition often resulted in a beautiful tone, and was reported by the majority of participants as a focus target commonly used in their voice lessons.

Teachers and performers work to create beautiful tone quality and create musical expression in performance through a variety of techniques. Instructors have developed these techniques intuitively, passing them along to students and colleagues. The results of this study indicate that singing in the Point and Fill conditions resulted in articulatory movement that created better *Ring* and *Overall Vocal Quality* in all four singing tasks. The results of this study indicate that these focus of attention instructions are effective in producing better resonance for the classically trained singer.

Further research exploring the effects of focus of attention on tone production may reveal greater insight into the effective use of pedagogical strategies. The experiment in this chapter replicates a protocol that may be used in the future to explore the processes of music learning and performance.

CHAPTER 5: DISCUSSION

Recent research in skill learning has demonstrated that motor performance in familiar tasks is often advantaged when performers focus on the effects of their movements rather than on the movements themselves (for a review see Wulf, 2013). Until recently, positive effects of an external focus of attention had not been documented in the context of vocal production.

Voice teachers for generations have employed various strategies to help focus singers' attention away from the actual movements of the body and vocal mechanism and toward "external" outcomes. The experiments reported in this dissertation are the first to systematically examine vocal pedagogical strategies and the effects of focus of attention on tone production in trained singers.

The experiments I described in the preceding chapters were designed to assess vocal tone production when singers focused their attention on internal and external targets. In both experiments I sought to answer the following question: In what ways and to what extent is the tone quality of trained singers affected by their focus of attention while singing?

In the first experiment expert listeners' descriptions of tone in each of six focus conditions were used to develop an evaluation instrument for assessing vocal tone quality. I subsequently used that instrument to rate the 11 participants' singing on two singing tasks under six different conditions. I then replicated the first experiment with a larger group of singers who sang an expanded set of tasks in a larger performance space. The second experiment included two additional singing tasks and one additional focus condition. Following a summary of the results below, I discuss my findings in relation to the results of previous focus of attention investigations that tested performance of other skills.

SUMMARY OF RESULTS

Experiment 1

In Experiment 1, expert listeners' descriptions of the two singing tasks ([ɑ] vowel and solo piece) referred to positive and negative aspects of tone quality, color, intonation, vowels, consistency of vibrato, consistency of resonance, and consistency of air flow. Though not all singers were affected by the focus conditions in the same ways, expert listeners more often described participants' performances in the Vibrato, Soft Palate, and Baseline conditions negatively, and more often described their performances in the Stand, and Point conditions positively.

Experts most often identified resonance/ring as the variable that differentiated the vocal quality among the conditions. Descriptions of resonance/ring were especially prominent in the two most distal external focus of attention conditions. Listeners described the performances associated with the most distal external targets as having better resonance/ring than performances in the other conditions.

Using the listeners' descriptions and other published evaluation instruments as a starting point, I developed an evaluation instrument comprised of seven 5-point rating scales: *Ring, Evenness, Freedom, Color, Intonation, Vibrato,* and *Overall Vocal Quality*. I rated all performances of both singing tasks in the six conditions (132 total performances) and found significant effects of focus condition on ratings of *Ring* and *Overall Vocal Quality* in performances of the [α] vowel, and a significant effect of focus condition on *Ring, Overall,* and *Intonation* in performances of the solo piece. *Ring* was rated higher when singers focused on directing their sound to the two most distal targets (Stand and Point) than when singers performed in the Baseline condition, the Microphone, Soft Palate, and Vibrato conditions. The greater the distance was between the focus of attention and the vocal source, the higher the ratings for *Ring*.

Experiment 2

Similar results were found in the second experiment. A different group of singers participated in the same recording procedure used in Experiment 1, but performed in a large recital hall instead of a classroom. One additional condition (fill the room with your sound), and two additional singing tasks (a 3-note high-pitch [α] vowel pattern, and "My Country 'Tis Of Thee") were included as well.

I again found significant effects of focus condition on ratings of *Ring* and *Overall Vocal Quality* in performances of the [α] vowel tasks; significant effects of focus condition on ratings of *Ring, Vibrato, Evenness,* and *Overall Vocal Quality* in performances of the solo piece; and significant effects of focus condition on ratings of *Ring, Vibrato*, *Intonation*, *Color,* and *Overall Vocal Quality* in performances of "My Country 'Tis Of Thee." Performances were rated higher in the Point (far) and Fill conditions than were performances in the other external conditions (Tripod-near, Chair-middle), performances in the internal conditions (Soft Palate, Vibrato), and performances in a baseline condition in which no focus instructions were given.

Summary of combined results

In both experiments, *Ring* and *Overall Vocal Quality* (which are positively correlated) were the evaluation variables significantly affected by focus of attention in all singing tasks. The highest mean ratings were obtained in the Point (far) condition in both experiments, and in the Fill condition in the second experiment.

Results of these experiments demonstrate that trained singers' tone quality is affected by focus of attention. In all singing tasks evaluated in this study, ratings of overall tone quality and resonance/ring were highest when singers directed their sound to more distal targets.

DISCUSSION OF EACH CONDITION

Baseline

I had expected that trained singers' Baseline performances (no focus of attention instruction) would generally be of high quality. This was not the case in either experiment. Based on the expert listeners' descriptions in the first experiment, the Baseline performances by the majority of participants lacked support and ring. The mean ratings of most of the evaluation variables were also lowest in the Baseline conditions in both Experiment 1 and Experiment 2. Recall that the Baseline condition in both experiments was performed first, followed by the remaining conditions performed in random order. The poorer performance in the Baseline condition may be partially attributable to presentation order.

Internal versus external conditions

Based on the results of other focus of attention studies, I had expected that the internal conditions (Vibrato, Soft Palate) would have negatively affected vocal tone. In Experiment 1, expert listeners tended to describe participants' performances more negatively in the internal conditions than in the external conditions. Mean ratings for the majority of evaluation variables were also generally lower in these two conditions than in the external conditions in both experiments. For the majority of participants, the internal focus conditions resulted in inferior tone production.

Conversely, the external conditions in both experiments (Microphone/Tripod [near], Stand/Chair [middle], Point [far], and Fill) generally had more positive effects on tone production than did the internal conditions. In Experiment 1, expert listeners tended to describe participants' external condition performances more positively than negatively. In both experiments, mean ratings were generally higher in the external conditions, especially the more distal conditions.

Near external

The near external conditions (Microphone/Tripod) did not affect all singers in the same way. Participants generally performed more poorly in these conditions than the other external conditions in both experiments. In Experiment 1, the microphone was placed 18 inches in front the singer's mouth. Performances in the Microphone conditions tended to be rated lower than performances in the other external conditions. One participant commented that, because of the proximity of the microphone, he was afraid that the volume of his voice would peg the VU meter when he directed his sound to the microphone. In Experiment 2, I replaced the microphone with an empty camera tripod in the same location. Yet, in the second experiment I again found no significant differences between the Tripod condition and the Baseline and internal conditions. Participants commented again in Experiment 2 that directing the sound to such a close target felt awkward. The results from both experiments indicate that trained singers' performance is often negatively affected when the external target is too close.

These results are unlike the results obtained with untrained singers, who performed well in an identical condition in a previous experiment (Atkins & Duke, 2013). Further research is warranted to explore the relationship between skill level and distal focus effects on tone production.

Middle external

In the first experiment, I found that ratings of *Ring* and *Overall Vocal Quality* were significantly affected when participants directed their sound to the Stand (middle) compared to Baseline, Microphone (near), Soft Palate, and Vibrato conditions. In the second experiment, I found no significant differences in the ratings of *Ring* and *Overall Vocal Quality* between the Chair (middle) condition and the Baseline, Tripod (near), Soft Palate, and Vibrato conditions.

Even though the Stand and Chair conditions both marked the middle of the rooms in which the recordings were made, the middle targets were different distances from the singers in the two experiments; In Experiment 1, the Stand was located 9 feet from the singer, and in Experiment 2, the chair in the hall was 24 feet away from the singer. The difference in distance between singer and target may account for the differences in the results. In the second experiment, performances in the Chair condition were rated somewhat higher than performances in the Baseline, Soft Palate, Vibrato, and Tripod conditions, but the differences were not significant.

Far external

The Point condition in both experiments generally had positive effects on tone production. In Experiment 1, expert listeners described the majority of participants' Point condition positively. In both experiments, the Point condition generally received higher mean ratings than the other conditions. Singing to a point on the wall across the room resulted in more resonance/ring.

Fill the room

I defined the Fill condition as an external focus of attention. When directed to fill the room with sound, singers mostly focus on the sound in the performance space rather than on the vocal mechanism. Voice teachers often use this directive to help singers increase the carrying power of their voice without adding physical tension. The Fill condition in Experiment 2 clearly had the most positive effects on overall tone production, even more so than the Point condition. Through unconscious movement of the articulators and a lowering of the larynx, singers may have matched the space in the mouth to the image of the space all around them in a way that boosted their resonance.

Evidence from previous research on focus of attention in motor skills shows similar effects. McNevin et al. (2003), for example, found that participants who focused on the most distal markers showed more effective balance learning than did participants who focused on proximal markers (external), and their feet (internal). Similarly, Duke et al. (2011) found that as distance increased from the source of movement in a piano sequence, evenness improved. Similar results were also found for a long jump task (Porter et al., 2012) and a basketball free throw (Shojaei & Daneghian, 2010)

The results in these two experiments are in many ways consistent with results found in other motor skill learning. Significant effects were revealed in both experiments, especially in the two most distal external focus conditions. In all singing tasks, trained singers were rated higher in terms of *Ring* and *Overall Vocal Quality* as the distance of the focus of attention from the vocal source increased.

ACOUSTIC MEASURES

Studies of vocal quality have shown that acoustic measures of the human voice are not reliable indicators of human perceptions of vocal tone (Atkins & Duke, 2013; Callinan-Robertson et al., 2006; Kenny & Mitchell, 2006). Although I found a significant effect of condition on measures of Intensity and SPR in the [ɑ] vowel performances of Experiment 1, I interpreted these results with caution since the [ɑ] vowel performance samples were only 2 s in duration and devoid of note onsets. Due to the difficulty of obtaining reliable assessments of vocal quality in terms of acoustic measures, I used only listener ratings as a measure in Experiment 2.

Technological advances have enabled researchers in speech and singing to collect precise data related to phonation. Although these data may be helpful in measuring aspects of the vocal mechanism itself, they are less useful as measures of vocal tone as perceived by listeners. The human auditory system processes sound in ways that consider not only the individual acoustic properties of tone but also their interaction. Computer analyses of acoustic data are generally less effective in describing vocal tone quality. Expert listeners' assessments of vocal tone quality may be the most useful and reliable means of evaluating singers' tone production.

LISTENER PERCEPTIONS

To date, I have utilized three different types of evaluation processes to assess perceived tone quality. In a previous experiment (Atkins and Duke, 2013), listeners rank-ordered untrained singers' performances in five focus of attention conditions. Rankings, of course, did not identify which aspects of tone production were affected by condition. In Experiment 1 of this dissertation, I asked expert listeners to describe the tone production in six different focus conditions. These descriptions informed my creation of a rating instrument that included seven evaluation variables, rated along 5-point scales.

All three types of evaluation (ranking, description, and rating) were valuable, but they functioned in different ways. The rankings focused most on perceptions of overall tone quality. The descriptions of expert listeners included perceptions of overall tone quality, but identified the specific aspects of singing that seemed to have been affected by conditions. The rating instrument was effective in providing a numerical basis for comparing performances among conditions, but was in some ways less informative than the experts' descriptions.

The evaluation instrument created for the experiments in this dissertation included a separate rating scale for *Overall Vocal Quality*. Not surprisingly, this rating scale was positively correlated with *Ring, Vibrato, Freedom*, and *Evenness*.

The statistical analysis of the ratings was an effective means of identifying which evaluation variables were most affected by condition. *Ring* and *Overall Vocal Quality* were affected by condition in all singing tasks in both experiments. The effects of other evaluation variables (*Vibrato, Evenness, Intonation*, and *Color*) varied among singing tasks. The results also indicate that the numerical ratings were consistent with the expert listeners' descriptions.

These two experiments indicate that singers tend to perform with more resonance/ring when they focus on distal external targets than when they focus on internal targets. Resonance/ring tended to increase as distance to the focus target increased. The Fill condition in Experiment 2 had the most positive effect on *Ring*. Directing sound to distal targets and filling the room with sound are strategies commonly used by voice teachers to help singers produce a beautiful tone carries in large performance spaces.

OTHER CONSIDERATIONS

The trained singers in these two experiments varied in terms of age and experience level. The majority of singers in Experiment 1 were incoming college freshmen. The majority of the singers in Experiment 2 were college students about to complete a full semester of voice lessons. The effects of condition were generally the same in these two populations.

Singers are taught to respond to auditory feedback as they sing by adjusting articulators and controlling breathing. All participants at the time of recording were certainly affected by auditory feedback (i.e., the sounds of their own voices). In Experiment 2, I asked participants whether they were able to remain focused on the targets I had specified in each condition. Out of 354 responses, there were only 7 instances in which participants reported that they did not do so. Yet, they may very well have made unconscious adjustments while they sang.

The results of these experiments should be interpreted taking into consideration the limitations of the equipment used. Although I took great care to use high quality equipment for both recording and listening, listening to recordings is inevitably different than listening to live performances.

CONCLUSION

The evaluation protocol that I developed for these projects may be used to systematically examine tone quality in future investigations. This protocol could be adapted for a variety of instruments in addition to voice.

The results of this study contribute to existing focus of attention literature in motor skill learning. In both experiments, participants sang with more ring and better overall vocal quality, as determined by expert listeners, when directing their sound to distal targets, specifically the Stand (center) and Point (far) in the first experiment, and the Point (far) and Fill (entire space) in the second experiment. Though not all conditions affected each singer in the same ways, better *Ring* and *Overall* quality were revealed through both descriptions and ratings for the majority of singers.

These findings provide insight to the process of motor skill learning in the context of singing. The results demonstrate that focusing on directing sound to a point on the wall and filling the room with sound, directives that voice teachers have used for many years, do in fact produce measureable positive effects. Although further research is warranted to examine the effects of focus of attention on performance in singing, this study serves as an appropriate starting place for studying the development of singing skill.

Appendix: Details of the extraction of WAV files in Praat

I isolated individual WAV files for each participant performing each condition from the continuous session recordings using the acoustic analysis software Praat (Boersma & Weenink, 2011). I set the program to “show spectrogram” and “show pitch” (blue line) and then selected the first condition. A screen shot of the software is shown in Figure A.1.

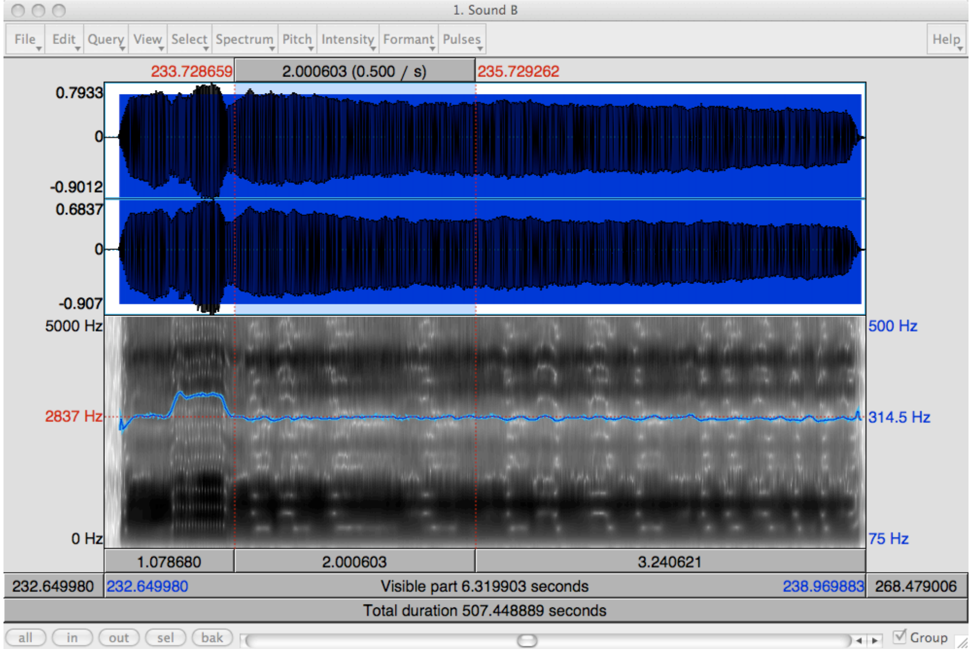

Figure A.1. Pitch line and spectrogram output in Praat software.

I selected the 2-s intervals of the [ɑ] vowel performances using the visual image of the pitch line (in blue in Figure A.1) by placing the cursor (vertical line in red in Figure A.1) at the onset of the third and final pitch of the 3-note pattern. I adjusted the starting point forward in 50-ms increments until the sound was stable (i.e., there was no sound in the signal from the previous pitch) on the final pitch. I adjusted the starting point no more than 250 ms in any trial. Once I had determined the starting point of the final pitch, I highlighted to an end point exactly 2 s later. I then saved the recording as a WAV file.

In both experiments I isolated the solo piece using the same process. Through visual inspection of the pitch-line image, I identified the start point and end point of the solo piece and highlighted the section between those points with the cursor. After verifying the selection through headphones, I saved each performance as a separate WAV file.

I followed a similar procedure in Experiment 2 to isolate the middle of the phrase from the song “My Country ’Tis Of Thee” (the words “sweet land of liberty”). Through visual inspection of the pitch-line image, I identified the start point of the word “sweet” and the end point after the word “liberty” and highlighted the section between those two points. I verified the selection by listening through headphones. I saved each performance as a separate WAV file.

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