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Focus of attention in singing: Expert listeners' descriptions of change in trained singers' tone quality

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Abstract

It is now well understood that skilled motor behavior is affected by performers' focus of attention (Wulf, 2013). This effect has been demonstrated in numerous and varied motor tasks from golf-putting to piano playing, but there has been little systematic research devoted to this aspect of vocal pedagogy. The 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. 11 trained singers performed a three-note pattern on an [a] vowel and an excerpt of a well-learned melody under 6 different focus of attention conditions: they first performed with no instructions, and then they were encouraged to think about (in random order) (a) positioning the soft palate, (b) keeping their vibrato steady, (c) directing their sound to the microphone 18 inches in front of them, (d) directing their sound to a music stand halfway across the room, and (e) directing their sound toward a circle, 19 feet across the room (far distance). 3 expert listeners freely described the changes in tone quality. Performance in external focus of attention conditions resulted in the most positive effects on the majority of singers in this study, especially in terms of resonance/ring. Expert listeners described singers' tone quality most positively when singers focused their attention on external rather than internal targets. The results of this experiment are consistent with the results of related investigations of attentional focus in motor skill performance.

Key Words:

focus of attention, vocal pedagogy, evaluation descriptions, music learning, motor skill learning, singing voice

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In both choral and solo singing, vocal tone is a fundamental element of beautiful singing. 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, kinesthetic awareness, and other strategies to shape the production of vocal tone. 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 the teacher to focus the students' attention strategically 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 may be places in the learning process where such focus is entirely appropriate. But, research across a variety of non-musical tasks for both novice and experienced learners 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 (Wulf, Höß, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999; Wulf, McNevin, & Shea, 2001; Wulf & Prinz, 2001; Wu, Porter, & Brown, 2012). Wulf and colleagues (1999) found improved performance in a golf pitch shot when participants focused on the motion of the golf club (external) rather than on the motion of their arms (internal). Similar improvement was found for a balance task when participants focused on markers affixed to the balance platform (external) rather than on their feet (internal) (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).

Recent research on focus of attention in music has yielded mixed results for some music learning tasks that involve motor skills. Duke, Cash, and Allen (2011) found that novice pianists performed a 16th-note keyboard exercise with better evenness and timing when they focused their attention on the sound (far distal external), rather than when they focused on their fingers (internal), the keys (near internal), or the hammers hitting the strings (distal external). However, they found no evidence that changes in focus of attention affected the performance of experienced pianists.

Stambaugh (2017) compared performance between control, internal, and external focus of attention instructions in a woodwind performance task. Novice and experienced woodwind players performed 120 trials of a two-note alternating sequence on a Yamaha WX5 MIDI Wind Controller under each of four conditions. Participants played in a control condition first, and then performed in randomized order while thinking about their fingers (internal), keys (near external), and sound (far external). Stambaugh averaged the measures for evenness and pitch accuracy across all trials at acquisition, transfer, and retention on both days. On Day 1, novice and experienced performers performed with less evenness and accuracy only in the control condition compared to focus of attention conditions. In general, performers played with increased pitch error as the focus of attention became more distal, but the differences were not statistically significant.

In a singing task (Atkins & Duke, 2013), an expert listener ranked overall tone quality (from the best to worst performance) of five different focus of attention conditions for 30 untrained singers' performances of a three-note [ɑ] vowel task (the listener was blind to the condition). Another expert listener (also blind to the conditions) listened and ranked 20% of the recordings (reliability = .84). The untrained singers' three-note task was ranked highest (first or second) when participants focused on directing their sound to a microphone located 18 inches in front of them, directing the sound to a more distal point on the wall, and directing the sound to their fingertips placed on the mask (across the cheekbones) of the face, and lowest when singing with no instructions or focusing on the vibrations they felt in the neck area.

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. Additionally, assessments in the previous study of untrained singers (Atkins & Duke, 2013) were based on within-subject rankings of overall tone quality and not evaluations of specific aspects of tone. In the present study, I was particularly interested in expert listeners' descriptions of the changes in vocal tone that may result from different attentional foci. The purpose of this study was to identify changes in specific aspects of vocal tone (resonance, intonation, timbre, etc.) and to what extent the tone quality of trained singers was affected by changes in focus of attention.

Method

Participants were 12 trained singers (two baritones, three tenors, five sopranos, two mezzos) ranging in age between 18 and 31 years old (M = 20 years). At the time of the study, participants were attending a summer opera workshop at a large university. Due to problems with the recording equipment, one soprano was excluded from the analysis. Of the remaining participants, five were incoming undergraduate voice performance majors, one participant was a third year master's degree voice performance major, one participant was a third year DMA voice performance major, and the remaining four participants were sophomore and junior voice performance majors.

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. Permission was obtained for this study through the Institutional Review Board.

Mean 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 years (Mdn = five 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 a mean 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 six 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 approximately 18 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.

Participants arrived individually at their appointed time already vocally warm from the opera workshop. Each participant practiced two different singing tasks as the microphone record levels were set. In the first task, participants listened to a three-note pattern played on a piano (see Figure 1) and then sang the three-note pattern sustaining the final tone until they could no longer produce a beautiful tone or 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 seconds of singing).

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 turned up as loudly as possible but set so that the peak level did not indicate distortion on the peak level indicator. (Recording levels were between 4.5 and 6 on the record level 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 and stay in one place with minimal movement.

For each of the six conditions, participants first listened to the three-note pattern played in tempo on the piano and then sang the sequence three times in a row. Following the three-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

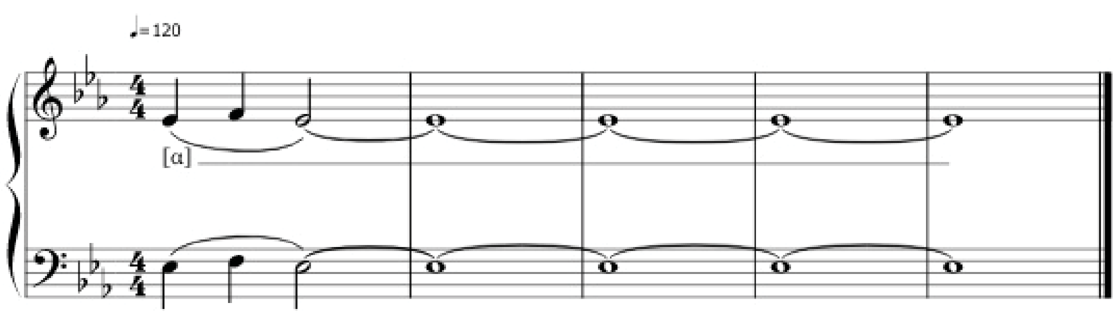

Figure 1. Three–note Pattern Sung on a Continuous [ɑ]* Vowel as in the Word "Father."
*International Phonetic Alphabet (IPA) symbol

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 (e.g., to think about) one of the following targets: (a) positioning the soft palate, (b) keeping their vibrato steady, (c) directing their sound to the microphone 18 inches in front of them at mouth height (near distance), (d) directing their sound to a music stand approximately 9 feet across the room at a height of approximately 4 feet (middle distance), and (e) 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

Two other expert listeners (Ph.D. candidates) and I listened to each participant's three-note pattern 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, and most were indistinguishable from one another. Therefore, 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 three-note Eb-F-Eb pattern, 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-second excerpt from the final pitch beginning immediately after onset of every participant's first three-note pattern 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-second [ɑ] vowel trials and six solo piece trials per subject (132 total WAV files).

Expert Listeners' Descriptions of Recordings

I first evaluated all 2-second [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 voice performance 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-minute 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 heard the first participant's six 2-second [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 purpose of the study and 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 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' [ɑ] vowel and solo pieces, groupings emerged describing tone quality, color, intonation, vowels, consistency of vibrato, consistency of resonance, and consistency of airflow. Understandably, given the brevity of the [ɑ] vowel recordings, descriptions pertaining to vowels, intonation, consistency of resonance, and consistency of air flow were not used to describe the two-second [ɑ] 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 the expert listeners again individually during a second session to review the list of descriptors I had compiled, 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 *under-supported*; 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*. Figure 2 is a compilation of exact language the two expert listeners and I used to describe the 60 performances of the 2-second [ɑ] vowel trials and the solo piece recordings. Each grouping under a bolded

Resonance/ring	**Freedom**	**Noise**	**Color**
good ring (+)	open (+)	less noise (+)	bright (+, n)
more ring (+)	relaxed (+)	less buzz (+)	dark (+, n)
warmth (+)	natural (+)	gravelly (-)	less bright (+)
resonance (+)	free (+)	hiss (-)	over bright (-)
balanced tone (+)	strident (-)	noisy (-)	darker (-)
full voice (+)	tight (-)	scratchy (-)	swallowed (-)
energized (+)	nasal (-)	less clear tone (-)	hollow (-)
supported (+)	pressed (-)	buzz (-)	over-covered (-)
round (+)	forced (-)		dropped soft palate (-)
some ring (n)	pushed (-)	**Air Flow***	
no deep overtones (-)	harsh (-)	consistent (+)	**Diction**
no firm tone (-)		inconsistent (-)	dark vowel (+, -, n)
thin (-)	**Intonation**	wavery (-)	bright vowel (+, -, n)
less resonance (-)	consistent (+)		good vowel (+)
less ring (-)	good (+)	**Breathiness**	consistent vowel (+)
consistent (+)*	inconsistent (-)	less breathy (+)	elongated vowels *(+)
inconsistent (-)*	problems (-)	breathy (-)	over-bright (-)
	sharp (-)		over-enunciated* (-)
Vibrato	flat (-)	**Support**	vowel problems* (-)
consistent (+)	wobble (-)	undersupported (-)	vowels pop out* (-)
inconsistent (-)	scooping (-)	less supported (-)	shadow vowels* (-)
straight tone (-)		weak (-)	
	Expression*	tentative (-)	
	legato (+)	softer (-)	
	nice line (+)		
	choppy line (-)		

Figure 2. Compilation of the Language Expert Listeners Used to Describe the 60 Performances of the two-second [ɑ] Vowel Trials and the Solo Piece Recordings.

heading includes words that describe the same characteristic. The symbols (+), (-), and (n) represent positive, negative, or neutral statements in the 2-second [ɑ] vowel and solo piece performances. Asterisks denote the language that was only used describing the excerpt of the solo piece, and not the 2-second [ɑ] vowel performance.

Each expert met with me again individually for another 75-minute 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 participants' [ɑ] vowel. Before we began, I asked them to read through the list I had compiled from the first session (Figure 2) 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.

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-minute session to complete the remaining participants' solo pieces.

Results

Expert Listeners' Descriptions

I summarized and compiled the descriptors the expert listeners used to describe performances in each condition. For reliability purposes, I asked a Ph.D. candidate to compile the language in 44 of the 66 song performance transcripts and determine the number of positive, negative, and neutral assessments given for each descriptor. We agreed on the wording, quality, and quantity of the terms in all but three instances.

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. For example, I described participant C's microphone condition as having "more elongated vowels" than another condition. Listener 2 described the same example as having "some ring to it, but not his real voice so [it was] hard to analyze." Listener 3 described the condition as having "more legato more elongated vowels—probably her favorite sweeter quality but not as well produced—air not managed as well."

I counted the number of musical descriptions given by each of the three experts (myself, the DMA student, and the voice faculty member). Expert 1 and Expert 2 were very similar in the number of descriptions reported per WAV file (1-3 descriptors). Expert 3 described WAV files with four or more descriptors more often than did Experts1 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 [a] 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 provide a description of the same aspect of tone quality. In four of these five 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 [a] vowel performances.

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 (see Table 1). 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. The same Ph.D. colleague who compiled 66% of the solo performance transcripts examined all verbal descriptions, counted the number of positive, negative and neutral statements, and made overall determinations for the [ɑ] vowel performances. Any disagreements of frequency or overall determination (3 of 66) were discussed, and agreement was reached. 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 Vi-

Table 1. Number of Positive, Neutral, and Negative Descriptors and Overall Assessment 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	1 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

Green = predominately positive, Red = prodominately negative, No box = neutral assesment
*Listeners commented that performers in all conditions were highly similar.

brato condition, Participant *A* received no positive comments, one neutral comment, and seven negative comments. Green boxes in Table 1 indicate the WAV files in which the assessments of overall tone production were predominantly positive. Red 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. For example, Participant *L*'s point condition on the vowel task was determined as neither predominately positive nor negative. In this case, each listener had both positive and negative comments ("nice ring but pushes sharp," "vowel not clear, not particularly clear, vibrato wavery, *[sic]* clearer tone than one," and "gets some ring to it, but has a little hiss to it").

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 (6) conditions than in the Stand (2) and Point Conditions (2). Of the 11 total participants, four were assessed positively in the Stand condition, three in the Microphone condition, two each in the Point and Soft Palate conditions, and only one each in the Vibrato and Baseline conditions.

The information in Table 1 also shows that focus of attention conditions did not affect all participants in the same ways. Based on listeners' descriptions, 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 [a] vowel performances.

I was interested in learning which aspects of singing were most affected by condition. Table 2 shows the number of specific musical descriptors (98 total) identified by two or more of the expert listeners when evaluating the [ɑ] vowel performances. Line 1 of Table 2, 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. Descriptions of negative aspects of tone quality (n = 71) outnumbered positive descriptions (n = *27*) by more than 2 to 1.

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 condition (i.e., 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. Expert listeners described seven participants' performances in the Stand condition and four participants in the Point condition as having good resonance/ring, and four participants in the Baseline condition 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 descriptions of undersupported performances in the Vibrato (4), Baseline (3), Microphone (3), and Soft Palate (2) conditions. Listeners also used negative descriptors related to Color, especially for 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.

Table 2. Numbers of Instances in Which Positive and Negative Terms Were Used to Describe the Eleven [ɑ] Vowel Recordings in Each Condition.

		Internal Focus		External Focus		
Tone Quality Descriptor	Baseline	Vibrato	Soft Palate	Mic (near)	Stand (middle)	Point (far)
Postitive 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	0	0
clearer vowel	0	0	1	0	0	0
brighter tone	0	1	0	0	0	0
Total Postitives (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 Negatives (n = 71)	15	16	15	11	9	5

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 the remaining five WAV files, none of the listeners described the same aspects of tone quality. In these five 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 – green = positive). 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.

Table 3. Number of positive, neutral, and negative descriptors and overall assessment 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

Green = predominately positive, Red = prodominately negative, No box = neutral assesment
*Listeners commented that performers in all conditions were highly similar.

As indicated in Table 3, expert listeners described tone as negative most often in the in the Baseline and Vibrato conditions and most positively in the Point and Stand conditions. The Vibrato and Microphone conditions had more of a balance of positive and negative comments.

The focus of attention conditions did not affect all singers in the same ways, however. For example, Participant *D*'s solo performance was described positively in the Vibrato and Soft Palate conditions but negatively in the Baseline, Stand, and Point conditions. Participant *E*'s solo performance was described negatively in the Baseline and Vibrato conditions but positively in the Soft Palate, Stand, and Point Conditions. Participant *B*'s performance was described positively in the Baseline and Stand conditions but negatively in the Vibrato condition and Microphone conditions.

Descriptors applied to the solo piece performances.

Table 4 shows the number of specific musical descriptors (109 total) identified by two or more of the expert listeners when evaluating the solo piece performances. Line 1 of Table 4, 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).

Results by condition for solo pieces were similar to the results in the [ɑ] vowel task. Only the conditions associated with an external focus of attention (Stand and Point) obtained more positive than 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 [ɑ] 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.

Results of Self-report of Focus of Attention

After the baseline performance, each participant was asked to report his or her focus of attention. Four participants reported thinking about technical aspects (e.g., breath, relaxed abdomen, resonance, space in the back, and registration across the break). Three reported interpretive aspects (e.g., thinking about character, emotion, and orchestration). One participant reported thinking, "What my voice professor would say if in the room?" Two participants reported feedback related to auditory feedback and space in the room. One participant thought about whether the microphone was close enough to pick up and imagined, "Letting the tone bounce off the back wall." Participant J reported thinking about

Table 4. Numbers of Instances in Which Positive and Negative Terms Were Used To Describe the Eleven Solo Recordings in Each Condition.

		Internal Focus		External Focus		
Tone Quality Descriptor	Baseline	Vibrato	Soft Palate	Mic (near)	Stand (middle)	Point (far)
Postitive 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 vowel/legato	0	1	2	2	2	2
banlanced	1	0	2	0	1	0
Total Postitives (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

"Singing out into the room instead of a specific place." I examined whether the response to this question was related to the quality of participants' performance in the baseline condition. I did not find any discernible relationships.

Acoustic Analyses Results

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 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-measure ANOVAs to test the effects of condition on the mean values of harmonic-to-noise ratio and intensity. The ring or resonance referred to in the expert comments is a result of singers' adjusting the articulators in a way that increases the amplitudes of the partials around 3000 Hz which is the so-called singer's formant (Sundberg, 1974). I 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 [a] 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 a significant difference among the means between the Vibrato condition and Stand ($p = .01$) condition, and approached significance between the Baseline and Point condition ($p = .05$), and the Vibrato and the Soft Palate condition ($p = .05$). 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), which is a difference of 2.56 dB.

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.

For measurements associated with resonance and ring, a one-way, repeated- measures ANOVA revealed no significant effects of condition in the [ɑ] vowel performance between F4 and F3 ($F(5, 50) = 0.70$, $p = .63$) or between F5 and F3 ($F(1.37, 13.67)^* = 1.16$, $p = .34$). I found an overall significant effect of condition in the [ɑ] vowel performances for SPR ($F(2.81, 28.05)^* = 3.26$, $p = .04$). However, in pairwise comparisons (using Bonferroni correction) no comparisons were significant, with the greatest difference in means between the Microphone and Point conditions ($p = .11$).

[*] Greenhouse-Geisser adjusted degrees of freedom

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 ($F(2.64, 26.35)$[1]* $= 0.93$, $p = .47$), difference between F4 and F3 ($F(2.22, 22.21)$[2]* $= 0.49$, $p = .78$), and SPR ($F(5, 50) = 1.28$, $p = .29$).

Discussion

The purpose of 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. Expert listeners positively described more performances in the external focus of attention conditions than in the Baseline and internal focus of attention conditions (see Tables 1 and 3).

Additionally, I was interested in determining which aspects of vocal production are most affected by focus of attention. 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.

Baseline

In the present study, 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. Therefore, I expected the Baseline condition to be performed well by the trained singers who participated in this experiment. However, listeners assessed only two performances positively and fourteen performances negatively (combined results of Tables 1 and 3). It seems that when singers were left to their own decision about focus of attention, the overall tone was negatively impacted for most compared to performances with focus instructions. These results are consistent with findings in a swimming task and a golf putt task (Freudenheim, Wulf, Madureira, Pasetto, & Corrêa, 2010; Wulf & Su, 2007). Wulf and Su (2007) found that professional golfers performed better in an external focus condition (i.e., movement of the club) than in an internal condition (i.e., movement of arms) and a condition where the performer was asked to adopt his or her typical focus of attention. Similarly, expert swimmers performed better under an external focus (i.e., pushing the water back) than when they performed under a control condition (i.e., no specified focus) and an internal condition (i.e., pulling your hands back) (Freudenheim et al., 2010). In the present study, the Baseline condition was always performed first, and although the two singing tasks were practiced briefly before recording began, the overall negative descriptions of the baseline performances may be at least partially attributable to presentation order. Additionally, performers arrived warmed-up from the opera workshop, though the time of day and number of hours of singing may have affected individual results.

Internal Focus of Attention Conditions

I defined the Vibrato and Soft Palate 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. Overall descriptions were generally negative for a majority of performances in the internal conditions (see Tables 1 and 3).

Vocal pedagogues agree that vibrato is a natural acoustic phenomenon and that problems occur with vibrato when singers have issues with alignment, breath pressure, breath management, coordination of muscular activity, and tension in the vocal mechanism (Bickel, 2016; Bunch & Vaughn, 2004; Davids & LaTour, 2012). Asking participants to focus on keeping the vibrato steady may have interfered with the already well-coordinated muscle movements of these trained singers. The results are consistent with studies in a variety of tasks (e.g., dart throwing, balance, jump height, basketball throws) using electromyography (EMG) to measure muscle activations (Lohse, Sherwood, & Healy, 2010; McNevin & Wulf, 2002; Wulf, Dufek, Lozano, & Pettigrew, 2010; Zachry, Wulf, Mercer, & Bezodis, 2005). Muscle movements under external focus of attention tend to be smaller in amplitude and higher in frequency (more efficient) than the same movements when the performer directs conscious attention to the body.

Results in the Soft Palate condition were less pronounced in terms of overall positive and negative performance. Expert listeners described eight performances in the Soft Palate condition negatively overall, and five participants' performances positively (combined results of Tables 1 and 3). These results may be attributed to the fact that some voice instructors and choral directors refer specifically to the movement of the soft palate to create changes in timbre, vowel shape, and resonance, followed by feedback on the effects of the change. Further research is needed to determine if tone quality differs between performers whose instructor commonly gives directives regarding the soft palate compared to tone quality of performers whose instructors do not commonly use directives concerning the soft palate.

External Focus of Attention Conditions

I had expected the Microphone condition to result in more positively described tone quality compared to the Baseline, Vibrato, and Soft Palate conditions, especially in light of the fact that untrained singers' Microphone conditions (also 18" at mouth height) were ranked higher than other conditions in a previous experiment (Atkins & Duke, 2013). In the current study, expert listeners described ten performances negatively, and only four positively (combined results of Tables 1 and 3). Trained classical singers learn to move the articulators in a way that boosts the energy in the upper partials so they can be heard above an orchestra without a microphone. The participants in the present study may have "held back" a bit in light of the microphone's proximity. In fact, one participant made an unsolicited comment at the end of the experiment that he was worried he would distort the recording in this condition because the microphone was so close. Additionally, the untrained singers in the previous study (Atkins & Duke, 2013) may have had little experience singing with microphones (especially this type), resulting in less concern about distortion, which may have resulted in more positive assessments.

Performances in the Stand and Point conditions were described more positively overall than were the performances in the other conditions, consistent with research studying distal effects of focus instructions in a balance task (McNevin, Shea, & Wulf, 2003), a golf pitch shot (Bell & Hardy, 2009), a long jump (Porter, Anton, & Wu, 2012), a piano keyboard sequence task (Duke et al., 2011), and 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 terms of acoustical analysis, only Intensity and SPR measurements of the [α] vowel performances revealed significant differences among conditions. Given the number of ANOVAs that I performed on the data and the small sample size, these results must be considered with some caution. The word "softer" was the only word relating to intensity for the [α] vowel performances used by the listeners, but almost always in conjunction with "under supported." I did find trends of lower decibel levels on WAV files that were described as softer, but high decibel levels seemed to have no relationship with positive assessments of tone. The pitches given on the piano were not controlled for volume, which may have had an effect on the volume of the singer within conditions.

Previous research has shown that SPR values are inversely proportional to perceptions of ring (Omari, Kacker, Carroll, Riley, & Blaugrund, 1996), meaning lower SPR value could represent more resonance. However, a visual inspection of the descriptors used to describe WAV files with low SPR values did not necessarily include positive assessments of ring/resonance. For example, participant E's soft palate condition had the lowest SPR value, but was described as "darker, flat, pressed and forced." SPR measurements in this experiment did not align with positive descriptions of ring/resonance.

Though researchers have linked perceptual ratings to acoustic measurements (Cao, Li, Liu, & Yan, 2008; Ekholm, Papagiannis, & Chagnon, 1998; Omari et al., 1996; Wapnick & Ekholm, 1997), studies comparing the effects of various vocal techniques have found no reliable differences in acoustic measures of tone (Atkins, 2013; Atkins & Duke, 2013; Callinan-Robertson, Mitchell, & Kenny, 2006). Similarly, the results of this study 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.

Through this study, I was able to discern whether focus of attention affects tone quality in trained singers and determine specifically what aspects of vocal tone were affected by focus instructions. However, the compilation and analysis of expert listeners' descriptions were time-consuming tasks. Additionally, some expert listeners had difficulty only describing the sound rather than explaining how the sound should be improved. And, 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. These factors made it more difficult to clearly identify and report the effects of the condition on tone quality.

Singing professionals have worked for many years to develop a consensus regarding terms used to describe the classical singing voice, but many different terms are used for evaluating voices, and the definitions of many of these terms are unclear (Van den Berg & Vennard, 1959). The list developed in this study was from descriptions by only three expert listeners of 132 WAV files. Further work is needed to identify, define and solidify language used to describe tone and terms used in vocal evaluation and instruction. Furthermore, the development of an appropriate evaluation tool to detect subtle change in tone quality for a within-subject design is warranted.

Choral Applications

The results of this study suggest that, in general, choral conductors might do well to employ external focus of attention techniques when working on tone. Some caution should be exercised, however. Expert listeners described changes in resonance and ring more than any other vocal characteristic. Resonant singing may not be the desired outcome in the choral setting depending upon preference of the director, the repertoire, and experience level of the individuals in the choir. Furthermore, there is evidence to suggest that non-resonant singing is preferred by listeners over resonant singing in a group setting (Ford, 2003).

Though the overall results in this study showed a general trend toward more positive assessments in the external conditions, it is important to reiterate that not all solo singers were affected in the same way by condition. Like voice teachers, choral directors use specific directives concerning adjustment of the mouth and articulators to produce a desired effect in timbre, vowel, and musical expression. The choral director makes an assessment of the effect as a group sound rather than individual sound. A specific directive in the choral setting may positively affect the overall sound, but negatively affect the individual singers' sound or technique. For example, to correct three or four singers' mouth positions, a choral director may state to the entire group "drop your jaw." This directive may add overextension to a singer who already has the optimal mouth position and may result in a negative tone quality and unhealthy singing technique for that individual singer. Choral directors should consider giving directives to specific singers rather than to the group. Additionally, choral directors could find more ways to assess singers individually on a regular basis through recordings and individual and small group singing.

Teachers and students alike work to improve vocal performance and carrying power in Western classical singing and choral singing, relying on a variety of techniques acquired through observations and trial and error. Very few studies have tested these techniques systematically. Through further study comparing the effectiveness of specific vocal tasks and pedagogical practices, music researchers may continue to provide further insight into the processes of music learning. The results of the present study together with results in many other motor learning investigations (Wulf, 2013) show that focus of attention affects performance outcomes and that external focus conditions are often associated with superior performance.

References

Atkins, R. L. (2013, August). *Focus of attention affects singer's tone production (Unpublished doctoral dissertation).* The University of Texas at Austin. Retrieved from http://repositories.lib.utexas.edu/handle/2152/21573

Atkins, R. L., & Duke, R. A. (2013). Changes in tone production as a function of focus of attention in untrained singers. *International Journal of Research in Choral Singing,* 4(2), 28–36.

Bell, J. J., & Hardy, J. (2009). Effects of attentional focus on skilled performance in golf. *Journal of Applied Sport Psychology, 21,* 163–177. doi:10.1080/10413200902795323

Bickel, J. E. (2016). *Vocal technique: A physiologic approach* (2nd ed.). San Diego, CA: Plural Publishing, Inc.

Boersma, P., & Weenink, D. (2011). Praat (Version 5.2.26). Retrieved from http://www.praat.org

Bunch, M., & Vaughn, C. (2004). *The singing book.* New York: W. W. Norton & Company.

Callinan-Robertson, J., Mitchell, H. F., & Kenny, D. T. (2006). Effect of pedagogical imagery of "Halo" on vocal quality in young classical female singers. *Australian Voice,* 12(1), 39–52.

Cao, C., Li, M., Liu, J., & Yan, Y. (2008, September). *An objective singing evaluation approach by relating acoustic measurements to perceptual ratings.* Paper presented at the Ninth Annual Conference of the International Speech Communication Association, Brisbane Australia.

Davids, J., & LaTour, S. (2012). *Vocal technique: A guide for conductors, teachers, and singers* (1st ed.). Long Grove, Ill: Waveland Pr Inc.

Duke, R. A., Cash, C. D., & Allen, S. E. (2011). Focus of attention affects performance of motor skills in music. *Journal of Research in Music Education, 59,* 44–55. doi:10.1177/0022429410396093

Ekholm, E., Papagiannis, G. C., & Chagnon, F. P. (1998). Relating objective measurements to expert evaluation of voice quality in western classical singing: Critical perceptual parameters. *Journal of Voice, 12,* 182–196. doi:10.1016/S0892-1997(98)80038-6

Ford, J. K. (2003). The preference for strong or weak singer's formant resonance in choral tone quality. *International Journal of Research in Choral Singing, 1*(1), 29–47.

Freudenheim, A. M., Wulf, G., Madureira, F., Pasetto, S. C., & Corrêa, U. C. (2010). Original research: An external focus of attention results in greater swimming speed. *International Journal of Sports Science & Coaching, 5,* 533–542. doi:10.1260/1747-9541.5.4.533

Kenny, D. T., & Mitchell, H. F. (2006). Acoustic and perceptual appraisal of vocal gestures in the female classical voice. *Journal of Voice, 20,* 55–70. doi:10.1016/j.jvoice.2004.12.002

Lohse, K. R., Sherwood, D. E., & Healy, A. F. (2010). How changing the focus of attention affects performance, kinematics, and electromyography in dart throwing. *Human Movement Science, 29,* 542–555. doi:10.1016/j.humov.2010.05.001

McNevin, N. H., Shea, C. H., & Wulf, G. (2003). Increasing the distance of an external focus of attention enhances learning. *Psychological Research, 67,* 22–29. doi:10.1007/s00426-002-0093-6

McNevin, N. H., & Wulf, G. (2002). Attentional focus on supra-postural tasks affects postural control. *Human Movement Science, 21,* 187–202. doi:10.1016/S0167-9457(02)00095-7

Omari, K., Kacker, A., Carroll, L. M., Riley, W. D., & Blaugrund, S. M. (1996). Singing power ratio: Quantitative evaluation of singing voice quality. *Journal of Voice, 10,* 228–235. doi:10.1016/S0892-1997(96)80003-8

Porter, J. M., Anton, P. M., & Wu, W. F. W. (2012). Increasing the distance of an external focus of attention enhances standing long jump performance. *The Journal of Strength & Conditioning Research, 26,* 2389–2393. doi:10.1519/JSC.0b013e31823f275c

Stambaugh, L. A. (2017). Effects of internal and external focus of attention on woodwind performance. *Psychomusicology: Music, Mind & Brain, 27,* 45–53. doi:10.1037/pmu0000170

Sundberg, J. (1974). Articulatory interpretation of the "singing formant." *The Journal of the Acoustical Society of America, 55,* 838-844. doi:10.1121/1.1914609

Van den Berg, J., & Vennard, W. (1959). Toward an objective vocabulary for voice production. *NATS Bulletin, 15*(3), 10.

Wapnick, J., & Ekholm, E. (1997). Expert consensus in solo voice performance evaluation. *Journal of Voice, 11,* 429–436. doi:10.1016/S0892-1997(97)80039-2

Wulf, G. (2013). Attentional focus and motor learning: a review of 15 years. *International Review of Sport and Exercise Psychology, 6,* 77–104. doi:10.1080/1750984X.2012.723728

Wulf, G., Dufek, J. S., Lozano, L., & Pettigrew, C. (2010). Increased jump height and reduced EMG activity with an external focus. *Human Movement Science, 29,* 440–448. doi:10.1016/j.humov.2009.11.008

Wulf, G., Höß, M., & Prinz, W. (1998). Instructions for motor learning: differential effects of internal versus external focus of attention. *Journal of Motor Behavior, 30,* 169–179. doi:10.1080/00222899809601334

Wulf, G., Lauterbach, B., & Toole, T. (1999). The learning advantages of an external focus of attention in golf. *Research Quarterly for Exercise and Sport, 70,* 120–126. doi:10.1080/02701367.1999.10608029

Wulf, G., McNevin, N., & Shea, C. H. (2001). The automaticity of complex motor skill learning as a function of attentional focus. *The Quarterly Journal of Experimental Psychology Section A, 54,* 1143–1154. doi:10.1080/713756012

Wulf, G., & Prinz, W. (2001). Directing attention to movement effects enhances learning: A review. *Psychonomic Bulletin & Review, 8,* 648–660. doi:10.3758/BF03196201

Wulf, G., & Su, J. (2007). An external focus of attention enhances golf shot accuracy in beginners and experts. *Research Quarterly for Exercise and Sport, 78,* 384-389.

Wulf, G., Tollner, T., & Shea, C. H. (2007). Attentional focus effects as a function of task difficulty. *Research Quarterly for Exercise and Sport, 78,* 257-264.

Wulf, G., Zachry, T., Granados, C., & Dufek, J. S. (2007). Increases in jump-and-reach height through an external focus of attention. *International Journal of Sports Science & Coaching, 2,* 275–284. doi:10.1260/174795407782233182

Wu, W. F. W., Porter, J. M., & Brown, L. E. (2012). Effect of attentional focus strategies on peak force and performance in the standing long jump. *Journal of Strength and Conditioning Research, 26,* 1226-1231. doi:10.1519/JSC.0b013e318231ab61

Zachry, T., Wulf, G., Mercer, J., & Bezodis, N. (2005). Increased movement accuracy and reduced EMG activity as the result of adopting an external focus of attention. *Brain Research Bulletin, 67,* 304–309. doi:10.1016/j.brainresbull.2005.06.035