THE EFFECTS OF THREE SINGER GESTURES ON ACOUSTIC AND PERCEPTUAL MEASURES OF SINGING IN SOLO AND CHORAL CONTEXTS

BY

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ABSTRACT

The purpose of this two-part investigation was to assess the potential effects of three singer gestures (low, circular arm gesture; arched hand gesture; and pointing gesture) on performances of choral singers (*N* = 31; Experiment 1) and solo singers (*N* = 35; Experiment 2). Participants sang the melody of three familiar songs from memory on the neutral syllable "m/i/." Songs were chosen for similarities of range, tessitura, and ascending intervallic leaps. Each song was sung seven times: Baseline (without singer gesture), five iterations of each song paired with a singer gesture, and a posttest (without singer gesture).

Experiment 1 measured acoustic (long-term average spectra) and perceptual (pitch analysis, expert panel ratings, and participant perceptual questionnaire) differences in choral sound across conditions. Results indicated a significant increase in mean signal amplitude in sung gestural iterations with the low, circular gesture and pointing gesture. Intonation differences were significant between baseline and the low, circular gesture, baseline and posttest for the pointing gesture, and between the arched hand gesture and posttest. Expert panel ratings were highest during gestural conditions across song selections, and the majority of participants gave positive comments regarding use of gesture during choral singing.

Experiment 2 measured acoustic (*Fo*, amplitude, formant frequency) and perceptual (expert panel ratings and participant perceptual questionnaire) differences of solo singers. Major findings indicated acoustic changes in intonation, timbre, and relative amplitude. Solo singers were more in tune when singing with gestures. Both the low, circular and arched hand gestures changed singer timbre indicated by lowered formant frequencies for the majority of participants. When performing with the low, circular and the pointing gestures, singers sang with increased amplitude, whereas, the arched hand gesture led to decreased amplitude. Expert ratings were highest for the posttest of low circular gestures and arched hand gestures, and the gestural iterations of pointing. The majority of participant comments related to intonation and timbre when using gestures. Video recording analyses from both performance contexts indicated participants mastered the gestures within the first three iterations. Results were discussed in terms of singing pedagogy, limitations of the study, and suggestions for further research.

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CHAPTER ONE

Introduction

The history of music education is replete with convictions about a pedagogical connection between music and bodily engagement. Evolutionary psychologists speculate that early human beings engaged in music-making involving music and movement to forge social bonds and group identity (Mithen, 2005). For the ancient Greeks, the term “mousike” conceives music itself as a combination of sound and corporeal movement. For example, the education of young citizens included membership in a chorus, a context described by Jaeger (1985) as “the high school of ancient Greece.” These choruses not only sang, but also moved as they sang, with these two behaviors viewed as one inclusive phenomenon.

Guido D’Arrezo (ca. 991 – 1050), noticing that singers experienced difficulty in remembering chants learned by rote, developed a mnemonic, solmization system using the human hand to map out syllables representing scale tones. Singers, if needed, could use the fingers of their other hand to point to or tap this mapping of syllables. During the nineteenth century, Sarah Glover (1785-1867) and John Curwen (1816-1880) popularized the use of manual hand signs to assist singers in learning to read a music score at sight. Zoltan Kodaly (1882-1967) refined this procedure by encouraging singers to “see” and internalize the height of a pitch by moving their hands upward or downward in accordance with the steps of the scale signified by a particular hand sign.

During the twentieth century, curriculum reform brought European educational concepts to the United States, particularly ideas about the use of movement in music education (Mark, 1986). Methodologies such as Dalcroze, Orff, and Kodàly, which focus on the internalization of rhythm, phrasing, and musical expression, gained exposure in music classrooms throughout the U.S. (Mark, 1986) and continue to be implemented in music curricula today.

Dalcroze Eurhythmics refers to a set of techniques developed by Swiss musician, Emile Jacques-Dalcroze (1865 – 1950). The basic belief is that movement can be used to strengthen the quality of learning as well as heighten the vividness of its recall at a later time (Dalcroze, 1972, p. 3). Exercises are recommended to develop a "sense of muscular rhythm and nervous sensibility" (Dalcroze, 1972, p.106). Crosby (2008) comments "Dalcroze's kinesthetic teaching model can be applied to the choral rehearsal effectively, using natural movement techniques to vitalize students' rhythmic internalization, breath energy, and phrasing" (p. 30). She went on to speculate that some vocal issues "can be improved by connecting their natural gestures to choral learning" (p. 34). Caldwell (1995) suggests using ideas of Eurhythmics for voice training in terms of breathing, articulation, and coordination of the ear, voice and body.

Another orientation to music education that utilizes movement is that of Carl Orff (1895 – 1982). Stemming from a belief that rhythm is the core of all music (Warner, 1991), the Orff approach focuses on natural rhythmic movements found in child's play, such as skipping, running, clapping, and stamping. Its application to singing includes the pairing of speech patterns and familiar chants to these naturally occurring rhythmic patterns.

In addition to its use of vertical ascending and descending hand signs in sight singing, the Kodàly Method, developed by Zoltan Kodàly (1882 – 1967), fosters other uses of movement, such as tapping and clapping. It also encourages students to show understanding of concepts including low/high and fast/slow through creative movement.

Many educators suggest using these methods of movement with young children, because they are a developmentally appropriate means to teach musical concepts such as rhythm and dynamics (e.g., Perlmutter, 2009; McFarland, 2007; Garner, 2009). Hoffer (1964) supports the use of physical activity in developing rhythm, saying that rhythm is “an elementary, physical phenomenon, and not an intellectual one” (p. 177). He goes on to suggest, “groups that are not musically advanced need many physical experiences related to the rhythm in music… There is need to feel rhythm, and especially the sensation of the beat…” (p.177).

Some other frameworks arise from contexts other than music education, but have been applied by music educators to particular teaching and learning situations. The Alexander Technique and Laban Movement Analysis are two such orientations.

The Alexander Technique refers to a set of ideas put forth by a young Shakespearean actor named F. Matthias Alexander (1869 – 1955), who experienced chronic hoarseness and periodically found himself unable to speak. In an effort to understand and ameliorate his voice problems, Alexander began a process of self-observation. Through use of multiple mirrors, he noticed and mapped recurring patterns of bodily movement and tension when speaking.

Results of these personal observations helped Alexander identify inefficient patterns and habits of posture and balance. Alexander believed that, unchecked, such habits could detract from well-being and optimal voice functioning. Through use of anatomical charts and body mapping, the Alexander Technique encourages a kinesthetic sense, which “tells you about your body: its position and its size and whether it’s moving and, if so, where and how” (Conable & Conable, 1995, p. 19). Gray (1991) describes this process as “inhibiting automatic habitual responses, allowing you to eliminate old habits of reaction and misuse of the body” (p. 13). Various singers, singing teachers, and choral teacher-conductors (Chapman, 2006; Rammage, Morrison, & Nichol, 2001; Sataloff, 2005; Sell, 2005; Sundberg, Thurman & Welch, 2000; Ware, 1997) endorse Alexander’s framework as a means of achieving vocal efficiency.

Laban Movement Analysis, developed by Rudolf Laban (1879 - 1958) for dancers as a means of notating and interpreting human movement, is based on the assumption that “the human body and mind are one and inseparably fused” (Newlove & Dalby, 2004, p. 16). According to Laban, “man uses movement to express himself; at the same time his movement can influence his inner attitude” (In Thornton, 1971, p. 2). Various music educators (Billingham, 2009; Reames, 2006; Jordan, 1996) suggest application of Laban analysis to music pedagogy contexts.

Movement in Choral and Solo Singing Pedagogy

Numerous choral educators advocate the use of movement in the rehearsal process (Apfelstadt, 1985; Bailey, 2007; Gordon, 1975; Henke, 1984; Lana, 2008; Leithead, 2009; Lewers, 1980; Peterson, 2000; Pfautsch, 1973; Phillips, 1994; Robinson & Winold, 1976; Stanton, 1971; and Roe, 1983), focusing primarily on the connection between movement and a sense of rhythm. Stanton (1971), for example, simply encourages singer walking during rehearsal to develop rhythmic sense. Likewise, Robinson and Winold (1976) advise use of movement to increase rhythmic understanding, suggesting that “vital and meaningful” rhythm should be experienced physically. Pierce (2007) proposes using movement to vitalize musical elements such as melody, rhythm, phrase shaping, and tone. Ehmann (1968) devotes an entire chapter to incorporation of physical exercises in the choral rehearsal, including descriptions of various body movements that can be utilized to develop student skill and understanding with concepts such as accents, stresses, and more.

Jost (2011) suggests using movement “to free up the singers, to help them experience kinesthetically the direction of line and phrasing, to get rhythmic patterns” and to “help them interiorize the stress…in a text and feel the mechanics of articulation” (p. 19). Cooksey (1992) advocates “utilizing kinesthetic movement as an essential element of warm-ups and choral singing,” in order that that “the body’s physical, emotional, and intellectual responses are released through appropriate movement activities” (p. 37). Robinson and Winhold (1976) propose that singer movement can have beneficial effects of physical well-being and enjoyment of the rehearsal process. One pedagogue has suggested the internal versus external focus of attention brought about by singer movement can impact a singer’s ability to experience a tension-free sound (Bailey, 2007).

Other authors suggest that movement could aid directly in development of efficient vocal technique. Thurman and Welch (2000) posit that singer movement during rehearsal time could assist in vocal training goals, such as efficient breath flow, easy inhalation and exhalation, efficient and healthy sound production, and body awareness. Reames (2006) suggests, “the use of movement activities in choral rehearsals enhances and improves singers’ vocal technique.” She believes movement contributes to “music reading, performance skills, and other behaviors conducive to good singing and performance (such as focus, concentration, and memorization)” (p. 80).

Jordan (1996) encourages movements such as swaying from side to side. He states, “it is important to remember that basic rhythmic impulse is learned through what amounts to a disturbance of the body kinesthesia” (p. 273).

Hylton (1995) recommends use of movement in rehearsal because it “adds life to choral music” (p. 68). He likens singing to playing baseball as a natural movement process: “The intake and outflow of air, the moment of suspension with the air held in the lungs, the vibration of the vocal cords, and the articulation of sounds all require dynamic motion” (p. 69). Hylton encourages using movement to provide singers with both physical and visual reinforcement of desired singing behaviors. In another such article, Peterson (2000) recommended having singers mirror the conductor's gestures in order to evoke certain sounds.

Using Specific Gestures in Choral and Solo Singing Pedagogy

While some pedagogues recommend larger body movement in singing contexts, others suggest use of specific, smaller gestures when singing, usually referring to some movement of the hands or arms. According to the *New Oxford American Dictionary* (2001), a gesture is "a movement of part of the body, especially a hand or the head, to express an idea or meaning" (p. 712).

Telfer (1997) states that gestures are powerful, work dramatically and quickly, and have long-lasting effects. She suggests that "singers' bodies can work with the voice to help the voice improve," and, consequentially, that when singers move certain parts of the body, "other parts of the body unconsciously react in certain ways" (In Brendell, 1997, p. 29). Telfer also asserts that "some of these gestures get the attention and the attention away from the throat," leading to improved vocal efficiency (In Brendall, 1997, p. 29).

In this regard, Jordan (1996) encourages moving hands and arms in an outward circular motion (p. 273) and pointing to improve pitch accuracy (p. 279). He goes on to say that when singers "point with directness, you will hear that the pitch of the work being rehearsed becomes very clear" (p. 280). Cooksey (1992) suggests using vertical staccato gestures to enhance consistency in large intervals and encourage less weight in the sound (p. 48).

The Perspective of Rodney Eichenberger

One conductor known to use gestural movement in rehearsals and give workshops on the topic is noted choral pedagogue Rodney Eichenberger (b. 1930). His work has been popularized through videos, workshops, conference presentations, and further elucidated by various interviews, articles, theses, and dissertations (Con, 2002; Haldeman, 2001; Hibbard, 1994; Wis, 1993; McClung, 1996).

Eichenberger offers two videos on singer and conductor gesture: *Enhancing Musicality Through Movement* (Eichenberger, 2001) and *What They See Is What You Get* (Eichenberger & Thomas, 1994). In *What They See Is What You Get,* Eichenberger speculates that the nature of conductor gesture can impact the sound of the choir as "we have been conditioned to respond to a wide variety of sights, sounds, and signals" (Eichenberger, 1994). Thus, according to Eichenberger, there is available to conductors, a wealth of nonverbal communication with wider, common understandings.

In his other video, Eichenberger focuses specifically on the use of singer gesture. Eichenberger (2001) suggests two main reasons for using singer gesture: (a) as a positive way to focus singers on improving their sound, because non-verbal gestures carry fewer negative connotations than verbal directions, and (b) as a means of time-efficient improvement of vocal sound and technique.

Wis (1993), Hibbard (1994), and Con (2002) offer a variety of insights into Eichenberger's use of gesture in the choral rehearsal. Wis (1993) finds that Eichenberger's conducting gestures are closely related to those gestures he has singers perform in rehearsals. Repetition of these gestures by the conductor may remind the singers of the rehearsal experience and thus 'trigger' the desired response. Hibbard (1994) notes that singer gestures recommended by Eichenberger are within the singer's personal space using the hands, arms and upper body, are multi-purposeful, and demonstrate a directional quality.

Con (2002) offers a catalogue of movements, gestures and activities, scripts of the Eichenberger videos, analysis of rehearsal techniques, and interviews of Eichenberger himself.

In one interview, Eichenberger states, "it is the discovery of the value of singer motion that has been the most effective for me in keeping the attention of singers and quickly achieving my musical goals" (In Con, 2002, p. 250). Eichenberger also contends "if gesture has such a strong effect on the way we say a word, it undoubtedly influences the way we sing" (In Con, 2002, p. 237).

Need for the Study

Although there is extensive anecdotal commentary regarding singer gesture, only two empirical studies to date (Brunkan, 2010, 2011) test the use of specific singer gestures in particular solo singing contexts. No study to date examines particular gestures in both choral and solo singing contexts, the time it takes to master particular gestures in choral rehearsal and private voice lesson contexts, at what point in the process singer gesture may affect vocal sound, or whether, having employed a gesture, singers continue to exhibit any vocal sound difference after the gesture is withdrawn.

Purpose of the Study

Thus, the purpose of this two-part study was to assess across iterations the potential effects of three singer gesture conditions (low, circular arm gesture; lifting with an arched hand; and pointing upward and outward) on performances of three familiar songs by choral singers ($N = 31$; experiment 1) and solo singers ($N = 35$; experiment 2), using selected acoustic and perceptual measurements.

Research Questions

To that end, the following research questions guided Experiment 1:

1. According to Long-Term Average Spectra (LTAS) measures, are there significant acoustical differences in choral sound (a) between baseline (without gesture) and final

performance (without gesture) conditions, and (b) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture?

2. According to Max/MSP pitch analyses, expert listener (*N* =9) evaluations, and singer questionnaire responses, are there perceived differences in choral sound (a) between baseline (without gesture) and final performance (without gesture) conditions, and (b) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture?
3. How long does it take choristers to master each gesture in a choral rehearsal context, as measured by video analyses?

The following research questions informed Experiment 2:

1. According to formant profile, fundamental frequency (*Fo*), and amplitude measures, are there significant acoustical differences in solo sound (a) between baseline (without gesture) and final performance (without gesture) conditions and (b) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture?
2. According to expert listener (*N* =9) evaluations and singer questionnaire responses, are there perceived differences in solo sound (a) between baseline (without gesture) and final performance (without gesture) conditions, and (b) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture?
3. How long does it take singers to master each gesture in a private studio voice context, as measured by video analyses?

Definitions

The following definitions clarify the three singer gestures employed in this study.

Low, circular arm gesture. Both hands are used, with fingers together and palms towards the midline of the body. Arms, with elbows slightly bent, begin at the level of the hips on either side of the body and follow the upward and outward circular motion of the hands. The hands move in an outward direction in circles in front of the torso no lower than the hips and no higher than the lower edge of the sternum. The arms move at the speed of the quarter note or steady beat of the song.

Pointing gesture. The index finger of the right hand points upward and outward at a 45-degree angle from the torso, starting at the height of the lower edge of the sternum. It then arches outward in front of the forehead. As the index finger leads, the arm follows. The arm begins with elbow slightly bent, extends from the shoulder, and straightens as the point moves outward and upward.

Arched hand gesture. This gesture is done with fingers slightly arched (as if holding a tennis ball) so that the inward surface of the hand (palm) faces downward. The hand moves vertically upward in front of the torso from the level of the hip to no higher than the eyebrows. As the hand moves upward, the arm, starting with elbow slightly bent, follows with elbow slightly bent throughout the gesture.

The following are definitions of the acoustical terminology used in this investigation:

Amplitude. Amplitude is a physical measurement of a sound's acoustic energy, reported in decibels (dB). Amplitude relates, psychoacoustically, to the volume of a sound (i.e., a greater amplitude equals a louder sound.)

Formant Profile. Formants are resonance regions of the vocal tract. Movements of the tongue, jaw, lips and velum, as well as variances in larynx height, modify these resonance regions. A formant profile reports frequency and amplitude characteristics of sound pressure waves as modified by the vocal tract, typically for the first four formants.

Fundamental frequency (*Fo*). The fundamental frequency is the lowest frequency of a periodic, complex sound signal, sometimes called the first partial or harmonic. From a psycho-acoustical perspective, the *Fo* is the perceived "pitch" of a sound.

Long -Term Average Spectra (LTAS). Transmitted human vocal sound includes an array or spectrum of simultaneous frequencies, each of which constitutes a part (or partial) of the whole. Each spectral frequency, moreover, exhibits energy or power. Depending on context, some partials may be dampened (exhibit less energy) or amplified (exhibit more energy).

Long-term average spectra measurement provides information averaged over a period of time about the timbre or resonance of vocal sound. More particularly, LTAS graphs present sound level amplitude as a function of frequency. This quantifiable index of sound quality across a specified period of time can be useful for detecting persistent spectral events.

CHAPTER TWO

Review of Literature

This chapter reviews empirical research literature related both directly and indirectly to singer gesture. As mentioned in Chapter One, only two controlled studies to date (Brunkan 2010, 2011) have examined effects of specific singer gestures. Thus, was this review of literature confined to empirical studies of singer gesture alone, it would constitute a very short chapter indeed.

However, procedures and findings from various related investigations can inform the design and execution of studies that examine an under-investigated phenomenon. Moreover, a review of studies relative to the use and understanding of gesture in music performance, in general, and to singer gesture, in particular, can be useful to researchers.

To these ends, this chapter first reviews research literature related to (a) focus of attention, (b) use of gestures by conductor-teachers, (c) singer imitation of specific nonverbal conducting behaviors, and (d) use of movements and gestures by singers in voice pedagogy. The chapter concludes with the two studies to date that focus on singer gesture specifically, and a chapter summary.

Focus of Attention

Some music pedagogues have suggested that a primary reason for using singer gesture is to evoke changes in vocal sound, and that such changes occur, in part, because of students' focus of attention shifts from an internal to an external focus (e.g., Eichenberger & Thomas, 1994, Con, 2002). Although most focus of attention research has examined activities such as golf, swimming, and balance, some studies in music contexts have been executed.

Focus of Attention in Studies of Golf, Soccer, Darts, Juggling, and Balance

Several investigations in sports and psychology have investigated the topic of focus of attention through golf tasks. In one such investigation, Beilock, Carr, MacMahon, and Starkes (2002) executed a two-part study on the impact of attention on sensorimotor skills. Their first experiment required expert golfers (*N* = 21) to putt as they normally would as well as while distracted by a skill-focused, step-by-step instruction condition. Results indicated that distracted or dual-task conditions led to more accurate putting. In the second experiment, beginning and experienced soccer players (*N* = 20) dribbled through a slalom course under the same conditions (distracted and normal with both dominant and non-dominant feet). When experienced players dribbled with their dominant foot, they performed better under the dual-task condition. Beginners dribbling with both feet and experienced players dribbling with their non-dominant foot dribbled better under the skill-focused condition.

Beilock, Bertenthal, McCoy, and Carr (2004) performed two experiments to examine the mechanisms of attention that facilitate sensorimotor skill performance over varying levels of expertise in golfers. In the first experiment, beginning and expert golfers executed a series of putts under conditions designed to distract attention and under conditions that focused attention on step-by-step performance of the task. Results indicated that beginning golfers performed better with the step-by-step performance focus, whereas expert golfers performed better under the distracted attention condition. In the second experiment, beginner and expert golfers putted while instructed to achieve either accuracy or speed. Again, results indicated opposite outcomes for the two types of golfers. Beginners putted better when instructions emphasized accuracy, and expert golfers putted better when focused on speed. Results of the two experiments indicated that novice performance is improved by conditions that encourage attention to skill focus or accuracy, whereas experts seem to benefit from procedures that limit attention to the task.

Shafizadeh, McMorris, and Sproule (2011) studied golfers (*N* = 30) divided into three external focus groups: target, swing, and target-swing. Participants in the target group focused on the hole, the swing group focused on the club's swing, and the target-swing group was asked to attend to both the hole and the club. Each participant performed the task fifty times in the first phase of the study and ten additional times one day later. Results indicated that participants in the swing group scored better in skill acquisition and retention. Researchers concluded that external focus instruction was more effective in skill acquisition than other instructions.

Wulf, Lauterbach, and Toole (1999) examined 22 novice golfers who were asked to practice pitch shots. Participants were given 80 practice trials. Thereafter, one group was asked to focus on the arm swing (internal focus) with the other group focusing on the swing (external focus). Results indicated that external focus of attention was more beneficial to performance during practice and retention phases.

Zentgraf and Munzert (2009) investigated the effects of type of instruction (body-related vs. ball-related) given to beginning jugglers. Participants (*N* = 61), observed a video of an expert juggler performing a two-ball juggling task. Three experimental groups were established (internal, external and control). The internal group was given body related verbal instructions, the external group was given ball-related instructions and the control group was given no guiding instructions. Results indicated that juggling performance improved in all groups, with the control and external groups exhibiting similar ball trajectories. The researchers concluded that information aiding in skill acquisition might be picked up independently of instructions.

Jackson and Holmes (2011) examined the effects of focus of attention and task objective consistency on learning of a balancing task. They hypothesized that their results would align with previous findings indicating that individuals learn motor skills more effectively when they focus on the effects of their movements (external focus of attention) than focusing on the movements themselves (internal focus of attention). Participants (*N* = 36) with no experience in the task were instructed to balance on a stability platform aiming to keep the platform level with the ground. Each participant wore headphones while performing the task to prevent auditory distractions and were asked to focus on an X on the wall in from of them to keep head position consistent across trials (each 90 seconds). Participants were randomly placed into four experimental groups (internal focus/feet, internal focus/board, external focus/feet, and external focus/board). ANOVA analysis indicated that an external focus of attention was more effective in skill acquisition when the objective was external.

Stoate and Wulf (2011) examined the effects of focus of attention on expert swimmers' speed. Participants (*N* =30) swam 3 lengths of a 25-yard swimming pool under each of three focus conditions. The first condition was an external focus condition wherein participants were asked to focus on pushing the water back. The second condition entailed participants focusing on pulling the hands back. The final condition (control) gave no instructions to the swimmers. Results indicated that swim speed was similar in the control and external focus conditions with a slower speed recorded during the internal focus condition. Posttest participant questionnaires indicated that during the control condition, swimmers focused on the speed or specific body parts. Post hoc analysis indicated that when swimmers focused on specific body parts their time was slower.

Balance has been a specific motor task of interest to several attentional focus researchers. Totsika and Wulf (2003) examined the influence of external and internal focus of attention by asking participants (*N* =22) to ride a Pedalo (two-pedaled, six-wheeled scooter) for 7 meters. Participants completed twenty trials in one of two groups (internal or external focus). Researchers instructed those in the internal focus group to focus on pushing their feet forward. Participants in the external focus group focused on pushing the platforms under their feet forward. Results of ANOVA analysis indicated faster times in the external focus groups. It was concluded that external focus of attention increases efficacy of motor performance that involves speed pressure, distractions and modifications of the skill.

Wulf (2008) examined the effects of focus of attention on acrobats. Participants (*N* = 12), who performed with Cirque de Soleil, performed a balance task (standing on an inflated rubber disk) under three conditions: (a) external focus of minimizing movements of the disk, (b) internal focus of minimizing movements of the feet, and (c) control condition of no focus instruction. Measurements indicated that the frequency of movement adjustments was higher for the control condition. Findings suggested that movement success and postural stability were greatest when participants adopted their own focus of attention. Results may have also indicated that external focus instructions for expert performers may not always enhance performance.

In another study on balance, Shea and Wulf (1999) asked participants (*N* = 32) to balance on a stabilometer (65 x 105 cm. wooden platform) for as long as possible, up to 90 seconds. Two groups of participants were asked to focus on their feet (internal) or on markers attached to the platform (external). The two other groups received feedback about the deviations from the horizontal goal and were given internal feedback (feet) or external feedback (markers). Results indicated that both external focus of attention and feedback increased learning. The authors suggested that one function of feedback in learning might be to encourage external focus of attention.

Chiviacowsky, Wulf, and Wally (2010) also examined stabilometer balance, but in older adults. Participants (*N* = 32) were divided by participant code and sex into two groups and were asked to stand on a balance platform (stabilometer) for thirty seconds at a time for ten trials. One group (external focus) was instructed to focus on keeping markers on the platform horizontal. The internal group was instructed to focus on keeping their feet horizontal. Retention was also tested with five additional trials one day later. Results indicated that the external focus group performed better than the internal focus group possibly indicating that the benefits of external focus do apply to older adults as well.

Lohse, Sherwood, and Healy (2010) examined focus of attention in dart throwing tasks. The researchers examined this task through surface electromyography with motion analysis in order to assess changes in motor performance as it related to attentional focus. Participants (*N* = 12) were fitted with a pair of EMG electrodes on the biceps and the triceps. Each trial was videotaped from a side view in order to assess shoulder angle, elbow flexion, throwing time, and angular velocity of the dart. Results indicated that external focus of attention led to better performance, decreased preparation times in between throws, and reduced EMG activity the triceps The authors concluded that external focus of attention may lead to improved movement economy.

Focus of Attention in Music Contexts

Several investigations have examined focus of attention in music listening (Madsen, 2009; Madsen & Geringer, 1990, 1995; Sims, 1986; Williams, 2005). Studies found differences in music listening focus of attention dependent upon level of experience and/or whether participants were music majors.

Stephens (2010) executed a two-part study examining individual attention and feeling in groups coordinating to efforts in a music composition activity. In the first study, participants (*N* = 204) were divided into fifty-five groups of three and twenty-two groups of two in one of four categories: (a) focus of attention to self, (b) other-focused, (c) self in relation to other, and (d) control (time-focused). Researchers told participants that the Psychology and Marketing department at the university was developing new ‘jingles.’ In the self-focused group, researchers instructed participants to make their best contribution and evaluate themselves on their own work. In the other-focused group, researchers instructed participants to evaluate others’ contributions to the group. Findings suggested that participants coordinated with others based on their perceptions of either ‘parts’ or ‘wholes’ through attention and feeling. Groups with more responsive members were judged to have higher coordination quality.

In the second phase of the study, Stephens (2010) recorded personal experiences, took field notes, and performed interviews with members of a community choir. The researcher used ethnographic methods, participant observation, and qualitative interviews to examine the primacy of feelings or aesthetics in choral singing. Thirty-five choir members were interviewed as to their personal experiences in rehearsing and performing with the choir. The choral singing aspect indicated that performers use the aesthetic as well as attention to coordinate actions and that the choral conductor shaped performers’ attentional focus to coordinate singers.

Duke, Cash and Allen (2011) examined how participants performing a 13-note keyboard passage might be affected if their focus of attention was directed to different aspects of their movements. Music majors (*N* = 16) performed a keyboard passage under four focus conditions in a counterbalanced design. The four focus conditions included focus of attention on either (a) their fingers, (b) the keys of the keyboard, (c) the hammers in the piano, or (d) the sound the piano produced. Performances were recorded via MIDI technology. Results indicated that performance of the piano passage was most accurate when participants focused on the effects their movements produced instead of on the movements themselves. Motor control became more accurate with focus of attention that was more distanced from the task (focus on hammers and sound).

Use of Gestures by Conductors-Teachers

A growing body of research has examined gesture from the standpoint of the conductor or teacher rather than the singer. One such study (Nafisi, 2010) examined gestures displayed by teachers in private voice instruction. She described studio voice instructors' (*N* = 5) pedagogical use of gesture with selected students (*N* = 18). She asked three main questions: (a) did the teachers use gestures to aid the communication of singing-related concepts?, (b), which concepts were being communicated through the use of gestures?, and (c) could the observed gestures be categorized according to their pedagogic intent? (p. 107). She found that gestures fell into two main categories: (a) those aimed at technical ("technical gestures") and (b) those aimed toward musical phenomenon such as phrasing and articulation ("musical gestures"). Some of the technical gestures included movements that mirrored the teacher's understanding of physiological phenomenon ("Physiological Gestures"). Movement representing acoustic phenomena such as vocal timbre/tone quality was put in the "Sensation-Related Gestures" category. She concluded that gesture did play a role as a pedagogic and communicative tool for solo singing instruction. She noted that the movements of the voice instructors were deliberate and related to musical and/or vocal goals.

The Effect of Nonverbal Conducting Gestures on Instrumentalists

Many more studies have investigated ensemble conductor gestures. Sousa (1988) examined nonverbal gestures used by conductors to determine how effective these gestures might be at communicating specific musical ideas. In preparation, he examined five standard instrumental conducting textbooks. Through this process as well as the aid of other expert conductors (N =3), he identified 55 common conducting gestures. These gestures were organized into eight categories: beat patterns, dynamics, styles, preparations, releases, fermata/holds, tempo changes, and phrasing. Instrumental music students (N = 306) viewed videos of the conductor to test accuracy interpreting the gestures. Results indicated that gesture recognition increased with age and experience.

In another study on conducting gesture, Cofer (1998) investigated the effect of conducting instruction on young band members (seventh grade students, N = 60). Students in the treatment group (n = 30) received five days of instruction in gestures from Sousa's (1988) analysis of conducting emblems. The emblems corresponded to several musical expressive concepts: fermata, forte, piano, subito forte, subito piano, crescendo, decrescendo, marcato, staccato, legato, tenuto, accelerando, and ritardando. Cofer designed a lesson plan including sections on instruction in the gestures, vocal responses to the gestures on a neutral syllable, and practice on the gestures on a constructed four-bar melody. The treatment group recognized significantly more conducting gestures than the control group, with participants in the treatment group performing piano, forte, subito piano, subito forte, crescendo (increasing pattern size), decrescendo (with left hand), decrescendo (decreasing pattern size), staccato (with rebound), and staccato (without rebound) more accurately as compared to participants in the control group.

Kelly (1997) investigated the possible effect of conducting instruction with 151 fifth grade students in beginning bands (*N* = 8). For ten weeks, each band performed an identical warm-up during each of their 30-minute rehearsals. The bands in the experimental group (*n* = 4) received up to 10 minutes of conducting instruction in each class, whereas the control bands (*n* = 4) did not receive the conducting instruction. The conducting instruction included several topics: (a) time-beating patterns of four and three, (b) a combination of time-beating patterns with gestures in dynamics, (c) gestures in dynamics, staccato, legato, and phrasing, (d) preparatory and cut-off gestures, and (e) a combination of time-beating patterns with gestures in staccato, legato, and phrasing. Results indicated that the experimental bands displayed significantly more improvement than those in the control bands in three areas (rhythmic performance, rhythm reading, and phrasing abilities) with no differences between the groups in other areas (legato and staccato, dynamic performance, or overall performance).

Byo (1990) investigated beginning conductors' (*N* = 320) ability to correctly determine changes in conducting intensity of beginning conductors (*N* = 25) after some instruction in high and low intensity contrasts in conducting. These conductors recorded a stimulus videotape that graduate music majors (*n* = 80), undergraduate music majors (*n* = 80), non-music majors (*n* = 80), and high school band and choir students (*n* = 80) viewed and assessed. They evaluated conductor high and low intensity in 15-second intervals and using a 10-point Likert scale to rate overall intensity. Results indicated that participants accurately identified the conductor intensity level in 77% of the evaluations. Those in the graduate group were also significantly less likely to make evaluation errors than the other evaluators.

Expressive Conducting

A recent area of interest among conducting researchers has been expressive conducting. Ervin (1975) suggested that expressive conducting occurs when a conductor strays from a traditional beat pattern, exhibits varied facial expressions, or varies the size of beat patterns.

Sidoti (1990) explored how closely high school band students ($N = 139$) would follow expressive gestures displayed by a conductor. The gestural ideas included crescendo, decrescendo, staccato, marcato, legato, accelerando, ritardando, and fermata. Results indicated that students more accurately played the expression markings when the conductor displayed expressive conducting than during the strict time beating condition.

House (1998) investigated trumpet playing and expressive conducting. Sixty college trumpet players played a newly composed etude while observing a videotaped conductor displaying expressive and non-expressive conducting conditions. Next, an expert listening panel ($N = 3$) rated each audio taped excerpt on a scale of little expression to highly expressive. Panelists rated performances under the expressive conducting conditions significantly higher than performances under the non-expressive conducting conditions.

Grechesky (1985) studied the possible relationship between conducting behaviors and ensemble musicality. First, he randomly selected bands ($N = 20$), seventeen of which submitted audiotapes to be evaluated by an expert panel. Experts used a Likert scale to rate the bands from outstanding to poor both globally (overall rating) and with respect to balance and blend, rhythmic precision, articulation, phrasing, tone quality, intonation, and musical expression (sensitivity, nuance). Grechesky then chose eleven bands as participants.

Each of these bands was videotaped during rehearsals and final performances of two movements from "Brevities" by Robert Keyes Clark. Results indicated that the conductors of the more highly rated groups conducted with significantly more body movement as well as approving facial expressions, left hand dynamics, and right and left hand coordination. Limited body movement and disapproving facial expressions had a negative effect on performance rank.

Silvey (2011) investigated whether excellent or poor ensemble performances would influence ratings assigned to highly expressive conductors by ensemble members. The researcher videotaped the conductors (*N* = 2) while conducting one of two excerpts from Frank Ticheli's "*Loch Lomond.*" The researcher synchronized videos of the performance and prerecorded university wind ensemble audio recordings of either excellent or poor performances. College band, choir, and orchestra members (*N* = 120) viewed each of the four excerpts and rated conductor expressivity and ensemble performance quality on 10-point Likert-type scales as well as writing a comment about each video stimulus. Most comments addressed the conductor in the excellent performance condition and the ensemble in the poor performance condition. Results indicated that ensemble performance quality significantly affected ratings of conductor expressivity.

Price and Chang (2001) investigated conductor expressivity and its possible relationship to middle and high school bands' expressivity. The researchers videotaped conductors and audio taped performances of bands (*N* = 15) performing at a district band festival. A group of 27 college-aged instrumental music education majors rated conductor expressivity while viewing the videotape of conductors on a scale of 1 (least expressive) to 100 (most expressive). They also listened to the audio recording in order to evaluate ensemble expressiveness. Results indicated no significant relationships between the conductor expressivity and ensemble expressivity ratings.

In a second study, Price and Chang (2005) followed the same protocol at a state-level concert festival. Results of the judges' ratings did not reveal a significant correlation between the expressivity ratings of the audio and video excerpts with the audio ratings. Interestingly, conductors of the higher-rated bands were judged to be significantly less expressive than the conductors of lower rated bands.

Price (2006) extended the exploration of this topic in a third study. He examined the relationship between festival ratings, conducting, and ensemble performances. In this third investigation he not only examined expressiveness, but also overall conducting quality and performance quality using the recordings of the bands and conductors from the second study (Price & Chang, 2005). Participants ($N = 51$) evaluated the videotaped conductors and the audio taped bands on a scale of 1 to 100. Evaluations of bands that had received a superior festival rating of I were significantly higher than those bands receiving either a II or III.

Price (2006) also asked judges to provide a reason for their scores of both the conductors and the ensembles. Judges viewed video-only excerpts and listened to audio-only excerpts of nine bands and rated them from 'poor quality' to 'excellent.' Comments most often cited when rating the conductor on audio excerpts included intonation, expressivity, ensemble, tone quality, balance, technical, blend, and performance error. Judges' perceptions of the video excerpts were categorized into several categories: nonverbal communication, beat pattern, expressivity, beat clarity, body movement, hand, baton, intensity, gesture, and posture. Results indicated no significant differences for conducting across festival ratings, but did find that bands receiving festival ratings of Superior received significantly higher scores from the judges used in this study.

Krudop (2003) examined expression in performance in a choral context. In this study, he examined the use of conductor kinesics (use of nonverbal physical gestures that act as Emblems, Illustrators, Affect Displays, Regulators, and Adaptors) on the expressive performance of choirs ($N = 8$). Three college/university choirs, three high school choirs, and two community choirs participated in the study. Krudop selected the piece "Sing Me to Heaven" for use in the study as it was thought to be an expressive musical selection. A conductor was videotaped displaying a neutral level of gesture or a more expressive gesture (heightened level of kinesics). A group of five panelists viewed the videotaped performance and judged that the choir sang more expressively when the conductor applied kinesic gestures.

Skadsem (1996) contrasted choral singers' responses to verbal and non-verbal conductor stimuli. Thirty-seven high school choral ensemble members learned the folk song "Michael Row Your Boat Ashore." Participants then sang the song on a neutral syllable ("la") ten times while observing a videotaped conductor who conducted a basic four beat pattern. The conductor used a larger gesture or smaller gesture during loud and soft gestural conditions. Participants wore headphones and sang as they listened to a pre-recorded group of women and men singing the melody. Results indicated that verbal instructions appeared most effective at encouraging correct dynamic changes. However, it is interesting to note that gestural differences may have been confounded as mean eye contact scores indicated that participants watched the conductor for only 23% of the excerpt.

In a follow-up study, Skadsem (1997) examined 48 conductors, 48 collegiate singers, and 48 high school singers learned the folk song "Michael Row Your Boat Ashore." Singers sang while observing a pre-recorded conductor exhibiting a variety of gestural sequences focusing on size of gesture: (a) medium/medium, (b) medium/small, and (c) medium/ large. She used the same verbal and written instructions as the previous investigation. Once again, verbal instructions were found to be the most effective tool in evoking dynamic changes from the singers. In this study, however, there was a significant positive correlation between gesture and eye contact, indicating that participants may have watched the conductor more of the time, thus responding more frequently to conductor gestures.

Napoles (2011) examined the influences of presentation modes on perceptions of expressive choral performance. She used a stimulus recording of four choral music excerpts, each conducted by four different conductors in two ways: (a) using expressive conducting gestures (frequent body movement, expressive gestures, approving and disapproving facial expressions, and group eye contact) and (b) using strict conducting gestures (using little to no body movement, expressive gestures, facial expressions, or group eye contact). Singers in the chorus (*N* = 12) sang 8 to 12 measures of each selection. High school students (*N* = 131) assigned to three experimental groups either (a) listened to audio excerpts, (b) listened and viewed the conductor from the rear, or (c) listened and viewed the conductor from the front. Participants then answered questions on expressivity, tone quality, and overall impression of the performance. Results showed significant differences between presentation modes and conducting style. Participants rated performances conducted with expressive gestures higher than those conducted with a strict gesture in all presentation modes.

Effects of Specific Nonverbal Conducting Gestures on Vocal Sound

While studies of expressive conducting have tended to view gesture in very broad terms, i.e., simply according to whether or not conducting gestures differ from strict pattern beating or include facial animation, other researchers have begun to look at the effects of very specific, singular conductor gestures on vocal sound.

Madsen (1991) investigated the effects of conductor gestures in evoking desired sound from a chorus. A chorus of university singers (*N* = 20) performed Orlando di Lasso's "O Occi Manza Mia" two times under the direction of a conductor with whom they had never worked. The conductor utilized an amorphous group of simultaneous gestures intended to evoke good vocal sound (weight evenly distributed, knees slightly bent, tall body, posture free from unwanted tension, left palm in front of abdomen, right palm turned downward with fingers slightly bent, and facial gestures were expressive and appropriate to the music) every one or two phrases and another simultaneous group of gestures intended to evoke bad vocal sound (torso pulled back, elbows almost touching the rib cage, palms facing each other, gesture done in a "chopping" motion, and non-expressive facial gestures). Thirty-six music majors and thirty-six non-music majors evaluated recordings. Ratings indicated no significant differences in preference for choral sound under either gestural condition. Listeners most often preferred the sound of the first recording even though the recordings were counter balanced in presentation.

Grady (2011) examined whether three conducting gestures affected perceptual and acoustical measures of choral sound in a choir soprano section. Participants (*N* = 10) performed six measures of a movement from Faure's "Requiem" while observing a videotaped conductor displaying (a) a traditional conducting pattern, (b) a vertical conducting gesture, and (c) a lateral conducting gesture. Results indicated that singer participants noticed differences between the three conditions and had the most positive comments about the vertical gesture. Expert listeners (*N* =10) employed for the investigation preferred recordings of both the lateral and vertical gesture over the traditional gesture. Long-term average spectra (LTAS) data showed significant mean signal amplitude differences in the vertical condition. Lastly, pitch analyses indicated that the excerpt sung to the vertical gesture condition was most in tune with itself and the traditional gesture condition led to the most out of tune singing.

Fuelberth (2003a, 2003b, 2004) conducted a series of studies that examined whether specific conducting gestures evoked either perceived or actual tension in vocal performers. In a pilot study (2003a), participants (*N* = 16) viewed a video stimulus of a conductor leading a 10-bar song excerpt. The conductor utilized a standard four-beat pattern in the first four measures. Over the next six measures, the conductor used six left hand conducting conditions: (a) no change, (b) fisted gesture, (c) palm up, (d) palm down, (e) stabbing gesture, and (f) sideways phrase-shaping gesture. Singers performed the examples on a neutral syllable and then viewed a different ordering of the six conditions and assessed the level of inappropriate singer tension that each gesture might evoke. Singers perceived more vocal tension during the stabbing and fisted gestures compared to the no change conditions. The sideways, phrase-shaping gesture had the lowest mean rating of inappropriate singer tension.

Fuelberth's second study (2003b) used the same song excerpt and conducting conditions. Participants (*N* =103) included conductors, college-aged singers and high school-aged singers. The researcher videotaped singers from the participating choirs performing the excerpt from memory. These videotapes were subsequently viewed by three experienced choral conductors, who evaluated the performances on a 10-point Likert scale (from minimum inappropriate vocal tension to maximum inappropriate vocal tension) during both baseline (first four measures) and treatment (subsequent six measures) conditions. Comparison of baseline and treatment condition videos indicated a perception of increased inappropriate vocal tension during all treatment conditions, with the fisted and stabbing gestures yielding greater mean differences than the other gestures employed. These differences did not vary significantly according to singer age groups.

Fuelberth's third study (2004) once again used the same song excerpt and conducting gestures. Undergraduate and graduate students (*N* = 192) evaluated the videotaped conducting with respect to perceived inappropriate vocal tension in each of the specific conducting gestures. Participants indicated that they thought the palm, stabbing, and fisted gestures would increase inappropriate vocal tension with significantly less vocal tension anticipated for the sideways, phrase-shaping gesture.

Singer Imitation of Specific Nonverbal Conducting Behaviors

Several researchers have studied the phenomenon of imitative behavior. In a flagship study, Di Pellegrino, Fadiga, Fogassi, Gallese, and Rizzolatti (1992) were the first to call certain nerve cells "mirror neurons" because of their imitative functioning. In a related study, Fadiga, Fogassi, Pavesi, and Rizzolatti (1995) found that human participants displayed significantly increased levels of motor evokes potentials (MEPs) while observing particular actions. Various functional magnetic resonance imaging (fMRI) studies have shown that observation of finger, hand, arm, mouth, or foot movement activates motor areas of the frontal cortex (e.g., Buccino et al., 2001; Grafton, Arbib, Fadiga, & Rizzolati, 1996; Iacoboni et al., 1999; Manthey, Shubotz & von Cramon, 2003; Rizzolatti et al., 1996; Stevens, Fonlupt, Shiffrar, & Dacety, 2000). Studies by Fadiga, Craighero, Buccino, and Rizzolati (2002) and Watkins, Strafella, and Paus (2003) found that participants who listened to or watched speech evidenced increases in the oropharyngeal muscle potentiation.

Fewer studies have examined mimicking behavior in musical contexts. Manternach (2009) investigated instances of posture sharing in private voice teaching contexts. Participants wore a KayPENTAX Ambulatory Phonation Monitor (APM, Model 3200), which measures the wearer's phonation behaviors. Participants sang *America* ("My Country 'Tis of Thee") four times while facing the instructor/researcher. In each trial, the instructor/researcher took on the following body positions: (a) standing, upright posture, (b) standing, slumped-leaning posture, (c) seated, upright posture, (d) seated, slumped-leaning posture. A panel of five experienced voice instructors examined photos of the participants immediately prior to inhalation. Findings of their ratings did not indicate differences in postures based on the instructor/researcher postural conditions. Further, participants did not identify the differences in the postural conditions. The researcher posited that expressed discomfort with proximity of instructor/researcher to singer participants may have inhibited mimicking behaviors.

In a second study, Manternach (2011a) examined chorister mimicry during conductor preparatory gestures. Participants ($N = 60$), dressed in choir robes, stood in front of a set of choral risers as well as in front of and beside grids of one-centimeter lines pasted behind the singer for subsequent measurement. Singers were videotaped from both the front and side so that a mark on their nose and a clip on the shoulder were visible against each of the two grids. Singers sang "America" seven times while observing a videotaped, life-sized projection of a conductor. The conductor performed various preparatory conducting gestures in advance to the first phrase and the second phrase in one of ten conditions (Up gestures: up gesture beginning on conducting plane, raised forehead height and back to the plane for the first beat, Uphead condition: added upward head movement to the Up gesture, Shoulder condition: added shoulder shrug, Down condition: began at roughly sternum height dropping to establish conducting plane, rebounded up and the back to the conducting plane, Downhead condition: added downward head nod to the Down gesture). Results showed that singers moved their heads in the vertical direction more during the Uphead condition compared to the Up condition. They also showed more vertical shoulder movement during the Shoulder condition than during the Up condition. Results may indicate that singers may mimic certain conductor movements.

In a pilot study, Daugherty and Brunkan (2009) examined the possible relationship between mimicking of conductor behavior and lip rounding while singing an /u/ vowel. Singers sang the first phrase of Mozart's "Ave Verum Corpus" while observing a videotaped conductor. The conductor first performed a standard conducting pattern with neutral facial affect as the baseline condition. Next, the conductor modeled an /u/ vowel with rounded lips on the words "verum" and "corpus" (experimental condition). An expert panel of experienced voice educators rated singers' videotaped performances. Results indicated that nearly all participants displayed more lip rounding on at least one /u/ vowel when the conductor modeled the /u/ vowel.

A second investigation by Daugherty and Brunkan (2011) ameliorated some issues brought to light by panelists in their pilot study. First, in the pilot study, panelists viewed complete video excerpts and experienced some difficulty in judging one excerpt against the other because of length of each clip. Panelists in the first study also watched the baseline video first in each pair, another possible confounding variable the researchers wished to readdress. The researchers employed similar procedures for the second study, with expert judges ($N = 7$) viewing counterbalanced still photos of participants ($N = 114$) for each condition. Results of this visual analysis indicated increased participant lip rounding during the experimental condition of the two excerpted /u/ vowels for a significant majority of participants (90%), a finding confirmed by subsequent grid analyses of a random sample of these photos.

Acoustical measurements of formant frequency indicated that more than 90% of participants exhibited lowered formant frequency profiles each time the conductor rounded his lips. Interestingly, some participants did not report perceived changes in conductor behavior (13.16%) or did not identify changes accurately (14.91%). Almost half (49.12%) of singers cited some change in conductor mouth behavior with almost a quarter (22.81%) specifically noting conductor lip rounding during the two /u/ vowels.

Manternach (2011b) investigated potential singer mimicry by use of a motion capture system. Participants (*N* = 47) applied reflective sensors above each eyebrow, above and below the lips, on the corners of the mouth, and on a headband. The system tracked motion in three dimensions (X, horizontal; Y, vertical; Z, depth). Participants sang the first phrase of Mozart's "Ave Verum Corpus" while observing a videotaped conductor performing counterbalanced conducting conditions in random order. The conducting conditions included (a) eyebrow raise during the first half of the phrase and a modeled /u/ vowel during the second half, (b) neutral eyebrows during the first half of the phrase and neutral lips during the second half, (c) eyebrow raise during the first half of the phrase with neutral lips during the second half, and (d) neutral eyebrows during the first half and a modeled /u/ during the second half.

ANOVA analysis indicated that sensors on the corners of the mouth were closer together (possible increased lip rounding) during the conductor lip rounding condition. A second ANOVA analysis indicated significantly more eyebrow raise during the second occurrence of the raised condition compared to the second occurrence of the neutral eyebrow condition. In addition, lip rounding increased during posttest singing without a conductor compared to the pretest, possibly indicating training effect. Some participants (44.7%) noted changes in conductor lip rounding during the /u/ vowels in the study. Few participants (12.5%), however, noticed conductor eyebrow lift. Again, this study may indicate the existence of singer mimicry of conductors.

Use of Movement by Singers in Voice Pedagogy

As mentioned in Chapter One, the *New Oxford American Dictionary* (2001) defines gesture as "a movement of part of the body, especially a hand or the head, to express an idea or meaning" (p. 712). Thus, the term movement in this study is reserved for larger activities that entail more than the use of just one part of the body. Some researchers have investigated the pedagogical use of larger bodily movements such as walking, swaying, and gliding in choral singing contexts.

Use of Larger Singer Body Movements in Voice Pedagogy: Dalcroze Eurhythmics

Numerous studies have examined the use of Dalcroze techniques in the general music classroom (Ardrey, 1999; Berger, 1999; Bugos, 2011; Crumpler, 1982; Fairfiled, 2010; Jeong, 2005; Joseph, 1982; Metz, 1986; Rose, 1995), music theory learning (Urista, 2001; Walker, 2007), piano pedagogy (Jacobson, 1989; Nalbandian, 1994), as well as theater and dance education (Hecht, 1971; Lee, 2003; Rogers, 1966; Thomas, 1995). Research on the use of Dalcroze Eurhythmics in solo voice education, however, is very limited.

Johns (2002) examined Dalcroze-type movement while singing. He posited a neurobiological basis for the effect of movement on the voice after measuring trial length, peak loudness and number of breaths taken per trial. Singers ($N = 13$) were recorded while singing "The Star Spangled Banner" a cappella under three conditions: (a) without moving, (b) while copying live movements similar to tai chi movement, and (c) while copying movements connected to a specific concept. Audio recordings were analyzed using Pro Tools Free for volume and song length and video recordings were analyzed for changes in posture. Results indicated that trials with movement were longer. Posture changed between trials. However, differences were attributed to changes in researcher posture.

Several researchers have examined the use of Dalcroze techniques with choirs. Manganello (2011) observed two middle school (grade 6 and grade 7) choirs to (a) investigate the students' description of their experience using Dalcroze techniques, b) how the movement contributed to students' ability to express the music, (c) why the choral teacher used movement, and (d) what movements were being use and for what purpose. She carried out a participant-observation case study of the directors. Results suggested that movement in the choral rehearsal aided musical expression, developed social camaraderie, and fueled deeper musical understanding. Movements used by the director were aimed at evoking changes in dynamics, phrasing, breathing, articulation, and interpretation. Finally, the use of movement helped students to recollect expression and interpretation when performing the music.

McCoy (1986) examined the effect of Dalcroze-based singer body movement in high school choral rehearsals on musical learning and perceived experience of the singers. She developed a set of movements, trained the directors, and recorded rehearsals over a nine-week period. The researcher employed four choirs at two schools: two choirs made up of less experienced singers and two with more experienced singers. At School A, the less-experienced group was the control group and the more-experienced, the experimental group. At School B, the less-experienced group was the experimental group and the more-experienced group was the control group.

Following the nine-week rehearsal period, McCoy measured choral ensemble performance proficiency, individual ability to discriminate metrical groupings, and student attitude toward participation in the choral ensemble. She used the Cooksey Choral Performance Rating Scale (CPRS), the Colwell Music Achievement Test 1(Part 3), and a researcher-designed Attitude Rating Scale as measurement tools.

McCoy found that for the more-experienced/advanced ensemble in the study, the "movement strategies used throughout the rehearsal process were effective in producing performances with steadier tempi and better balance and blend among parts" (p. 60). She also found a significant difference in attitude, with the more-experienced ensemble having more positive attitudes toward choral participation than the less-experienced ensemble.

Survey and Observation Studies: Movement and Gesture in Choral Rehearsals

Weaver (1977) examined the development of vocal, choral, and musical concepts based on a sequenced integration of vocal/choral principles with interpretive body movements such as walking and swaying. He used pre- and posttest videos of a community choir to rate the choir's tone production, diction, technique, range, musical effect, discipline, presence, and appearance. In the experimental stage, a series of lesson plans were designed and executed to develop all skills of the choir in interpretation, diction, and voice. Weaver concluded that movement techniques were successful. However the study was not tightly controlled and therefore, results and conclusions must be read with caution.

Wis (1993) surveyed literature on the use of movement in the choral rehearsal suggesting that it may facilitate learning and enhance musical experience. She posited that movement activities allowed choral singers to use the natural inclination of bodily-based learning, may encourage more active participation from the singer, and are less subject to misinterpretation than words. Wis aimed to develop a theoretical framework as to how body movement in the choral rehearsal could function as physical metaphor to facilitate learning and enhance musical experience. Wis commented that much of the writing on movement in the choral rehearsal focuses on the development of rhythmic skill and musical understanding, but noted, "there are also bodily-based activities…that have as their goal other kinds of musical or vocal/choral skills, such as expressive or tension-free singing" (p.3). According to Wis' analysis, the Eichenberger orientation "automatically searches first for some kind of movement to get at a musical or vocal problem" (p.238).

Hibbard (1994) examined the use of movement in the choral rehearsal through a review of literature and observations of choral conductors. She interviewed choral conductors as to their usage and beliefs about movement, identified, and categorized movements using Laban movement analysis, and developed a grounded theory regarding the use of movement as an instructional technique. She concluded that all movements (a) function as a means of calling singers to attention, (b) provide a visual, aural, and kinesthetic experience for singers, and (c) heighten awareness of differences in sound. Moreover, Hibbard suggested that larger movements were used for general purposes (i.e., breath) whereas smaller gestures were used for more specific goals (i.e., release of a note, intonation of a pitch). She noted that the majority of the movements observed or described were upper body gestures done with hands and arms, and that the majority of movements were employed in the belief that they had a direct or indirect effect on tone quality.

Chagnon's (2001) compared data from Wis and Hibbard. On this basis, he suggested that singer movement mentally engages the singer and releases tension, and
may be a viable instructional technique in the choral rehearsal, particularly with respect to modifying dynamics, rhythm, tempo, articulation, and intonation.

Con (2002) documented Rodney Eichenberger's life, achievements and professional engagements, described the elements of his philosophy, analyzed Eichenberger's instructional videos in order to develop a catalogue of movements, gestures and activities employed, and documented Eichenberger's use of gestures in an All-State choral rehearsal. Among comments from the interviews, Eichenberger states, “it is the discovery of the value of singer motion that has been the most effective for me in keeping the attention of singers and quickly achieving my musical goals” (In Con, 2002, p. 250).

Empirical Studies of Specific Singer Gestures

Two previous studies (Brunkan, 2010, 2011) most closely align to the present investigation. In a pilot study, Brunkan (2010) examined selected acoustic and psychoacoustic measurements of the effects of three conducting conditions, singer gestural training, and singer gestural movement on singers’ ($N = 58$) performance of an /u/ vowel in the final phrase of the song “Happy Birthday.” Thirty-eight singers were randomly assigned to three different groups during the treatment phase. The control group sang to the tempo of a metronome, one experimental group practiced the phrase while watching a videotaped conductor, and the other experimental group sang while watching the conductor and doing the circular arm gesture. An expert panel ($N = 10$) rated pre- and posttest audio samples.

Results indicated statistically significant main effects for type of gesture by group in the posttest. Significant differences in deviation in cents from target frequency (pitch accuracy) were found when participants physically mimicked the conductor’s gestures. Perceptual results also offered some interesting insight into the perceived effects of singer gesture. Participants most often described the low gesture as offering a feeling of deeper breath, the high gesture as lighter and tense sound, and the standard conducting gesture as affording a sense of familiarity and comfort. The expert panel ratings of intonation aligned with acoustical measures of deviation in cents from target frequency in the posttest.

In a related study, Brunkan (2011) measured the low, circular gesture from the aforementioned investigation utilizing a 3D infrared motion capture system. In this follow-up study, she analyzed the possible relationships between a low, circular singer arm gesture and changes in fundamental frequency and formant frequency by standard acoustical measures, assessed possible relationships between magnitude of motion (measured by motion capture technology) and changes in frequency contour, explored relationships between singer hand, head, eyebrow and mouth movement, and examined participant perceptual responses in regards to singing with and without gesture.

Participants ($N = 49$) sang the final phrase of “Happy Birthday” with and without motion. While singing, participants were recorded using the OptiTrack 3-D infrared motion capture system capable of synchronizing acoustical and motion data.

Results indicated that most singers were closer to the target pitch when doing the low, circular gesture. She also found a statistically significant difference in pitch measurements. Singers were closer to the target frequency when doing the low, circular motion. Movement of the arm markers and other motion markers (bottom lip and head) were positively correlated, indicating similarities in movement. Correlations between hand markers and eye and lip motion markers, however, were negative. Singer perceptions of singing with the gesture included producing a fuller tone and singing with more breath. When singing without gesture, singers commented that it seemed easy and comfortable.

Summary

This chapter reviewed research literature related to (a) focus of attention, (b) use of gestures by conductor-teachers, (c) singer imitation of specific nonverbal conducting behaviors, (d) use of larger movements by singers in voice pedagogy, and (e) two studies that focused on potential pedagogical effects of smaller, specific singer gestures. On the basis of this review, several factors and findings to date appear pertinent to the present investigation.

In a vocal music education context, interest in singers employing gestures as a rehearsal or practice strategy has arisen from beliefs expressed by some vocal pedagogues (e.g., Eichenberger & Thomas, 1994) that particular gestures may facilitate improvements in vocal sound in a largely non-verbal and thus time efficient manner, perhaps through an external focus of student attention. However, testing of such beliefs has only just begun. To date, most research of gesture as a potential means to change vocal sound has focused on teacher or conductor gesture.

Previous research on focus of attention during a motor task has indicated that such focus may influence the outcome or performance of said tasks. That finding raises two matters that could inform research of singer gesture. First, while singing is obviously different from playing golf, dribbling a ball, or throwing darts, it does entail complex bodily coordination of fine muscles. Secondly, it may be far too early in research of an under-investigated phenomenon, such as the potential impact of singer gesture on vocal performance, to seek explanations of why it may occur. The prior question is whether and to what extent it occurs at all. Still, it may be appropriate to inquire through an exit questionnaire about participants' perceived focus of attention while simultaneously singing and employing particular gestures.

More studies to date (e.g., Price, 2006; Morrison & Selvey, 2011; Napoles, 2011) of conductor-teacher gesture have focused on score-centered factors of musical expressivity. Comparatively fewer studies (e.g., Fuelberth, 2003b, Grady, 2011) have explored whether conductor gesture influences vocal physiology and efficiency of vocal sound. Some studies (e.g., Daugherty & Brunkan, 2011, Manternach, 2010, 2011) have suggested that particular conductor behaviors and gestures (such as lip rounding, eyebrow raising, moving the head) occasion mimicry or empathetic singer responses that have acoustical consequences, such as changes in vocal timbre and intonation. Studies that have focused on potential changes in vocal sound through conductor gesture contribute to the present investigation primarily by employment of dependent measures (formant profiles, fundamental frequency (*Fo*), video analysis, long-term average spectra (LTAS), rating scales, motion capture procedures) that could be used as well for assessment of vocal behaviors evidenced by singers employing specific gestures.

Studies of larger body movements while singing (e.g., Johns, 2002; Mangello, 2011) have focused largely on independent variables of rhythmic precision and internalization, phrasing, dynamics, articulation, and student engagement. Some researchers (e.g., McCoy, 1986; Wis, 1993), however, have posited that larger movements may also release vocal tension and, in choral contexts, promote better balance and blend of voice parts. Measuring the potential impact of larger movements on singing physiology and sound may be confounded by the engagement of numerous, simultaneously moving parts of the body. Thus, a research decision first to measure more discrete, specific, and therefore isolatable, singer gestures appears indicated.

Several factors from two previous studies (Brunkan, 2010, 2011) of such gestures suggest some refinements that could be implemented in the present study. First, these studies measured gesture in solo singing contexts. If, as several commentators have proposed, singer gesture may impact choral sound, measurements of singer gesture in a choral singing context appear warranted.

Secondly, the primary singer gesture employed by Brunkan (2010, 2011) was a low, circular gesture moving up and out in front of the torso, and thus a hybrid gesture. Eichenberger (1994), however, suggested a low circular gesture moving from the center of the torso, upward and outward to the sides of the body for more energy. It would seem prudent for this study to test some particular gestures recommended in the methods literature. Thus, in addition to the low, circular gesture recommended by Eichenberger, this study investigates as well use of a pointing gesture, recommended by Eichenberger and Jordan (1996), and singer employment of an arched hand gesture, a gesture also recommended by Eichenberger.

Finally, if singer gesture is employed as a teaching tool, vocal music educators would likely benefit from data that indicate how long it takes singers to master particular gestures in both solo and choral singing contexts and at what point, if any, in an iterative gestural learning process, employment of a specific gesture begins to influence vocal sound. To date, no study has addressed such matters.

CHAPTER THREE

Method

The purpose of this two-part study was to assess across iterations the potential effects of three singer gesture conditions (low, circular arm gesture; lifting with an arched hand; and pointing upward and outward) on performances of three familiar songs by choral singers (N = 31; experiment 1) and solo singers (N = 35; experiment 2), using selected acoustic and perceptual measurements. This chapter details the participants, procedures, and equipment employed in this investigation.

Participants

Singer participants. Participants (N = 66) constituted a convenience sample recruited by word of mouth from the student body of a large Midwestern University, with effort made to include females and males of varying (a) ages, (b) previous choral singing experiences, (c) years of private voice study, and (d) conducting experience. Participants ranged in age from 18 - 32 years. More experienced was defined as 5 or more years of experience from junior high to present, whereas less experienced was defined as 2 or fewer years of experience from junior high to the present. All participants (N = 66, 100%) stated that they were familiar with and could sing from memory the melody of song excerpts used for this study.

To control for potential training effects between experiments one and two, approximately half of the singers (N = 31) participated in the choral singing portion of the study and approximately half (N = 35) participated in the solo singing portion of the investigation. Choral context participants (N = 31) were male (n = 15) and female (n = 16) singers between the ages of 18 – 32 (M = 21 years). All singers were currently in choir and had varied experience in elementary school choir (M = 3.387 years), middle school choir (M = 1.967 years), high school choir (*M* = 3.0967 years), college choir (*M* = 2.613 years), adult choir (*M* = .29 years), voice lessons (*M* = 3.193 years) and dance lessons (*M* = 2.838 years) and conducting experience (*M* = .742 years). Solo context participants (*N* = 35) were male (*n* = 15) and female (*n* = 20) singers between the ages of 18 – 31 (*M* = 23 years). All singers were currently in choir and had varied experience in elementary school choir (*M* = 2.888 years), middle school choir (*M* = 1.485 years), high school choir (*M* = 1.685 years), college choir (*M* = 1.514 years), adult choir (*M* = .514 years), voice lessons (*M* = 1.748 years) and dance lessons (*M* = 1.328 years) and conducting experience (*M* = 1.228 years). Overall, participant demographics, including sex, age range, and experience levels in choral singing, private voice study, and conducting experience, were similar.

Expert panel participants. Two panels of expert listeners (*N* = 9 per panel) participated in this investigation. These listeners were experienced choral conductors and voice teachers with advanced degrees and a minimum of 10 years' experience in working with singers in choral and/or solo singing contexts. Most expert listeners (*n* = 7) for Experiment 1 (choral singing context) were experienced choral conductors. Similarly, most expert listeners (*n* = 7) for Experiment 2 (solo singing context) were experienced studio voice teachers. No listener reported a hearing problem at the time of the study. Choral context experts (*N* = 9) were made up of current choral conductors (*n* = 7) and studio voice teachers (*n* = 2). Male (*n* = 2) and female (*n* =7) ranging in age from 30 – 58 years (*M* = 41.56 years) with general music teaching experience (*M* = 7 years), choral conducting experience (*M* = 11 years), and studio voice teaching experience (*M* = 5 years) comprised the panel.

Solo panel experts (*N* = 9) were choral conductors (*n* = 1) and studio voice teachers (*n* = 8). Male (*n* = 4) and female (*n* =5) ranging in age from 34 – 51 years (*M* = 39.99 years) with general music teaching experience (*M* = 8.29 years), choral conducting experience (*M* = 10.86 years), and studio voice teaching experience (*M* = 11.89 years) comprised the panel.

Sung Musical Excerpts

Participants in both solo and choral singing contexts sang the same set of three sung melodies excerpted from familiar songs. For consistency across conditions and to avoid diphthongs, participants sang each syllable of the lyrics on “m/i/.” That is, the melodies were sung on a neutral syllable throughout the study. These melodies were selected because (a) they were compositions likely to have been performed or heard at some point by participants, (b) they lent themselves to a moderate tempo, (c) they contained ascending octave leaps, (d) they contained at least two sustained tones on a high d (female voice: 587.33 Hz, male voice: 293.66 Hz), and (e) they were all in the range of D (female voice: 293.66 Hz, male voice: 146.83 Hz) to high D (female voice: 587.33 Hz, male voice: 293.66 Hz).

The first sung excerpt consisted of the first four phrases of the melody line of “Somewhere Over the Rainbow” (see Figure 1). The second selection was “Singin’ in the Rain” (see Figure 2). The folksong “Hawaiian Rainbows” (see Figure 3) constituted the third singing task.

Figure 1. First four phrases of melody line of "Over the Rainbow" (brackets = low, circular arm gesture).

Figure 2. Melody of “Singin’ in the Rain” (arrow = pointing gesture).

Figure 3. Melody of "Hawaiian Rainbows" (bracket = arched hand gesture).

Gestures Employed

Each of the melodies illustrated in Figures 1 – 3 employed one of these singer gestures at indicated junctures. The three gestures used in this study were: (a) a low, circular gesture, (b) an upward pointing gesture, and (c) an arched hand gesture.

Low, circular arm gesture. Both hands are used, with fingers together and palms towards the midline of the body. Arms, with elbows slightly bent, begin at the level of the hips on either side of the body and follow the upward and outward circular motion of the hands. The hands move in an outward direction in circles in front of the torso no lower than the hips and no higher than the lower edge of the sternum. The arms move at the speed of the quarter note or steady beat of the song.

Figure 4. Participant performing the low, circular arm gesture in “Over the Rainbow.”

Pointing gesture. The index finger of the right hand points upward and outward at a 45-degree angle from the torso, starting at the height of the lower edge of the sternum. It then arches outward in front of the forehead. As the index finger leads, the arm follows. The arm begins with elbow slightly bent, extends from the shoulder, and straightens as the point moves outward and upward.

Figure 5. Participant performing the pointing gesture in “Singin’ in the Rain”

Arched hand gesture. This gesture is done with fingers slightly arched (as if holding a tennis ball) so that the inward surface of the hand (palm) faces downward. The hand moves vertically upward in front of the torso from the level of the hip to no higher than the eyebrows. As the hand moves upward, the arm, starting with elbow slightly bent, follows with elbow slightly bent throughout the gesture.

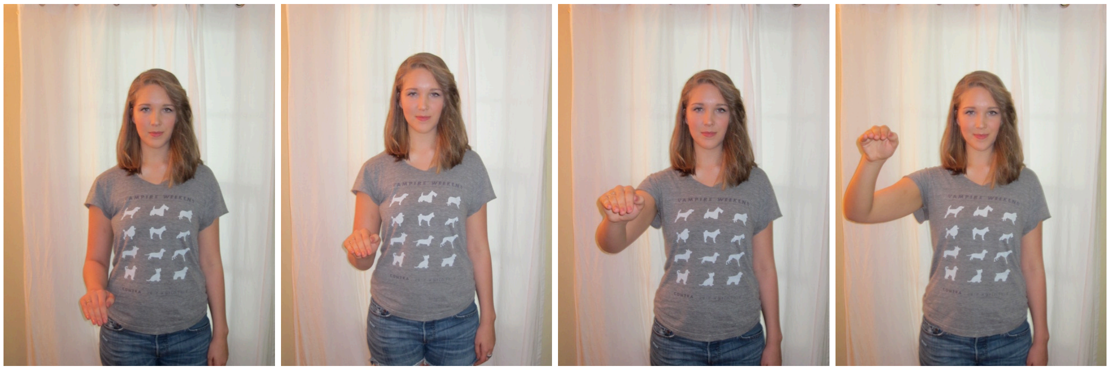

Figure 6. Participant performing the arched hand gesture in "Hawaiian Rainbows"

Experiment 1 – Choral Context

Research Room

The choral singing portion of this study took place in a room (54'7" x 60' x 30' x 48' 6") used for choral rehearsals (See Figure 7). Singers stood on 3-step choral risers (Wenger Tourmaster) with consistent 24-inch lateral spacing between singers throughout Experiment 1.

During the recording session, singers observed and responded to a live conductor. Gestures were taught by the conductor in attempts to create a naturalistic choral rehearsal environment. The conductor stood 15 feet from the front step of the risers, a distance commonly assumed by conductors during choir rehearsals in this room.

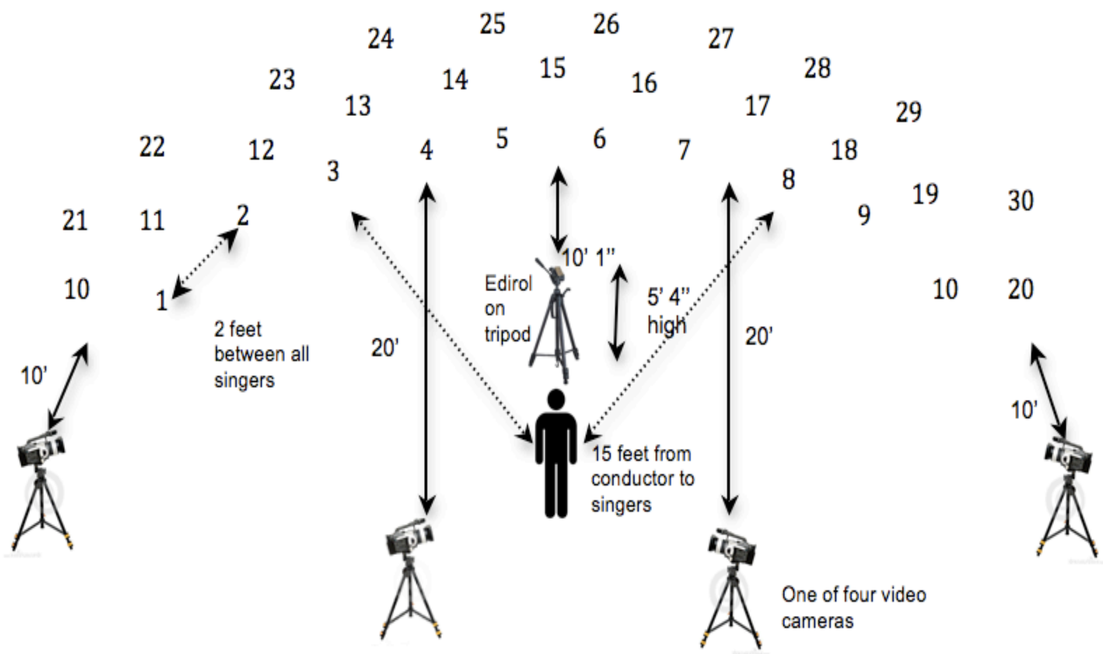

Figure 7. Choral rehearsal research room configuration (Numbers represent singer participants).

Equipment

An Edirol R-109 digital sound recorder captured each performance at a sampling rate of 44.1 kHz (16 bits) in .wav format. The recorder was placed 3.8 meters (10’1’’) from the front row of the choir, in a mixed to diffuse sound field, at a height of 1.65 meters (5’4’’) or approximate conductor ear height. Volume and gain controls were set manually at the beginning of the recording session and remained the same throughout all recordings. Singers heard the starting pitch for each selection sounded by a Master-Key pitch pipe (C – C range) prior to each sung trial.

Four digital video cameras (RCA Small Wonder EZ2000) captured video footage of the entire rehearsal process. Two cameras were placed 20 feet from the front row of singers (one to each side) with two additional cameras placed 10 feet from the choir on a diagonal and to the side of the choir to record a side view (see Figure 4). The cameras were set up such that all singers could be videotaped throughout the process for subsequent analysis of their progress in learning and mastering the gestures used for this study.

Procedure

Upon entering the rehearsal room and prior to taking their places on the risers, participants completed an Institutional Review Board (IRB) pre-approved consent form (see Appendix A), a brief demographic questionnaire (see Appendix D), and demonstrated individual ability to sing each of the three melodies using the neutral syllable "m/i/," for research assistants. The research assistants pointed out any errors of pitch or rhythm, as needed, and then helped participants correct those errors without commenting on singer tone quality, stance, breath support, or any element of vocal production.

Prior to singers' arrival, I tested all recording equipment tested. Choral risers were set up such that singers would have at least two feet of space on either side of them. I measured the space with a 24-inch dowel from one singer's shoulder to the next. Participants were randomly assigned to a position on the risers. I then assigned each participant a participant code according to sex and experience level for use in subsequent video analysis.

Two weeks prior to the recording session, I gave singers a copy of each song selection employed in the study. They were asked to practice the songs so that when they arrived at the recording session, they could sing the melody with the group from memory. Therefore, I quickly reviewed singers' answers to the last question on the demographic questionnaire, "Can you sing the three melodies from memory? Yes or No?" The majority of singers indicated that upon arrival they could sing the melodies from memory. All participants (100%, $N = 31$) stated that they had "Over the Rainbow" memorized upon arrival. Most participants (90.32%, $N = 28$) also had "Singin' in the Rain" and "Hawaiian Rainbows" (71.6%, $N = 22$) memorized upon entering the research room. Participants' ability to sing each of the three selections by memory on they syllable "mi" was tested by the research assistant. I then led the singers (*N* = 30) through a brief vocal warm-up in order to give singers a chance to become familiar and comfortable with the overall group sound.

Following this warm-up, I led the group in singing each melody once, using standard conducting patterns of a consistent plane and size. A metronome with a blinking light insured consistency of tempo.

After these "get acquainted" performances, baseline recordings and treatment iterations began. The choir sang the melody of "Over the Rainbow" once while following the conductor who exhibited a standard conducting pattern. I then taught the low circular arm gesture to the singers. I explained and demonstrated this gesture in detail.

Thereafter, I asked the choir to sing this melody five times while performing the low, circular arm gesture along with the conductor. Singers and conductor employed the gesture at the junctures indicated in Figure 1. Occasional verbal reminders were given, as needed, between iterations. At the end of this process the melody was performed without gesture in order to assess any possible short-term training effects. The same procedure employed for "Over the Rainbow" was repeated for "Singin' in the Rain," and "Hawaiian Rainbows" with only the specific gesture varying between songs.

At the end of the recording session, signers completed a post-test questionnaire (see Appendix E). This survey inquired about (a) any differences participants perceived in their own sound/singing during the recording session, (b) their personal focus of attention, and (c) participants' perceptions of overall choral sound. These questionnaires were coded with a participant number and collected for subsequent analysis.

Dependent Measures

Acoustic evaluation. Choral singing constitutes a more complex acoustic phenomenon than solo singing (Rossing, Sundberg & Ternström, 1986, 1987; Ternström, 1989, 1999). Therefore, long-term average spectra (LTAS) analysis constituted the dependent acoustic measure for choral sound in this study.

All choral context recordings were transferred digitally to a Dell Latitude 830 laptop computer with Windows XP operating system equipped with Computerized Speech Laboratory (KayPENTAX 4500) software. LTAS data were obtained for each recording using a window size of 512 points with no pre-emphasis or smoothing, a bandwidth of 86.13 Hz, and a Blackman window. Resulting data were put in Excel Spreadsheet files for subsequent statistical analyses.

Max/MSP Measurement of Perceived Intonation. For purposes of this study, perceived in tune or out of tune choral singing was defined by any deviation from the scored pitch exceeding the range of ±14 cents (Ternström, 1993). Because the complexity of choral sound makes computerized extractions of *Fo* inadvisable, I followed procedures used by Howard (2005) and Daugherty (2005) to evaluate perceived pitch with the assistance of Max/MSP software and a MacBook Laptop computer.

For the first selection, "Over the Rainbow," I used the following measurement points: (a) the midpoints of the "m/i/" vowel (corresponding to the /ɛ/ vowel on the word "somewhere") in measures 1 and 9, and (b) the midpoints of the "m/i/" vowel (corresponding to the /u/ vowel on the words "blue," and "true") in measures 12 and 16. For the second selection, "Singin' in the Rain," I used the following measurement points: (a) the midpoints of the "m/i/" vowel (corresponding to the /I/ of "singing") in measures 1 and 29, (b) the midpoints of the "m/i/"

vowel (corresponding to the vowel /o/ of “glorious”) in measure 5, and (c) the “m/i/” vowel (corresponding to the vowel /a/ of “dark”) in measure 11. For the third selection, “Hawaiian Rainbows,” I used the following measurement points: (a) the midpoints of the “m/i/” vowel (corresponding to the vowel /e:I/ of “rain”) in measure 2, (b) the midpoints of the “m/i/” vowel (corresponding to the vowel /o/ of “rainbows”) in measures 2 and 10, and (c) the midpoints of the “m/i/” vowel (corresponding to the vowel /i/ of “sea”) in measure 16. As a control for vowel stability, the middle one second of each vowel was extracted and analyzed.

The Max/MSP configuration (see Figure 8) produced a sinusoidal reference tone set initially to the score notated pitch for each extracted sustained vowel and starting pitch of interest. Intensity of the sine wave output was constant for all conditions to control for possible variations in subjective pitch due to varying intensity levels of the sine wave (Terhardt, 1974). One cent is $1/100^{th}$ of a half-step; there are 12 half-steps to an octave in equal temperament. Fine tuning frequency values were converted to cents using the following equation (Howard & Angus, 2001): Value in cents =3886.3137 x $\log_{10}$ (fine-tuning value/440).

The *Fo* of the sine wave reference was adjusted to match each pitch investigated by (a) setting the sinusoidal reference tone to the fundamental frequency displayed in the score and (b) then adjusting the fine-tune control up or down to achieve a pitch match. Both the notated fundamental frequency and the fine-tune setting were recorded on an Excel spreadsheet. Fine tuning frequency values were converted to cents using the following equation (Howard & Angus, 2001): Value in cents =3886.3137 x $\log_{10}$ (fine-tuning value/440).

This configuration also enabled simultaneous playing of the extracted sung performances. I therefore was able to adjust the frequency of the reference tone (presented in both Hertz and cents) until it matched the perceived pitch of the sung excerpt. The score-notated fundamental frequency, the fine-tune setting, and the perceived pitch, each converted to cents were then recorded on an Excel spreadsheet for statistical analyses. I repeated the same procedures for all excerpts a day later. Obtained reliability (agreements divided by agreements plus disagreements) was .91.

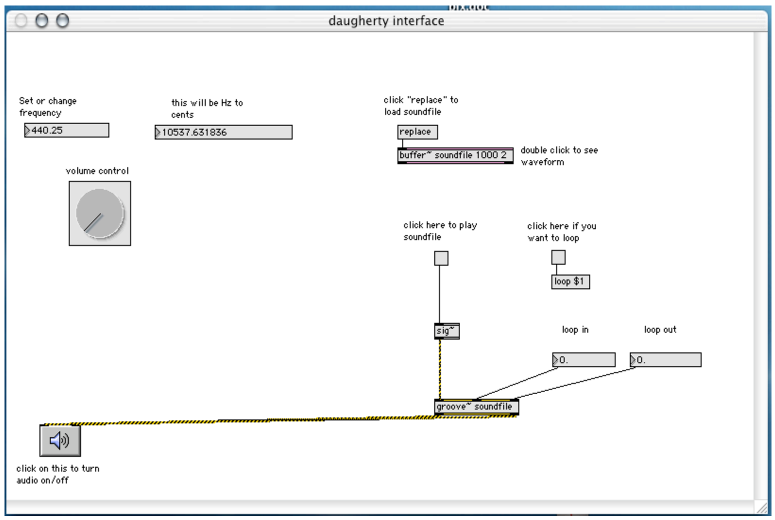

Figure 8. Max/MSP Configuration.

Expert panel evaluations. Expert panelists ($N = 9$) for Experiment 1 (choral context) individually listened to the same recordings used for LTAS and Max/MSP analyses. Panelists sat in a quiet room and listened to randomly ordered performances of each song through AKG 240 professional headphones attached to a Continuous Response Digital Interface (CRDI) system interfaced with a MacBook laptop computer. Volume remained consistent for each example. At no time was there compression of the electronic signal. Because it was impractical for judges to listen to the entire excerpt of each iteration of every song, I played the first two phrases of each iteration for the choral experiment.

Before listening to the recordings, listeners were instructed to turn the CRDI dial according to how pleasing they perceived the choral sound to be. The pictorial overlay utilized labeled the dial on the CRDI from "Less Pleasing Overall Sound" on the left to "More Pleasing Overall Sound" on the right side.

Choral context video analysis. Video recordings from four cameras employed during the choral portion of this study were used to measure how much time it took each singer to master each of the gestures. For this purpose, each singer was assigned a number.

I then observed each singer on videotape while they did a particular gesture in each of its iterations, and evaluated mastery according to a research-devised gesture checklist (see Appendix H). The singers were determined to have learned the gesture when they had accomplished at least 7 of the 8 items on the list. The number of repetitions needed for the singer to learn and perform each gesture accurately was recorded for subsequent analysis.

Participant survey. Participants completed a brief exit survey upon completion of the recording session (see Appendix E). Singers were asked what differences, if any, they noticed in their singing when doing no movement, low arm circles, pointing or the arched hand gesture. They were also asked what differences, if any, they noticed in the group's sound while doing the above gestures. Finally, they were asked if the gestures had any impact on their focus of attention while singing. Questionnaires were coded by participant number and results were entered into an Excel spreadsheet for analysis. Analysis included disaggregation of responses according to the demographic variables of experience level, sex, and age range.

Experiment 2 – Solo Singing Context

Research Room

The solo singing portion of this investigation took place in a research room equipped with necessary recording devices (video camera and microphone). Singers stood at a pre-marked position (toes on a line) four feet from the video camera (see Figure 9).

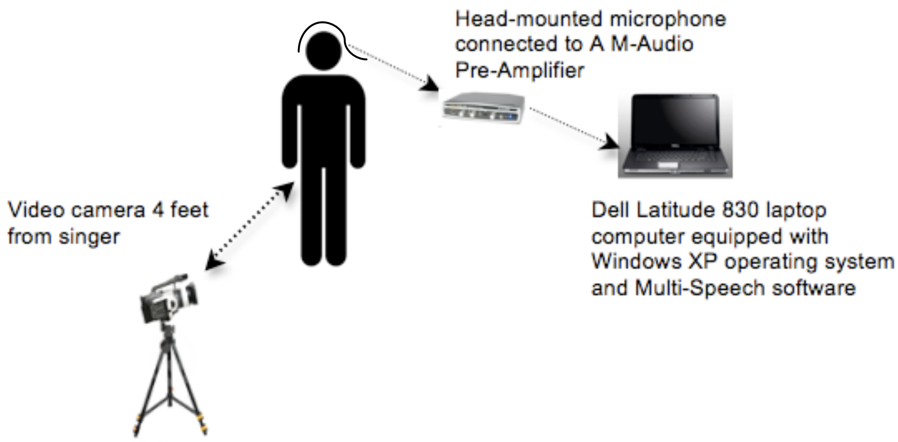

Figure 9. Solo singing research room configuration.

Equipment

A head-mounted AKG C-420^{III} (cardioid polar recording pattern) condenser microphone (AKG Acoustics, Vienna, Austria) was positioned at a constant 7-cm distance from the corner of the each participant's mouth. The distance was confirmed with a thin 7-cm dowel prior to each iteration of the song selections. This placement conformed to the distance used in previous research (e.g., Kenny & Mitchell, 2006; Ferguson, Kenny, & Cabrera, 2010). Kenny and Mitchell (2006) noted that such placement "ensured that the direct energy of the voices was recorded rather than room reflections, which enabled us to use a studio environment with low ambient noise rather than an anechoic studio" (p. 59). The microphone signal was amplified by an M-Audio Mobile Pre-Amplifier, which connected via USB to a Dell Latitude 830 laptop computer with Windows XP operating system and Multi-Speech software (KayPENTAX, Model 3700, version 3.3.0). The gain on the pre-amp was adjusted such that very loud singing would be slightly below distortion level. All levels were set prior to the first participant and remained consistent throughout data collection. These recordings (16 bit .wav files, 44.1 kHz sampling rate) were saved for subsequent analysis.

One RCA Small Wonder EZ2000 digital video camera attached to a tripod was utilized to capture video footage of each singer. The camera was placed 4 feet at an angle from the singer such that each singer's performance and gestures could be videotaped throughout the process. Each video file was coded with participant number and saved for subsequent analysis.

Procedure

Upon entering the research room, singers were asked to complete an Institutional Review Board (IRB) pre-approved consent form (see Appendix C) as well as a demographic questionnaire (see Appendix D). Each participant was fitted with a head-mounted microphone and stood on a marked line four feet from the video camera.

Solo singer participants were given a copy of the three musical selections two weeks prior to recording. Like the choral rehearsal, participants were asked on the demographic questionnaire if they could sing the melodies from memory. If participants could not sing the phrases from memory, the melody of each selection was played for the participants on a keyboard until they felt they could sing the phrases a cappella and from memory.

A Master-Key pitch pipe (C – C range) was used to give a starting pitch (D) prior to each repetition of the melodies. The distance from recording devices was consistent for all participants. All participants were audio and video recorded while doing these tasks for subsequent analysis.

The same activities were utilized in the choral and solo singing contexts with one exception. As LTAS was not used to measure solo sound, the song selections did not need to exceed forty seconds. Therefore, solo singers sang the final two phrases of "Over the Rainbow" (see Figure 10), the first two phrases of "Singin' in the Rain" (see Figure 11), and the melody of "Hawaiian Rainbows" without repeat (see Figure 12) on the neutral syllable "m/i/." Singers first sang each selection without gesture (baseline condition). They then sang each selection five times under one of three gestural conditions: (a) pointing upward and outward, (b) moving arms in low circles, and (d) moving one hand with arched palm vertically upwards. Following the treatment condition trials, singers sang the song one last time with no gesture.

Figure 10. First two phrases of "Over the Rainbow" used for solo singers (brackets = low, circular gesture).

Figure 11. First two phrases of "Singin' in the Rain" used in solo singing context (arrow = pointing gesture).

Figure 12. Melody of "Hawaiian Rainbows" (bracket = arched hand gesture).

Following the treatment condition trials, solo singers completed a brief post-test perceptual survey (see Appendix F). The survey was identical to that used at the completion of the choral rehearsal, except that it did not ask about singer perception of group sound.

Dependent Measures

Formant profiles. Acoustic measures of solo sound included formant profiles and *Fo* (measured as deviation in cents from target frequency). Sound samples were edited using Praat version 5.1.32 (www.fon.hum.uva.nl/praat/) and loaded onto a laptop computer for playback.

For the first selection, "Over the Rainbow," I used the following measurement points: (a) the midpoints of the "m/i/" vowel (corresponding to the /ɛ/ vowel on the word "somewhere") in measure 1, and (b) the midpoint of the "m/i/" vowel (corresponding to the /u/ vowel on the word "true") in measures 8. For the second selection, "Singin' in the Rain," I used the following measurement points: (a) the midpoint of the "m/i/" vowel (corresponding to the /I/ of "singing") in measure 1, (b) the midpoints of the "m/i/" vowel (corresponding to the vowel /o/ of "glorious") in measure 5. For the third selection, "Hawaiian Rainbows," I used the following measurement points: (a) the midpoints of the "m/i/" vowel (corresponding to the vowel /e:I/ of "rain") in measure 2, (b) the midpoint of the "m/i/" vowel (corresponding to the vowel /i/ of "sea") in measure 16. As a control for vowel stability, the middle one second of each vowel was extracted and analyzed.

At the midpoint of each extracted vowel Praat extracted the fundamental frequency (*Fo*) and formant frequency for each vowel. Praat applied a Gaussian-like window to compute linear predictive coefficients through the Burg algorithm integrated in the software. Formant frequency and fundamental frequency (*Fo*) were recorded into an Excel spreadsheet for subsequent analysis.

Amplitude measurement. I used Pratt software to determine any differences in amplitude among sung iterations of each song. The mean of each participant's relative dB SPL for all excerpts served as a referent amplitude. Each sung excerpt was then compared to the referent amplitude, which yielded a dependent variable of ΔdB (change in decibels).

Fundamental frequency. The *Fo* of each vowel midpoint extracted by the Praat software for formant profile analysis was used to measure intonation by comparing the extracted *Fo* to the scored target frequency. To do so, I first converted all measurements in Hz to measurements in cents (1200 cents are equal to one octave). Deviations from target frequency were then expressed in cents for comparison and analyses.

For purposes of this study, in tune or out of tune solo singing was qualified by the measurement of ±7 cents (Lindgren & Sundberg, 1972; Sundberg, 1982; Sundberg, Prame, & Iwarsson, 1996). Any deviation greater than seven cents was considered out of tune for individual singers.

Expert panel evaluations. Expert panelists (N = 9) for Experiment 2 (solo context) individually listened to the same recordings used for acoustic analyses. Panelists sat in a quiet room and listened to randomly ordered performances of each song through AKG 240 professional headphones attached to a Continuous Response Digital Interface (CRDI) system interfaced with a MacBook laptop computer. Volume remained consistent for each example. At no time was there compression of the electronic signal. Because it was impractical for judges to listen to the entire excerpt of each iteration of every song, I the entire selection of the baseline and posttest conditions as well as one gestural iteration of ten randomly chosen participants for the solo expert listening panel.

Before listening to the recordings, listeners were instructed to turn the CRDI dial according to how pleasing they perceived the vocal sound to be. The pictorial overlay utilized labeled the dial on the CRDI from “Less Pleasing Overall Sound” on the left to “More Pleasing Overall Sound” on the right side.

Solo context video analysis. Video recordings from the camera employed during the solo portion of this study were used to measure how much time it took each singer to master each of the gestures. For this purpose, each singer was assigned a number.

I then observed each singer on videotape while they did a particular gesture in each of its iterations, and evaluated mastery according to a research-devised gesture checklist (see Appendix H). The singers were determined to have learned the gesture when they had accomplished at least 7 of the 8 items on the list. The number of repetitions needed for the singer to learn and perform each gesture accurately was recorded for subsequent analysis.

Participant survey. Participants completed a brief exit survey upon completion of the recording session (see Appendix F). Singers were asked what differences, if any, they noticed in their singing when doing no movement, low arm circles, pointing or the arched hand gesture. Finally, they were asked if the gestures had any impact on their focus of attention while singing. Questionnaires were coded by participant number and results were entered into an Excel spreadsheet for analysis. Analysis included disaggregation of responses according to the demographic variables of experience level, sex, and age range.

CHAPTER FOUR

Experiment 1 Results - Choral Context

The purpose of the first experiment was to assess the potential effects of three singer gesture conditions (low, circular arm gesture; pointing gesture; arched hand gesture) on performances of three familiar songs by choral singers ($N = 35$) using selected acoustic and perceptual measurements. Results are presented in order of the research questions posed for this part of the investigation. A predetermined alpha level of .05 (adjusted as necessary by Bonferroni corrections) served to indicate significance for all statistical procedures.

Research Question One: Long Term Average Spectra (LTAS)

The first research question for Experiment 1 asked whether according to Long-Term Average Spectra (LTAS) measures, there were significant acoustical differences in the choral sound of this ensemble (a) between baseline (without gesture) and final performance (without gesture) conditions, and (b) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture.

Human vocal sound is complex sound as it includes an array or spectrum of simultaneous frequencies, each of which constitutes a part (or partial) of the complex whole. There are numerous other simultaneous frequencies that inform the perceived timbre (color or quality) of the sound in addition to the perceived sung pitch (fundamental frequency) each of which have a spectral frequency exhibiting energy or power. Depending on conditions, some partials may be dampened (exhibit less energy) or amplified (exhibit more energy).

Long-term average spectra measurement provides information about timbre. This information is averaged over time and includes both frequency and sound pressure density (amplitude intensity) across the spectrum of complex sound. LTAS graphs present sound pressure power as a function of frequency. Sound pressure level amplitude is presented according to a decibel (dB) scale. Frequency is presented as Hertz (the number of sound cycles per second, abbreviated as Hz). KiloHertz (kHz) serves as a shorthand way of expressing cycles per second for these partials as higher frequency partials may entail thousands of sound cycles per second. LTAS data provide a quantifiable index of sound quality across a specified period of time. These data can be useful for detecting persistent spectral events.

LTAS (Entire Spectrum) – Low, circular arm gesture ("Over the Rainbow"). Figure 13 presents obtained LTAS contours across the entire spectrum (0 – 10 kHz) according to sung baseline, gestural, and posttest conditions in "Over the Rainbow." The displayed gestural condition reflects the mean of the five iterations with the low, circular arm gesture. (For LTAS contours of baseline, each of the five gestural iterations, and posttest, see Appendix I). Howard and Angus (2006) suggest that differences of 1 dB in the amplitude of complex sounds may constitute "just noticeable differences" for human hearing, dependent on the nature of the sound and the hearing acuity of listeners. For purposes of interpretation, then, LTAS signal amplitude differences exceeding 1 dB will be matters of particular interest.

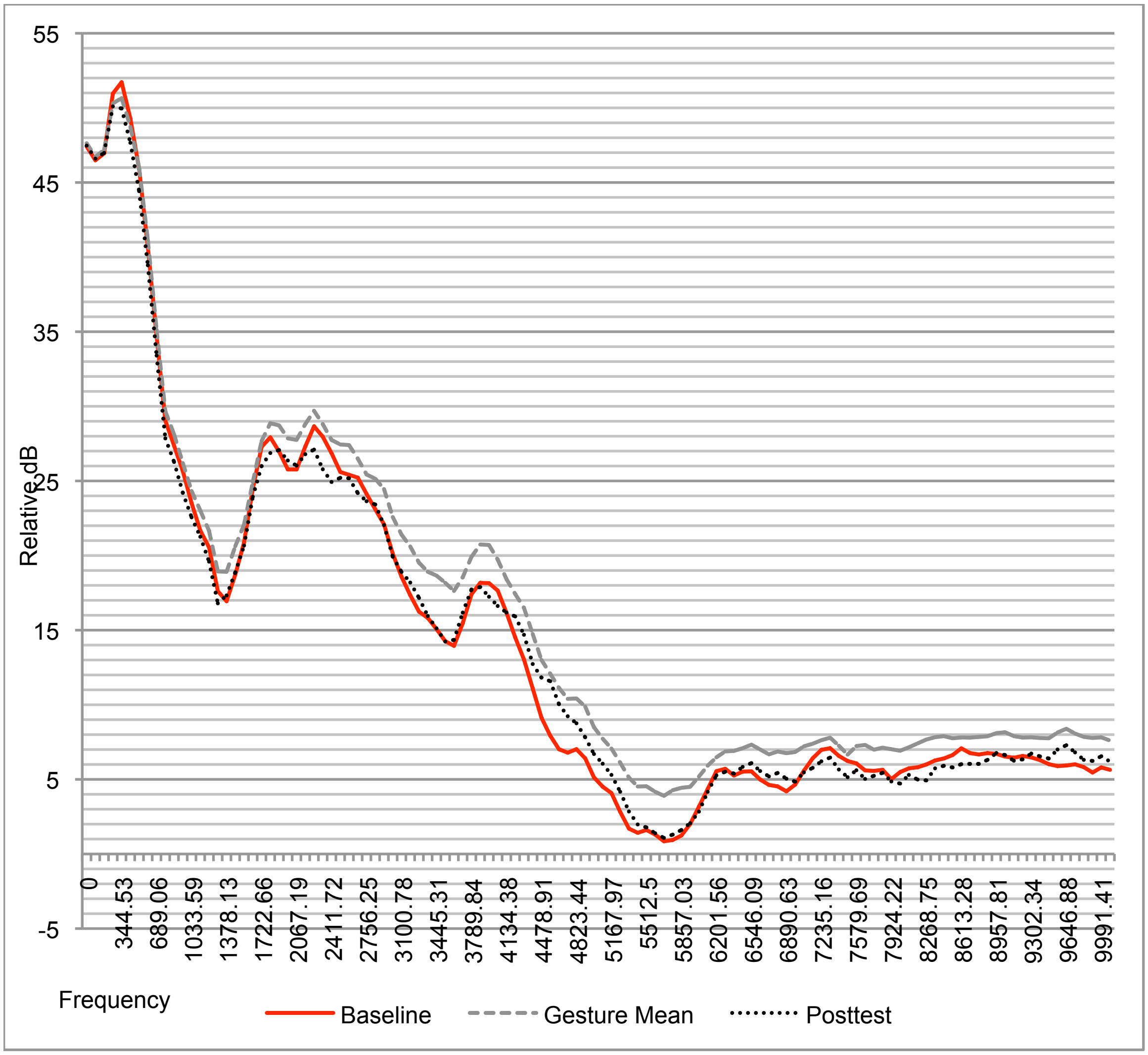

Figure 13. Low circular arm gesture: Entire spectrum LTAS of baseline, mean gestural, and posttest conditions for “Over the Rainbow.”

A Repeated Measures ANOVA indicated a significant main effect (F [2,21] = 78.502, $p <$ .005). Three follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 = .017). T-test results indicated significant differences ($p <$ .005) between the mean of gestural iterations (dB range: -10.50 – 31.65, M = 2.71 dB) and baseline (dB range: -13.87 – 32.72, M = 0.94 dB) as well as mean of gestural iterations and posttest measures (dB range: -4.65 – 30.96, M

= 3.47 dB). No significant differences were found between the baseline and posttest measures (p = .82).

Figure 14 presents LTAS contours across the 2 – 4 kHz region. The displayed gestural condition reflects the mean of the five iterations with the low, circular arm gesture. (For LTAS contours of baseline, each of the five gestural iterations, and posttest in the 2 – 4 kHz region, see Appendix I, Figures 7 - 16). The 2 – 4 kHz region is of interest for two reasons: (a) it contains frequencies to which the human ear is most sensitive (Fletcher & Munson, 1933), and (b) it corresponds roughly to the "singer's formant" frequency region.

A Repeated Measures ANOVA indicated a significant main effect (F [2,21] = 78.502, $p <$ .005). Three follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 = .017). T-test results indicated significant differences (p < .005) between the mean of gestural iterations (dB range: -1.37 – 10.69, M = 4.33 dB) and baseline (dB range: -5.05 – 9.66, M = 1.98 dB) as well as mean of gestural iterations and posttest measures (dB range: -4.65 – 8.1, M = 1.75 dB). No significant differences were found between the baseline and posttest measures (p = .82).

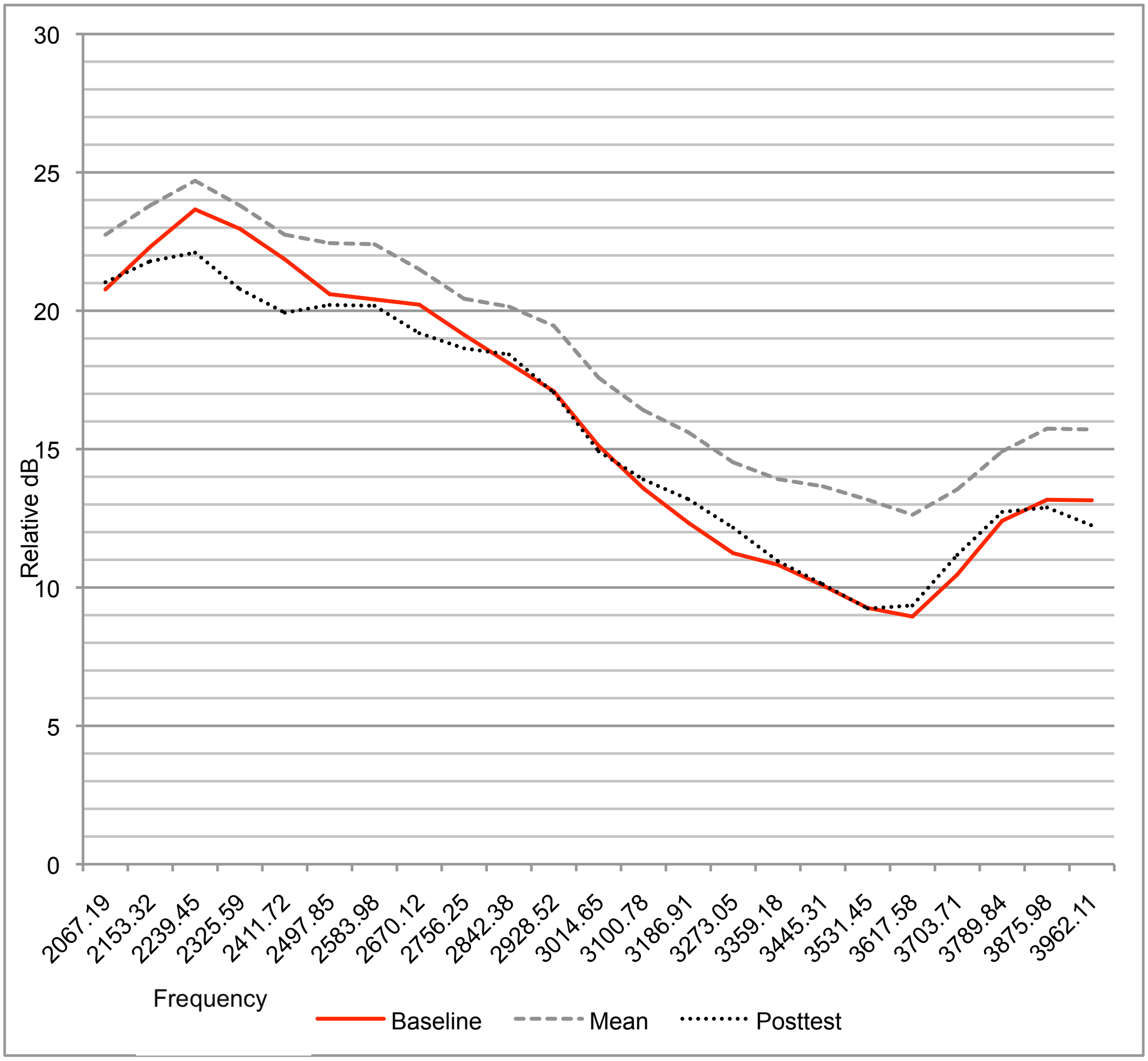

Figure 14. Low, circular arm gesture: LTAS of baseline, mean gestural, and posttest conditions in the 2 – 4 kHz region for “Over the Rainbow.”

LTAS (Entire Spectrum) – Pointing gesture (“Singin’ in the Rain”). Figure 15 presents obtained LTAS contours across the entire spectrum (0 – 10 kHz) according to sung baseline, gestural, and posttest conditions in “Singin’ in the Rain.” The displayed gestural condition reflects the mean of the five iterations with the low, circular arm gesture. (For LTAS contours of baseline, each of the five gestural iterations, and posttest, see Appendix I, Figure 16 - 26).

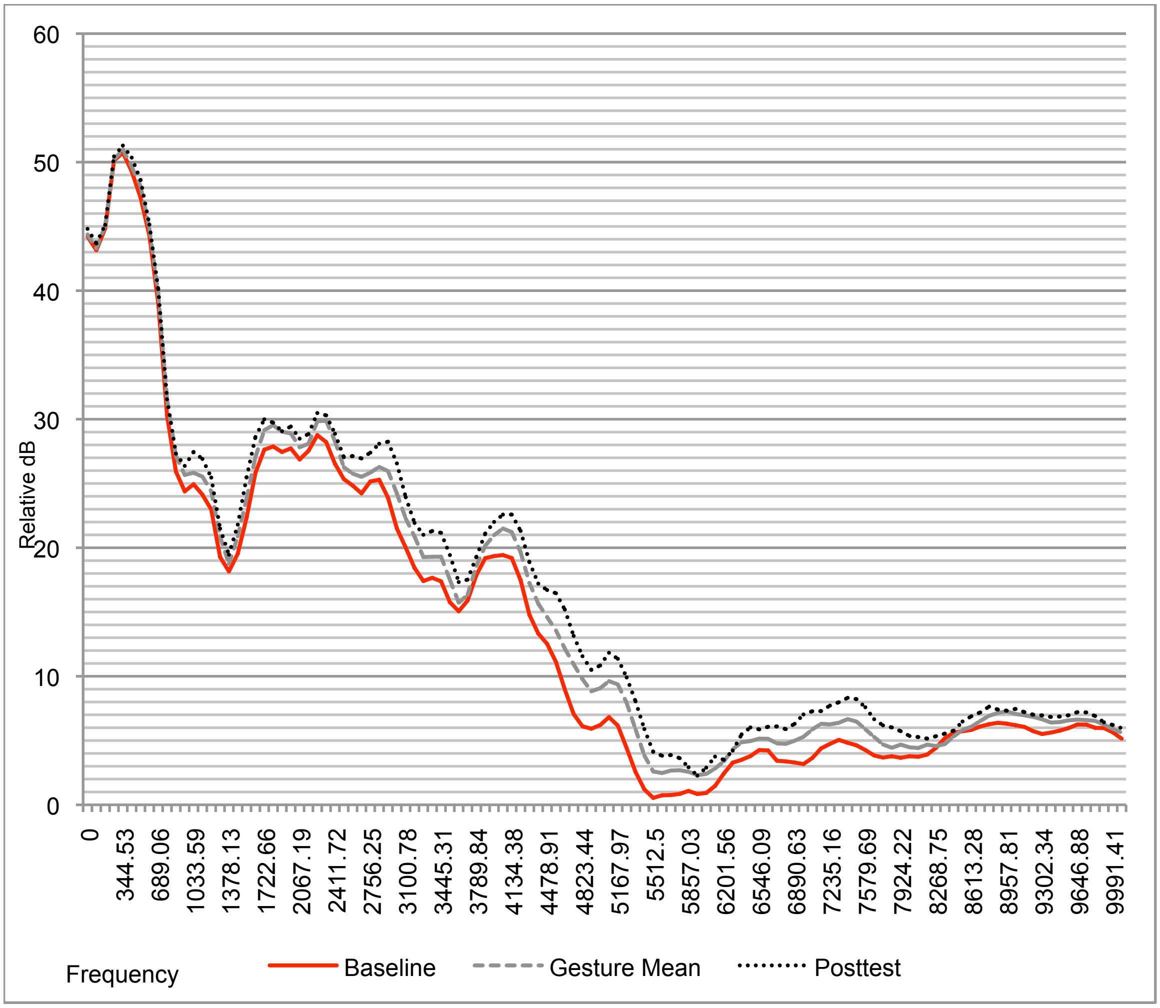

Figure 15. Pointing gesture: Entire spectrum LTAS of baseline, mean gestural, and posttest conditions for "Singin' in the Rain."

A Repeated Measures ANOVA found a significant main effect (F [2,57] = 95.280, $p <$ .005). Three follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 = .017). T-test results indicated significant differences ($p <$ .005) between all conditions: baseline (dB range: -15.46 – 34.22, M = -1.80 dB) and mean of gestural iterations measures (dB range: -13.68 - 34.21, M = -0.46 dB), posttest (dB range: -13.68 – 32.61, M = -57 dB) and mean of gestural iterations measures, and baseline and posttest measures.

Figure 16 presents LTAS contours across the 2 – 4 kHz region. The displayed gestural condition reflects the mean of the five iterations with the low, circular arm gesture. (For LTAS contours of baseline, each of the five gestural iterations, and posttest in the 2 – 4 kHz region, see Appendix I, Figure 17 - 27).

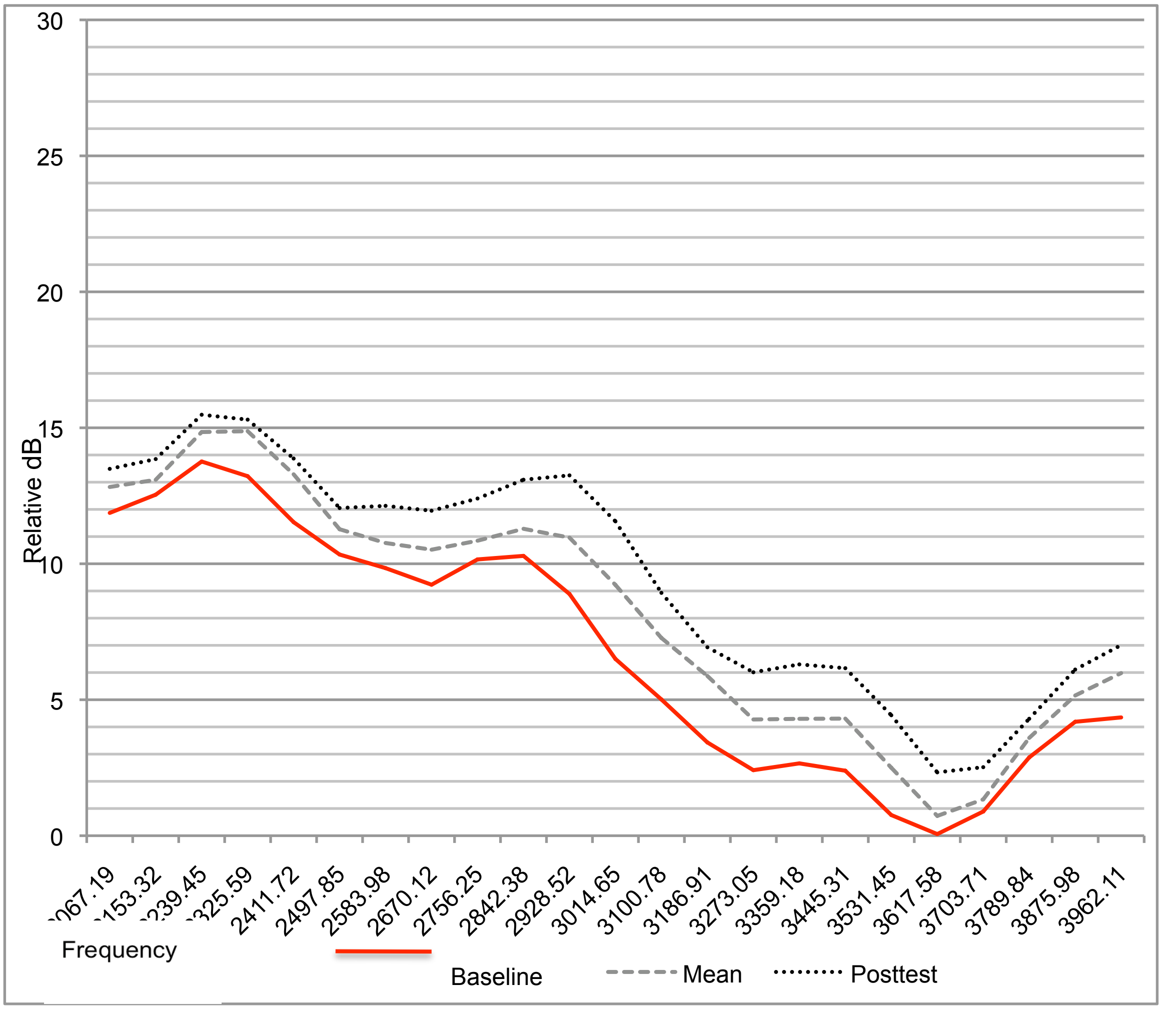

Figure 16. Pointing gesture: LTAS of baseline, mean gestural, and posttest conditions in the 2 – 4 kHz region for “Singin’ in the Rain.”

A Repeated Measures ANOVA found a significant main effect (F [2,57] = 95.280, $p <$ .005). Follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 =

.017). *T*-test results indicated significant differences ($p < .005$) between all conditions: baseline (dB range: -10.08 – 12.60, $M = 2.41$ dB) and mean of gestural iterations (dB range: -13.68 – 32.61, $M = 4.24$ dB) measures, posttest (dB range: -5.16 – 12.87, $M = 5.75$ dB) and mean of gestural iterations measures, and baseline and posttest measures.

LTAS (Entire Spectrum) – Arched hand gesture ("Hawaiian Rainbows").

Figure 17 presents obtained LTAS contours across the entire spectrum (0 – 10 kHz) according to sung baseline, gestural, and posttest conditions in "Hawaiian Rainbows." The displayed gestural condition reflects the mean of the five iterations with the low, circular arm gesture. (For LTAS contours of baseline, each of the five gestural iterations, and posttest, see Appendix I, Figures 27 - 36).

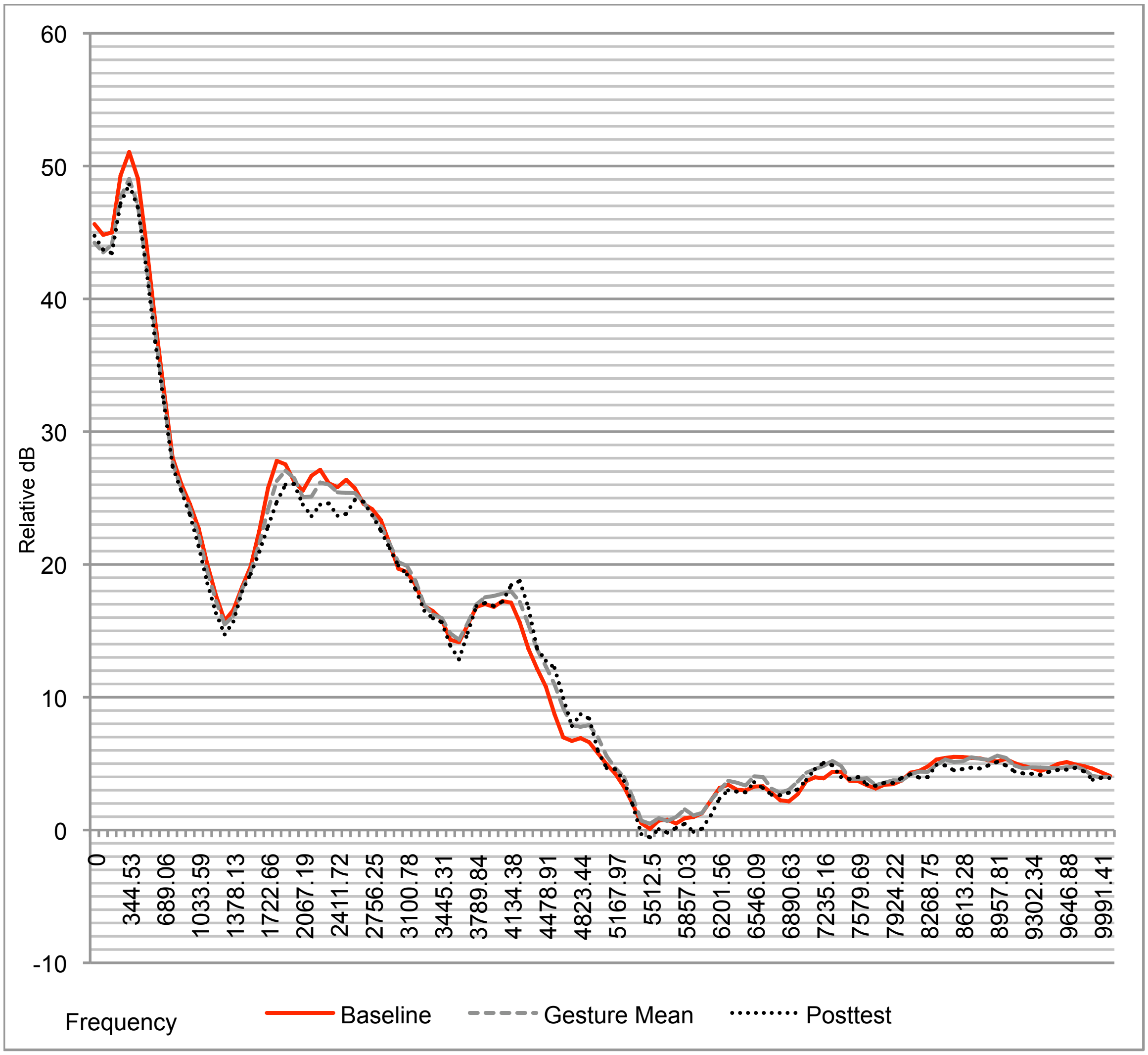

Figure 17. Arched hand gesture: Entire spectrum LTAS of baseline, mean gestural, and posttest conditions for "Hawaiian Rainbows."

A Repeated Measures ANOVA indicated a significant main effect by condition (F[2, 57] = 10.182, $p < .005$). Follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance ($p = .05/3 = .017$). T-test results indicated significant differences between baseline (dB range: -15.91 – 35.06, M = -2.77 dB) and posttest (dB range: -16.31 – 32.61, M = -3.15 dB) measures (p = .015) and between mean of gestural iterations (dB range: -15.53 – 33.03, M = -2.73 dB) and posttest measures ($p < .005$).

Figure 18 presents “Hawaiian Rainbows” LTAS contours across the 2 – 4 kHz region. The displayed gestural condition reflects the mean of the five iterations with the low, circular arm gesture. (For LTAS contours of baseline, each of the five gestural iterations, and posttest in the 2 – 4 kHz region, see Appendix I, Figure 27 - 36).

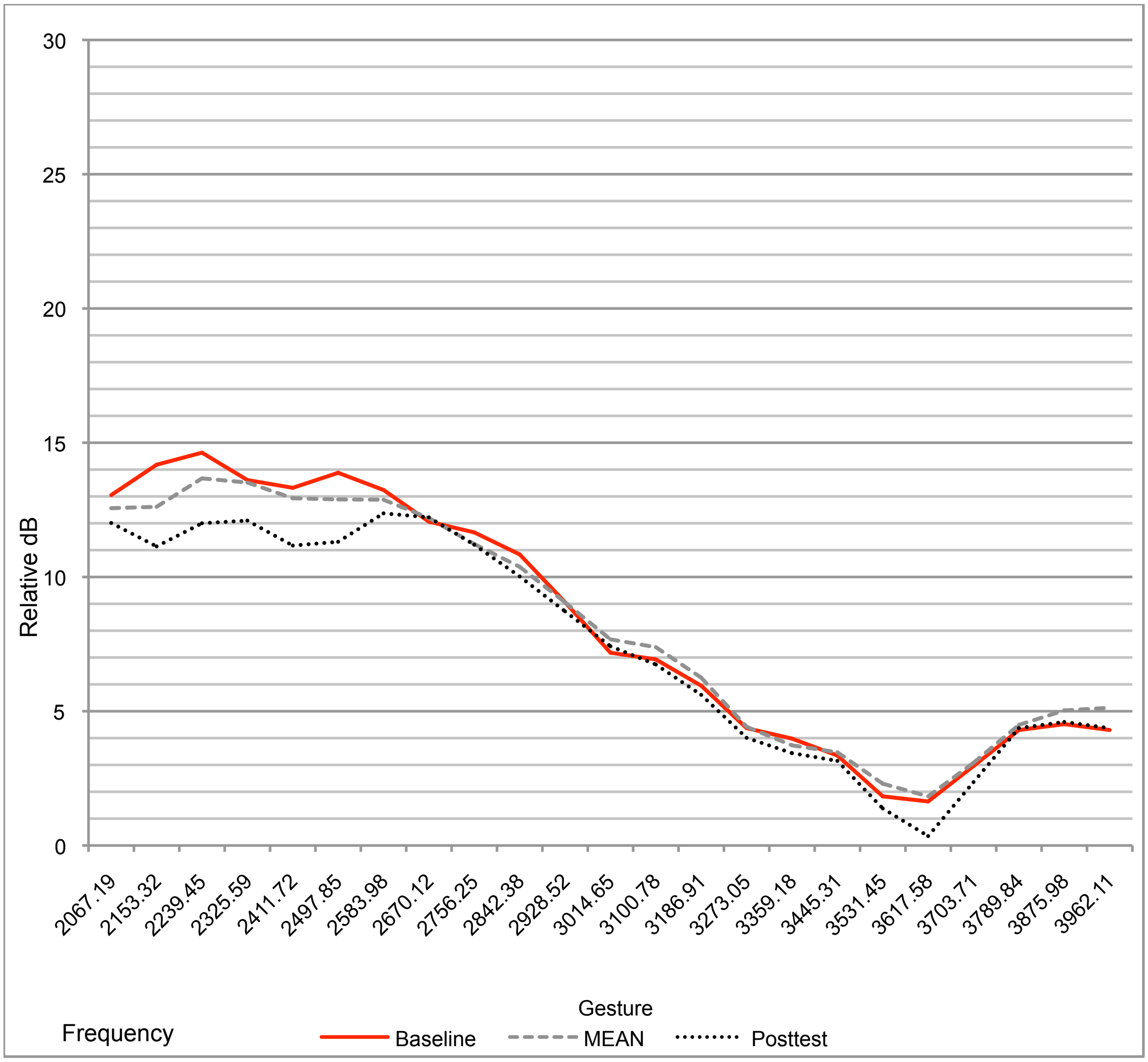

Figure 18. Arched hand gesture: LTAS of baseline, mean gestural iteration, and posttest conditions in the singer’s formant region (2-4 kHz) for “Hawaiian Rainbows.”

A Repeated Measures ANOVA indicated a significant main effect (F [2,21] = 20.704, $p <$ .005). Three follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 =

.017). *T*-test results indicated significant differences ($p < .005$) between the baseline (dB range: -10.55 – 11.13, $M = 1.33$ dB) and posttest measures as well as the mean of gestural iterations and posttest (dB range: -11.33 – 8.87, $M = -3.15$ dB) measures, but no significant differences between the baseline and mean of gestural iterations (dB range: -10.44 – 10.17, $M = 1.74$ dB) measures.

Summary of LTAS Results. Long-term average spectra (LTAS) analyses indicated perceptible changes in the choral sound of this ensemble attributable to each of the gestures used. The low, circular arm and the pointing gestures yielded increased mean signal amplitude in the sung gestural conditions when compared to the sung baseline and posttest conditions in "Over the Rainbow" and "Singin' in the Rain." The arched hand gesture produced lowered mean signal amplitude in the gestural conditions of "Hawaiian Rainbows." These differences were most robust in from 2 - 4 kHz, a range of frequencies to which human hearing is most sensitive (Fletcher & Munson, 1933). From a perceptual perspective of timbre, such findings may suggest that the choir sang, without verbal instruction to adjust vocal production, with a more energized and "brighter" sound while using the low, circular arm and pointing gestures, and with a somewhat "covered" or "darker" sound (due to dampening of certain higher frequency partials) while employing the arched hand gesture. Because the choir sang throughout on an /i/ vowel, these results may have particular import for adjusting timbre in the singing of that particular vowel.

Research Question Two: Perceptual Analyses

The second research question asked whether according to Max/MSP pitch analyses, expert listener ($N = 9$) evaluations, and singer questionnaire responses there would be significant perceived differences in choral sound (a) between baseline (without gesture) and final performance (without gesture) conditions, and (b) between baseline (without gesture) performance and five successive, intervening performances employing a particular gesture.

Max/MSP procedure results. The midsection of each measurement vowel was extracted using Praat software (version 5.1.32). Thereafter, I played the extracted vowel excerpt using the Max/MSP pitch analysis software. The Max/MSP configuration produced a sinusoidal reference tone set initially to the score notated pitch for each extracted sustained vowel and starting pitch of interest. The *Fo* of the sine wave reference was adjusted to match each pitch investigated by (a) setting the sinusoidal reference tone to the fundamental frequency displayed in the score and (b) then adjusting the fine-tune control up or down to achieve a pitch match. Both the notated fundamental frequency and the fine-tune setting were recorded on an Excel spreadsheet for subsequent analysis.

I adjusted the frequency of the reference tone (presented in both Hertz and cents) until it matched the perceived pitch of the sung excerpt. The score-notated fundamental frequency, the fine-tune setting, and the perceived pitch, each converted to cents were then recorded on an Excel spreadsheet for analyses. I repeated the same procedures for all excerpts a day later. Obtained reliability (agreements divided by agreements plus disagreements) was .91. Max/MSP pitch analysis procedures first compared sung pitch measurement points (steady state midpoints of the extracted vowels) in each of the three excerpts with the pitches notated in the score of each excerpt.

Figures 19 - 21 illustrate the data points used for intonation comparisons of each of the three singer gestures investigated.

Figure 19. Data points for *Fo* measures during the low, circular arm gesture ("Over the Rainbow").

Figure 20. Data points for *Fo* measures during the pointing gesture ("Singin' in the Rain").

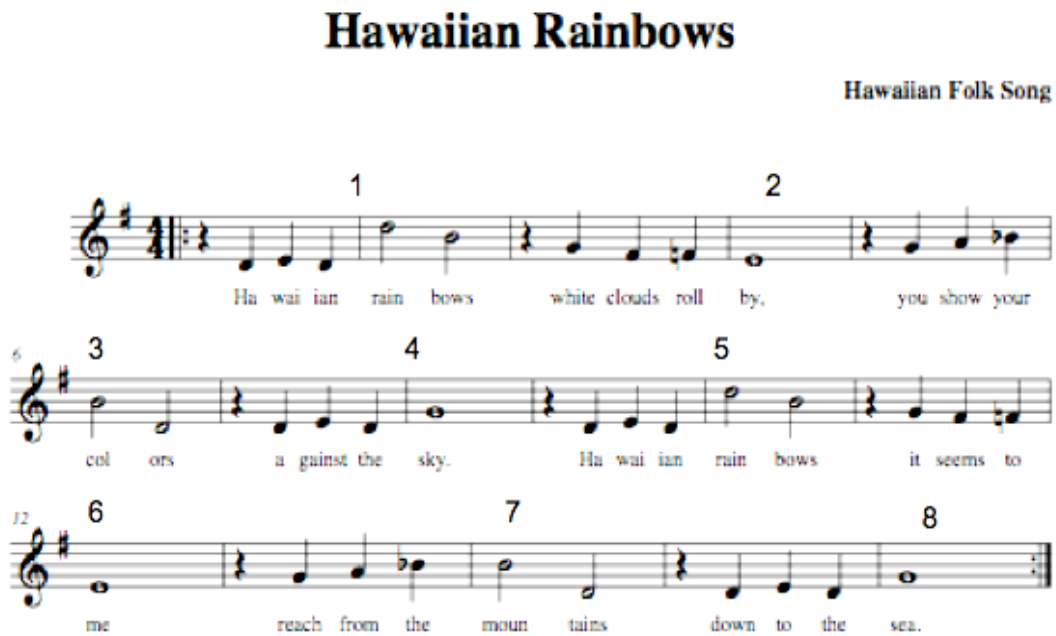

Figure 21. Data points for *Fo* measures during the arched hand gesture ("Hawaiian Rainbows").

For each of these data points, I recorded the frequency (Hz) and cents measurement of each pitch was recorded. Deviation in cents from the target frequency was then calculated for each sung note measured. This calculation was accomplished by consistently subtracting at each measurement point the cents difference between the sung pitches and the notated pitch. Mean deviation in cents from the target frequencies were recorded and graphed.

As the choir included both women and men, the songs were sung at octave intervals. The female and male pitches (octaves) were measured separately and showed negligible differences. Therefore, the female measures are reported here. Results indicated that this choir sang the actual notated pitch at very few measurement points.

For calculation of mean cents deviation per each iteration, I measured the data points at predetermined data acquisition point in each song excerpt. For baseline and posttest conditions, I then averaged the cents differences between scored and sung pitches at each data point to report baseline and posttest condition intonation.

To arrive at a grand mean of the five gestural iterations, I averaged the means acquired from data point measurements during each iteration. For purposes of interpreting results, a difference of ± 7 cents (Lindgren & Sundberg, 1972; Sundberg, 1982; Sundberg, Prame & Iwarrson, 1996) constituted a just noticeable difference in intonation. In order to calculate a mean of gestural iteration number, I took the average of the measurements taken for each of the data points in the song selections based on measurements of the five gestural iterations.

The choir sang above the notated pitch on a majority of the data points considered (80%, n = 45 of the 56 measured pitches) during the song "Over the Rainbow." When singing "Hawaiian Rainbows" the choir sang above the notated pitch only about half the time (54%, n = 35 of 64 measured pitches). The choir sang above the notated pitch more of the time in "Singin' in the Rain" as well (67%, 33 of the 49 measured pitches).

Max/MSP pitch measures: Low, circular arm gesture ("Over the Rainbow"). As shown in Figure 22, the choir in this investigation sang closest to the target frequencies during the gestural iterations of "Over the Rainbow" (Mean Range: -8.81 – 21.40 cents; *GM* = 4.42 cents) and further from target frequencies during the baseline (Range: -18.34 – 39.80 cents; *M* = 7.02) and posttest performances (Range: -30.00 – 38.77 cents; *M* = 4.52).

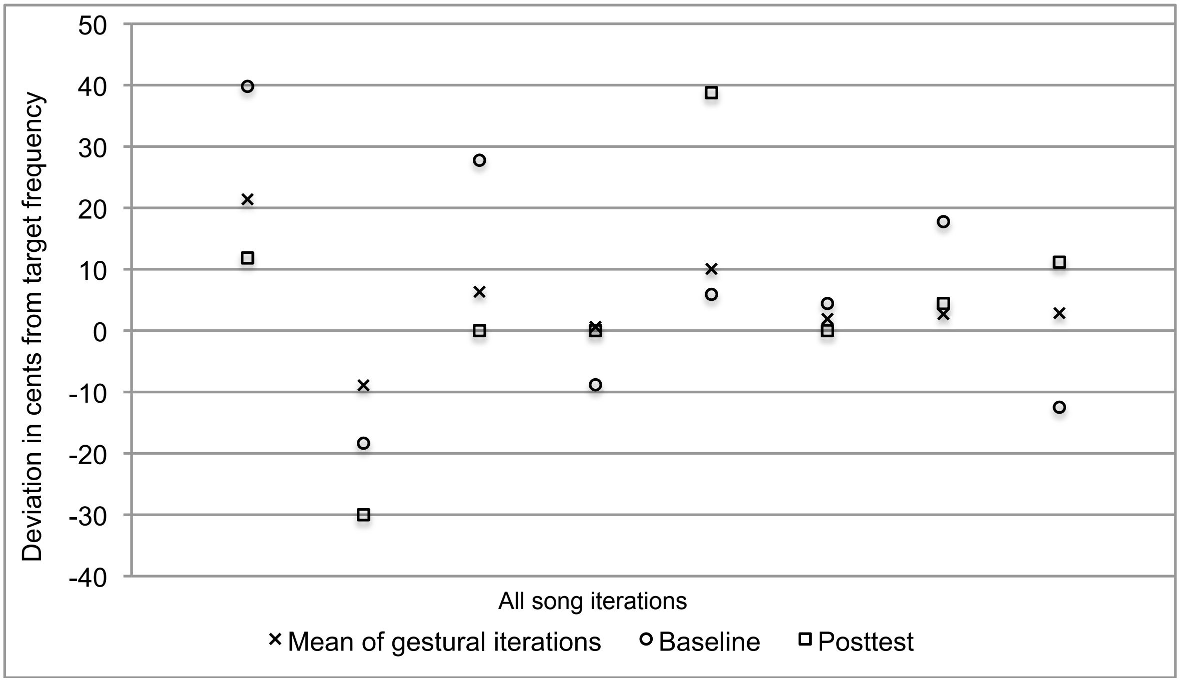

Figure 22. Scatterplot of deviation in cents from target frequency - Low, circular arm gesture ("Over the Rainbow").

A Repeated Measures ANOVA indicated a significant main effect (F [2,21] = 15.405, $p <$ .004). Paired *t*-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 = .017). *T*-test results indicated significant differences (p < .012) between baseline and overall mean gestural iterations. There were no significant differences between baseline and posttest measures (p = .31) and between posttest and overall mean gestural iterations (p = .51).

Figure 23 displays cents deviation means for each iteration (N = 5) of the low, circular arm gesture compared to the means of baseline and posttest (without gesture) conditions. Singers were furthest below the target frequency (M = -8.82 cents) during the baseline condition and closest to the target frequency during the fifth gestural iteration (M = -.01 cents). Further, there was a difference of more than 23 cents between the baseline and fourth gestural iteration and a difference of 14.40 cents between the fourth gestural iteration and the posttest. From baseline to posttest conditions, the choir tended to get closer to target frequency.

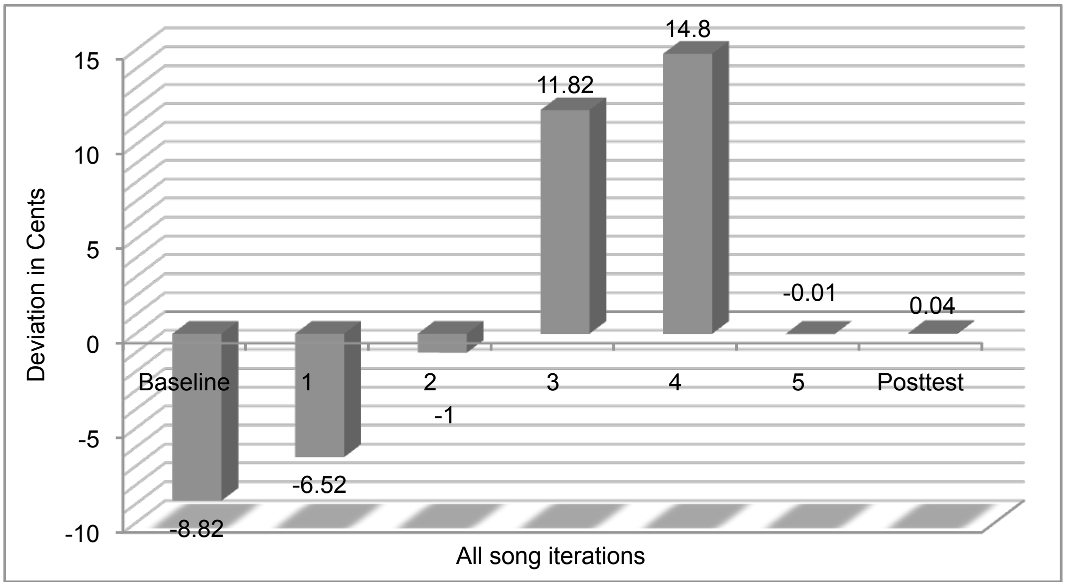

Figure 23. Fo deviation means for each iteration (*N* = 7) of the low, circular arm gesture compared to the means of baseline and posttest (without gesture) conditions.

Max/MSP pitch measures: Pointing gesture ("Singin' in the Rain"). As shown in Figure 24, the choir in this investigation sang closest to the target frequencies during the gestural iterations of "Singin' in the Rain" (Mean Range: -5.76 – 13.50 cents; *GM* = 1.87 cents) and further from target frequencies during the baseline measures (Range: -.001 – 50.878 cents; *M* = 24.05 cents) and posttest performances measures (Range: -8.83 – 22.22 cents; *M* = 9.74).

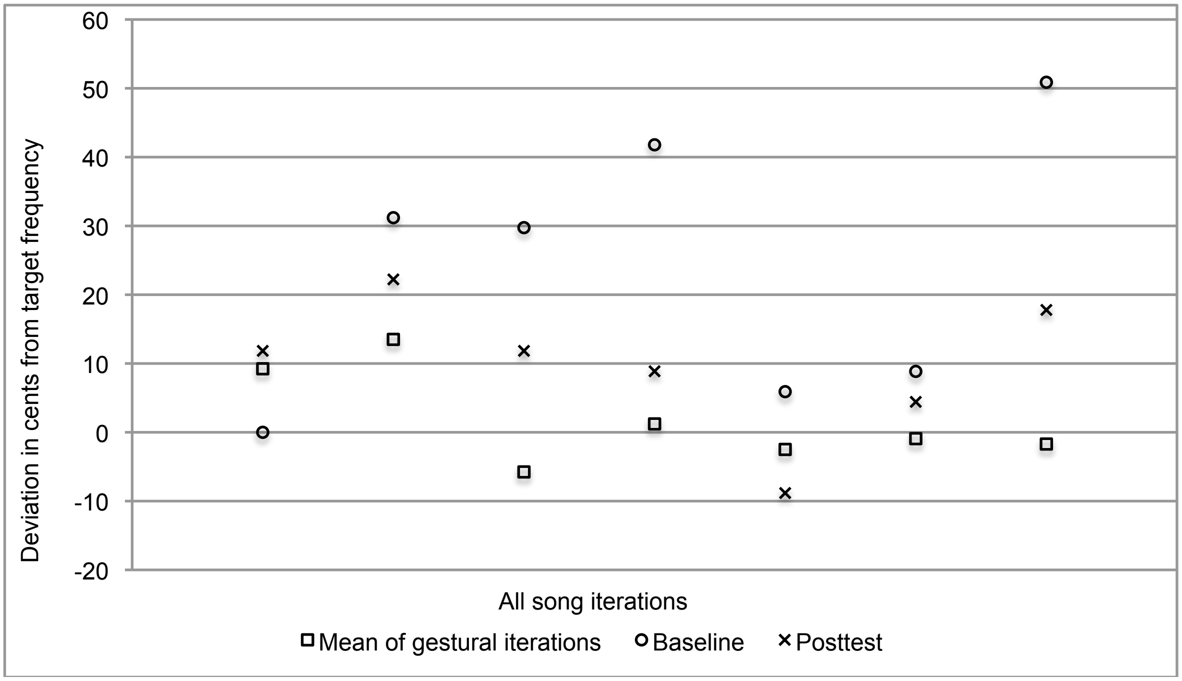

Figure 24. Scatterplot of deviation in cents from target frequency of all iterations – Pointing gesture ("Singin' in the Rain") (numbers correspond to points in score above (Figure 14)).

A Repeated Measures ANOVA indicated a significant main effects (F [2,21] = 20.704, p < .005). Paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 = .017). T-test results indicated significant differences (p < .001) between baseline and posttest measures and between posttest and overall mean gestural iterations (p < .001). There were no significant differences across the entire spectrum between baseline and gestural measures (p = .44).

Figure 25 displays cents deviation means for each iteration (N = 5) of the arched hand gesture compared to the means of baseline and posttest (without gesture) conditions. The choir was furthest below the target frequency (M = -8.82 cents) during the 5th gestural iteration and posttest conditions, whereas, the choir was closest to the target frequency during the third gestural iteration (M = 1.20 cents). While these mean deviations were within $\pm$ 7 cents, there was a difference of more than 10 cents between the third and fourth gestural iterations.

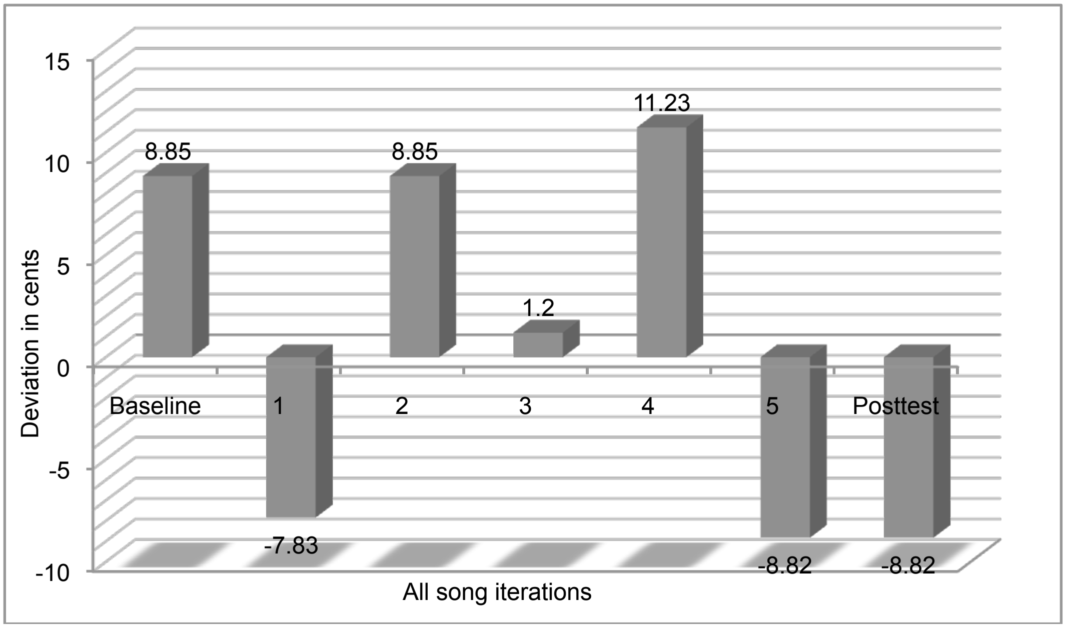

Figure 25. Fo deviation means for each iteration (*N* = 7) of the pointing gesture compared to the means of baseline and posttest (without gesture) conditions.

Max/MSP pitch measures: Arched hand gesture ("Hawaiian Rainbows"). As shown in Figure 26, the choir in this investigation sang closest to the target frequencies during the gestural iterations of "Hawaiian Rainbows" (Mean Range: 20.53 – 127.75 cents; *GM* = 53.51 cents) and further from target frequencies during the baseline (Range: 17.12 – 134.03 cents; *M* = 65.57) and posttest performances (Range: -12.49 – 29.75 cents; *M* = 9.80). The mean of gestural iterations (Range: 20.53 – 127.75 cents from target frequency), although near a quarter step from the target frequency was closer than the baseline measures (Range: 17.12 – 134.03 cents from target frequency) which were furthest from the target frequency overall.

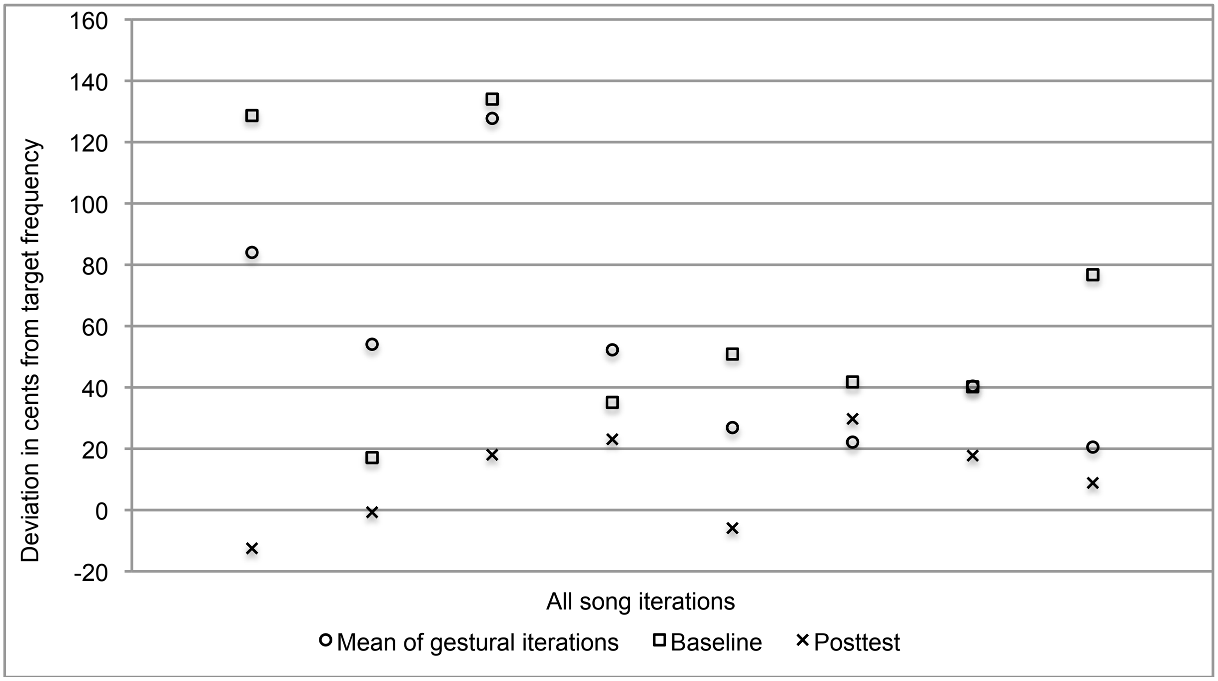

Figure 26. Scatterplot of deviation in cents from target frequency readings – Arched hand gesture ("Hawaiian Rainbows") (numbers correspond to data points in score above).

A Repeated Measures ANOVA indicated a significant main effect ($F[2,21] = 75.048$, $p < .005$). Paired *t*-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance ($p = .05/3 = .017$). *T*-test results indicated significant differences ($p < .001$) between baseline and posttest measures and between posttest and overall mean gestural iterations ($p < .001$). There were also significant differences across the entire spectrum between baseline and gestural measures ($p <.001$).

Figure 27 displays cents deviation means for each iteration ($N = 5$) of the arched hand gesture compared to the means of baseline and posttest (without gesture) conditions. Singers were furthest below the target frequency ($M = -5.93$ cents) during the 5th gestural iteration and closest to the target frequency during the first gestural iteration ($M = 2.95$ cents). While these mean deviations were within $\pm$ 7 cents, there was a difference of more than 38 cents between the baseline and first gestural iteration and a difference of 23.68 cents between the fifth gestural iteration and the posttest. From baseline to posttest conditions, the choir tended to get closer to target frequency.

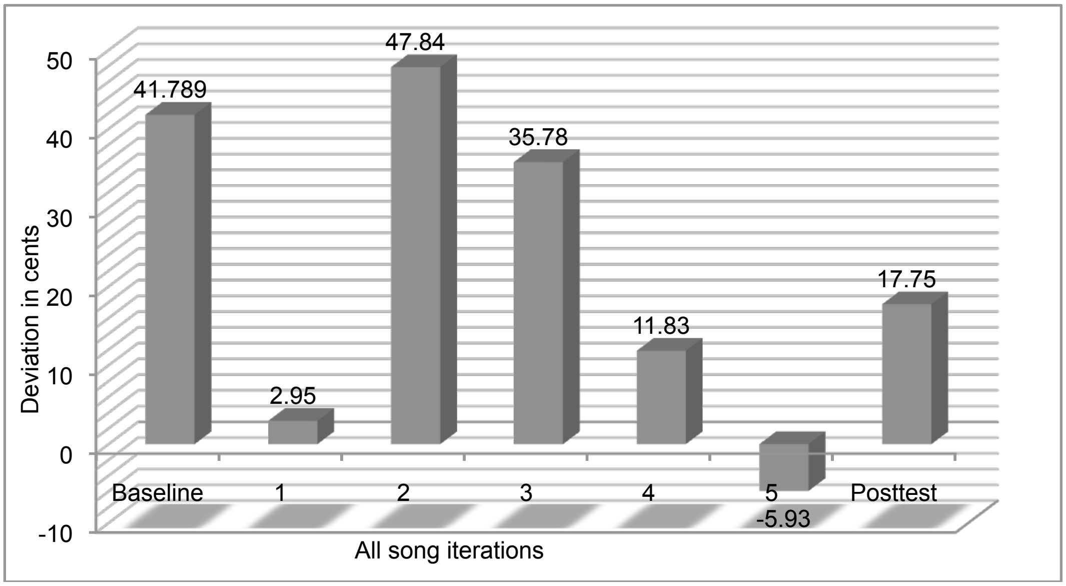

Figure 27. Fo deviation means for each iteration (*N* = 7) of the arched hand gesture compared to the means of baseline and posttest (without gesture) conditions.

Summary of Max/MSP pitch results. Significant intonation differences were found between (a) baseline and gesture conditions in "Over the Rainbow," (b) between baseline and posttest measures with "Singin' in the Rain," and (c) between gestural iterations and posttest measures with "Singin' in the Rain."

Gesture Intonation Comparisons: Negotiation of an ascending octave interval. Each of the three melodies sung for this investigation included a scored ascending octave leap on the same pitches (from D4 to D5 female voices; from D3 to D4 male voices). Because (a) participants sang the same vowel (/i/) throughout each melody and (b) this octave interval occurred at or very near the beginning of each melody, there is opportunity, as a matter of interest and within the limitations of the protocol followed in this investigation, to compare the three gestures (low, circular arm; pointing; arched hand) in terms of their respective potential effects on intonation as participants negotiated a particular singing task: execution of an ascending octave leap.

Figure 28 illustrates group deviation means in cents from target pitch per condition and iteration in the ascending octave task.

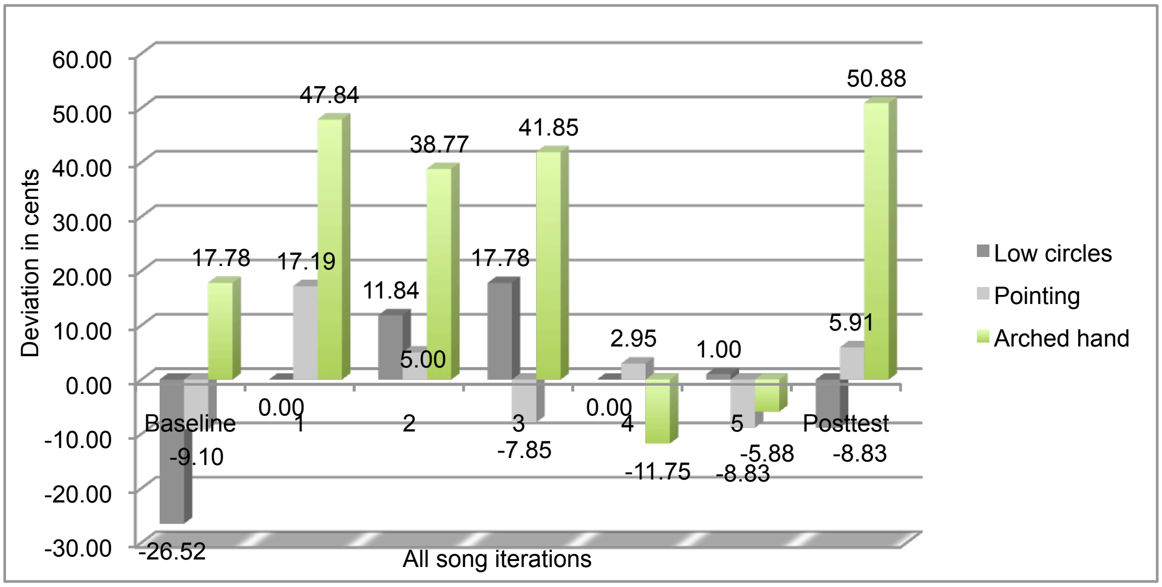

Figure 28. Singing an ascending octave: Group mean deviations in cents from target frequency across three gestural conditions.

As shown in Figure 28, the first iteration of each of the gestures appeared to move the choir sharper. From baseline to the first gestural iteration of the octave, means of sung excerpts with the low, circular arm gesture displayed a variance of 26.52 cents. Excerpts sung with the first use of the pointing gesture evidenced a variance of 26.29 cents from baseline, while excerpts performed with the arched hand gesture showed a variance of 30.06 cents between the baseline and first gesture conditions. Each of these mean variations exceeded the $\pm$ 7 cents, suggesting that they could be perceptible variances.

The arched hand gesture occasioned at the octave consistently more sharp mean singing (7 cents of more from target frequency) during its five iterations than either the low, circular arm of pointing gestures. This trend was particularly robust during the first, second, and third gestural iterations where the mean deviations of excerpts utilizing the arched hand gesture consistently exceeded tendencies of the other gestures by more than 7 cents. By contrast, use of the pointing gesture and low, circular arm gestures tended to decrease mean deviation slightly.

Considered solely from the perspective of overall group tendencies, then, the low, circular arm gesture and pointing gesture appeared to be more beneficial for intonation during an ascending octave leap than the arched hand gestures in a choral setting.

Expert Panel Evaluations. Expert listeners ($N = 9$) sat in a quiet room and heard digital recordings of the randomly ordered phrases of each song ("Over the Rainbow" – Low, circular arm gesture; "Singin' in the Rain" – Pointing gesture; "Hawaiian Rainbows" – Arched hand gesture) as played on a Sony CDP – 497 cd player connected to a Pre-Sonus distribution amplifier through individual AKG (K240 Monitor, Austria) headphones. Because it was impractical for judges to listen to the entire excerpt of each iteration of every song, I played the first two phrases of each iteration. As they listened, the judges rated the phrases by turning a Continuous Response Digital Interface (CDRI) dial to indicate "Less Pleasing Sound" (0 – 122 on the dial) or "More Pleasing Sound" (123 – 255 on the dial). For the gestural condition excerpts, I recorded expert ratings at data point corresponding to instances when participants utilized a particular gesture. These data were entered on an Excel spreadsheet for subsequent analysis.

Mean judges' ratings were compared for each take of each song selection. Results of a Cronbach's Alpha procedure indicated good reliability, $\alpha = .86$. Experts rated the sung baseline performances in each song lowest. Only in "Over the Rainbow" did the judges' mean rating of the baseline condition performances fall into the "More Pleasing" range on the CRDI dial.

Six of the experts gave "Over the Rainbow" the highest overall rating (range: 77.34 – 194.31) with gestural iterations (*M* = 149.30) rated higher than baseline (*M* = 126.13) and posttest (*M* = 146.71) conditions. All judges rated "Singin' in the Rain" the lowest overall (range: 41.29 – 145.50) with gestural iterations receiving higher ratings (*M* = 91.93) compared to baseline (*M* = 88.19) or posttest (*M* = 73.95) conditions. Ratings of "Hawaiian Rainbows" (range: 33.84 – 165.78) indicated preference for the gestural iterations (*M* = 128.46) compared to baseline (*M* = 120.23) or posttest (*M* = 72.95) conditions. Figures 29 – 31 present judges' mean CRDI ratings per each song and each condition.

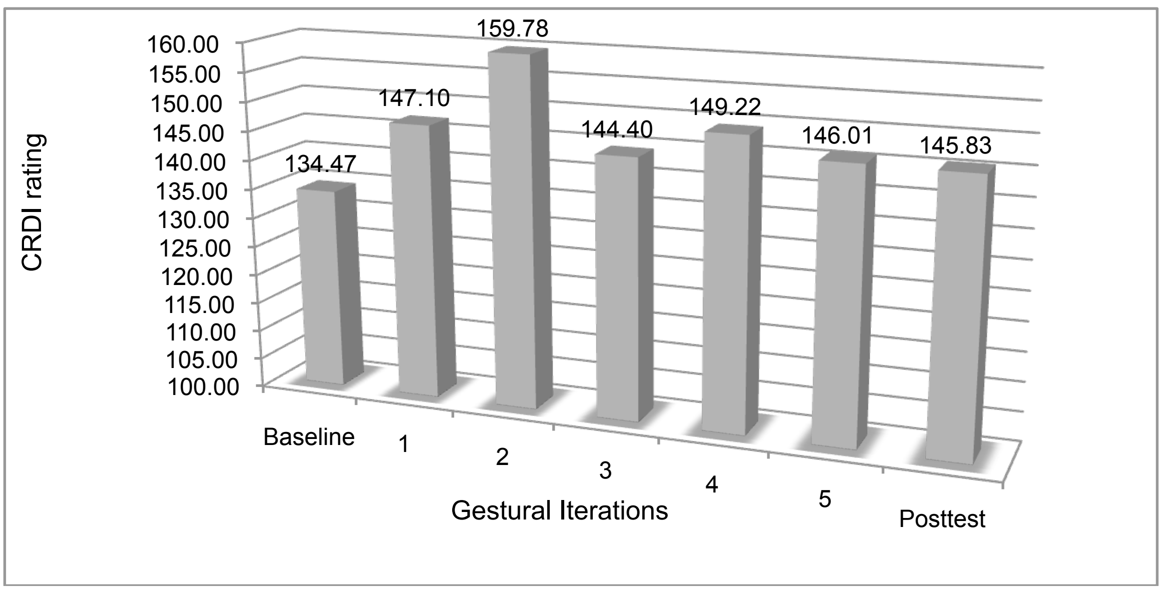

Figure 29. Mean CRDI ratings of expert panel – Low, circular arm gesture ("Over the Rainbow").

A Repeated Measures ANOVA found a significant main effect (F [2,8], $p < .05$) for expert ratings of "Over the Rainbow." Follow-up paired *t*-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance ($p = .05/3 = .017$). *T* –test results indicated significant differences ($p < .001$) between baseline and gestural iterations as well as baseline and posttest mean measures, with no significant differences between gestural and posttest measures ($p = .13$).

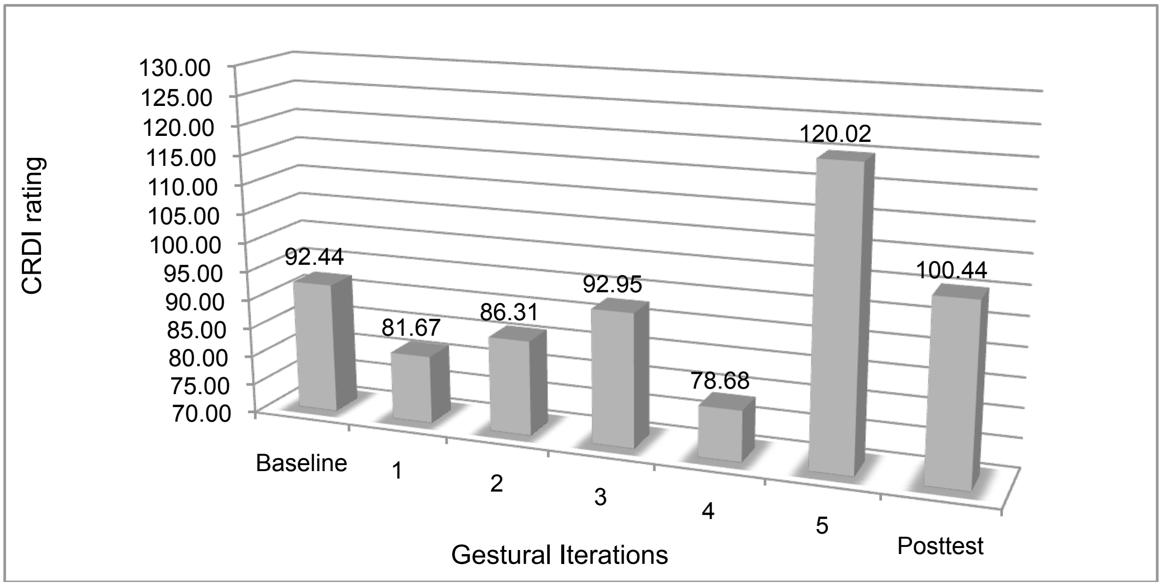

Figure 30. Mean CRDI ratings of expert panel – Pointing gesture ("Singin' in the Rain").

A Repeated Measures ANOVA found a significant main effect ($F [2,8] = 9.84$, $p < .05$) for expert ratings of "Singin' in the Rain." Follow-up paired *t*-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance ($p = .05/3 = .017$). *T* –test results indicated significant differences ($p < .001$) between baseline and gestural iterations as well as baseline and posttest mean measures, with no significant differences between gestural and posttest measures ($p = .39$).

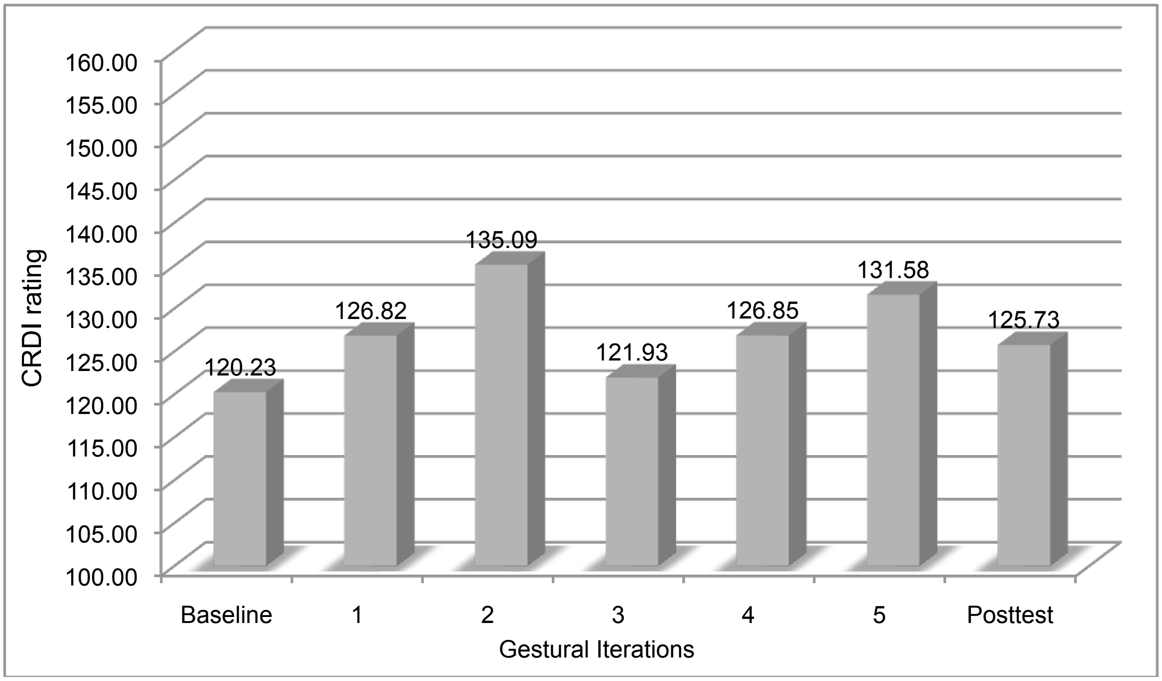

Figure 31. Mean CRDI ratings of expert panel – Arched hand gesture ("Hawaiian Rainbows").

A Repeated measures ANOVA found no significant main effect (F [2,8] = 22.89, p = .78) for expert ratings of "Hawaiian Rainbows."

The CRDI allowed judges simultaneously to listen to and rate each sung excerpt. Immediately thereafter, judges indicated on the Expert Listener Survey (Appendix G) factors (intonation, tone color, vibrato, other, and volume) that may have contributed most to their rating of a particular sung excerpt. These terms were presented in list form and each judge checked all factors that applied. Intonation was the most frequently cited factor (44% of judges), with blend as the second most chosen factor (22%). Other factors indicated by panel members to have influenced their decisions included balance (15 %), volume (11%), and vowel shape (8%).

Summary. Experts expressed significant preference for the sound of "Singin' in the Rain" (pointing gesture) in gestural as compared to baseline condition, and in posttest as compared to baseline condition. Judges most often endorsed the terms " intonation" and " blend" to describe primary factors contributing to their evaluations. That these listeners did not perceive the vocal sound of the gestural conditions to be significantly more pleasing than the sound of the posttest conditions heard may suggest at least a temporary persistence of effects of the pointing gesture after withdrawal of the gesture.

Expert listeners significantly heard as more pleasing the posttest conditions of "Over the Rainbow" (low, circular arm gesture) compared to both baseline and gestural iterations. Although a majority of judges rated the sound of the gestural conditions of "Hawaiian Rainbows" (arched hand gesture) as more pleasing, there were no statistically significant preferences for any of the sung conditions over other conditions in this song.

Participant Perceptions. Upon completion of the recording session, choral singers (N = 31) responded to an exit survey (Appendix E) that solicited overall thoughts and perceptions of singing with gestures in a choral singing context.

Almost all participants (n = 30, 97%) indicated that they thought the gestures affected their individual sound. One participant answered "not sure" to this question. As a part of this question, participants were also asked to rank the gestures on how much effect the gesture had on the choir's overall sound. Most participants rated the low arm circle as the most effective (n = 13, 42%) with arched hand (n = 8, 26%) and the pointing gesture (n = 6, 23%) ranked first by some.

Next, participants were asked if, when doing the gestures while singing, they focused most on the gestures or on their vocal sound production. Most participants (n = 18, 58%) said they focused on the gestures instead of their sound.

Participants were also asked which gestures they found easiest and hardest to do. The low arm circles, in comparison to the other two gestures, were judged by participants (n = 13, 42%) to be easiest to do followed by the arched hand (n = 9, 29%) and pointing (n = 6, 19%). The pointing gesture was judged to be the most difficult (n = 17, 55%) followed by the arched hand (n = 5, 16%), and circles (n = 5, 16%).

Table 1 shows participant responses to the query, "During which sung trial did you feel completely comfortable with doing the gesture?"

Table 1

Number of participant perceptions of comfort with gesture performance during each of the five iterations

	Low circles	Pointing	Arched Hand
Iteration	freq (%)	freq (%)	freq (%)
1	4 (*13.00%*)	3 (*9.60%*)	5 (*16.10%*)
2	11 *(35.50%)*	12 *(38.70%)*	12 *(38.70%)*
3	9 *(29.00%)*	9 *(29.00%)*	8 *(25.80%)*
4	2 *(6.00%)*	1 *(3.20%)*	0 *(0.00%)*
5	2 *(6.00%)*	2 *(6.00%)*	3 *(9.60%)*

In response to the prompt, "please share below any overall thoughts and perceptions of about singing with gestures in a solo singing setting," participants wrote a total of 31 discrete comments. After reading them, I first sorted participant responses into the mutually exclusive and exhaustive categories of "positive" and "negative." Significantly more, twenty-eight of the thirty-one comments, were categorized as "positive" ($x^2 = 20.48$, $df = 1$, $p < .001$).

Thereafter, I sorted participant comments into mutually exclusive and exhaustive categories of general and specific comments. There were 14 (46.67%) general and 17 (53.32%)

specific comments. Among general comments: “it helps,” “some gestures can be helpful,” “I think they work well,” and “different gestures work for different choirs.”

I further sorted the specific positive comments (*N* = 17) into these exhaustive and mutually exclusive categories: (a) timbre, (b) focus of attention, (c) intonation, and (d) timing. Results of a Kolmogorov-Smirov One-Sample Test indicated no significant distribution differences by category (D_{max} = .206, *p* = .28). Most (*n* = 8, 47.06%) of the specific positive comments addressed timbre. Included in this category were comments such a, “I thought that it helped focus the sound,” “it helps to focus my sound,” “I think it really helpful to achieve the sound,” and “I think it positively affects singers' vocal production.” Two comments in this category referred to specific gestures. These statements included “circles helped the song have energy” and “high notes were easier to reach with pointing.”

The next most frequency comments addressed intonation (*n* = 4, 23.53%). Comments about intonation included, “I think it is very helpful keeping pitch,” “the point over shot pitch sometimes,” “it eventually began to change our tone and pitch,” “gestures help keep the energy and pitch up,” and “it really improved our intonation.”

Among comments about focus of attention (*n* = 3, 17.65%) were “I was more attentive to the conductor with the gestures” and (the gesture) “helps by taking my focus off of sound production.” Another category had to do with comments (*n* = 2, 11.76%) regarding rhythm, including “low arm kept us from slowing down” and “timing was improved doing hand circles.”

The three negative comments (9.68% of all comments) voice by participants were “gestures would be more helpful if explained,” “The gestures made it harder to concentrate,” and “I don’t’ think gestures are the best thing since sliced bread.” Table 2 shows number of participant comments in each category.

Table 2

Participants' overall thoughts and perceptions of singing with gestures in the choral context

Category	Number of comments	Percent of comments
Timbre	$N = 8$	47.06%
Intonation	$N = 4$	23.53%
Focus of attention	$N = 3$	17.65%
Timing	$N = 2$	11.76%

Finally, singers were asked if they had choral singing experience prior to this time when signers were asked to employ gestures (hand and arm movements) while singing. Most participants (n = 24, 77%) had experience with gesture use in choir rehearsals. Most of those who had used gesture in rehearsals (n = 10, 42%) were very familiar with the practice (defined as having done it over 20 times).

Research Question Three: Video Analyses of Participants' Gestural Mastery

The third research question for Experiment 1 asked how long it might take, according to video analyses of participant behaviors, for singers to master each of the three gestures in a choral rehearsal context. To answer this question, I first analyzed each choir video recording using a researcher-created rubric for each singer individually (Table 3). A research assistant then repeated the video analysis task and rating reliability was found to be .93 (Agreements/Agreements + Disagreements). Singers were judged to have mastered the gesture when they successfully exhibited eight of the ten behaviors for each gesture on the rubric. Tables 3 – 5 present the results of this process.

Table 3

Participants' (N = 31) Mastery of the Low, Circular Arm Gesture ("Over the Rainbow")

According to Checklist Rubrics By Iteration

Specific Behavior: Iteration When Behavior Demonstrated:

	1	2	3
Both hands are used	34 *(97.14%)*	1 (*2.86%)*	
Fingers together	33 *(94.00%)*	1 *(3.00%)*	1 *(3.00%)*
Palms towards the midline of the body	34 *(97.00%)*	1 *(3.00%)*	
Arms, with elbows slightly bent	34 *(97.00%)*	1 *(3.00%)*	
Arms follow the upward and outward circular motion of the hands	34 *(97.00%)*	1 *(3.00%)*	
Hands move in circles in front of the torso	34 *(97.00%)*	1 (3.00%)	
Hands are no lower than the hips and no higher than the sternum	32 *(91.00%)*	2 *(5.70%)*	1 *(3.00%)*
The circles are done fairly quickly, not necessarily in the tempo of the song.	34 *(97.00%)*	1 *(3.00%)*	

Table 4

Participants' (N = 31) Mastery of the Pointing Gesture ("Singin' in the Rain") According to Checklist Rubrics By Iteration

Specific Behavior: Iteration When Behavior Demonstrated

	1	2	3
The index finger of your right hand points upward and outward	32 *(91.00%)*	3 *(8.60%)*	
Finger moving at a 45 degree angle from the torso	32 *(91.00%)*	3 *(8.60%)*	
Finger starting at the height of your sternum	32 *(91.00%)*	2 *(5.70%)*	1 *(3.00%)*
Finger/hand arches outward in front of the forehead	32 *(91.00%)*	3 *(8.60%)*	
Index finger leads, the arm follows.	32 *(91.00%)*	3 *(8.60%)*	
The arm begins with elbow slightly bent	32 *(91.00%)*	1 *(3.00%)*	2 *(5.70%)*
Arm extends from the shoulder	32 *(91.00%)*	3 *(8.60%)*	
Arm straightens as the point moves outward and upward	32 *(91.00%)*	3 *(8.60%)*	

Table 5

Participants' (N = 31) Mastery of the Arched Hand Gesture ("Hawaiian Rainbows") According to Checklist Rubrics By Iteration

Specific Behavior: Iteration When Behavior Demonstrated:

	1	2	3
Fingers arched (as if holding a tennis ball)	32 *(91.00%)*	3 *(8.60%)*	
Palm facing downward	35 *(100.00%)*		
The hand moves vertically upward	33 *(94.00%)*	2 *(5.70%)*	
Hand moves in front of the torso	33 *(94.00%)*	2 *(5.70%)*	

Hand moves from the level of the hip	33 *(94.00%)*	1 *(3.00%)*	1 *(3.00%)*
Hand moves up to level of the eyebrows	32 *(91.00%)*	3 *(8.60%)*	
As the hand moves upward, the arm starts with elbow slightly bent	35 *(100.00%)*		
Arm follows with elbow slightly bent throughout the gesture	33 *(94.00%)*	2 *(5.70%)*	

As indicated by Tables 3 - 5, most singers (90%+) achieved gestural mastery during the first iteration, regardless of gesture or song. Fewer participants required subsequent iterations of particular gestural behaviors with the arched hand gesture, while more participants required subsequent iterations to master behaviors associated with the pointing gesture. No participant, however, took longer than the third iteration to master any of the gestures employed.

Experiment 1 Chapter Summary. Overall measures of LTAS and Max/MSP indicate that the gestures employed in this investigation had an effect, although not universally, on the sound produced by the choir in this study. While employing the low, circular arm gesture during sung iterations of "Over the Rainbow" and the pointing gesture during sung iterations of "Singin' in the Rain," the choir tended to sing with increased signal amplitude. Specifically, employment of the low, circular gesture increased overall spectral energy compared to both baseline and posttest conditions across the 2 – 4 kHz region, with some spikes of 4 dB differences in the 2 – 2.5 kHz region and the 3.5 – 3.8 kHz region. The pointing gesture also increased overall spectral energy across the entire spectrum compared to both baseline and posttest conditions. When singing with the arched hand gesture, however, the choir sang with very minimal increased energy across the entire spectrum compared to both baseline and posttest conditions.

Significant intonation differences were found between (a) baseline and gesture conditions in "Over the Rainbow," (b) between baseline and posttest measures with "Singin' in the Rain," and (c) between gestural iterations and posttest measures with "Singin' in the Rain." Although significant differences were not found for "Hawaiian Rainbows," the choir, overall sang more in tune during the gestural iterations.

In several ways, the results of expert listener ratings and participant perceptions mirrored tendencies and trends suggested by the acoustical data. Experts expressed significant preference for the sound of "Singin' in the Rain" (pointing gesture) in gestural as compared to baseline condition, and in posttest as compared to baseline condition. Judges most often endorsed the terms " intonation" and " blend" to describe primary factors contributing to their evaluations. Expert listeners also significantly heard as more pleasing the posttest conditions of "Over the Rainbow" (low, circular arm gesture) compared to both baseline and gestural iterations. Although a majority of judges rated the sound of the gestural conditions of "Hawaiian Rainbows" (arched hand gesture) as more pleasing, there were no statistically significant preferences for any of the sung conditions over other conditions in this song.

Participants commented most frequently on intonation and timbre and achieved gestural mastery within the first three gestural iterations, regardless of gesture or song. Fewer participants required subsequent iterations of particular gestural behaviors with the low, circular arm gesture, while more participants required subsequent iterations to master behaviors associated with the pointing gesture.

CHAPTER FIVE

Experiment 2 Results – Solo Context

The purpose of Experiment 2 was to assess across iterations the potential effects of three singer gestures (low, circular arm gesture; arched hand gesture; pointing gesture) on performances of three familiar melodies by solo singers ($N = 35$) using selected acoustic and perceptual measurements. Results are presented in order of the research questions posed for this part of the investigation. A predetermined alpha level of .05 (adjusted as necessary by Bonferroni corrections) served to indicate significance for all statistical procedures.

Research Question One: Acoustical Measures

The first research question for the solo singing context asked if, according to measures of fundamental frequency (*Fo*), relative amplitude (Δ dB), and formant behaviors, there were acoustical differences in solo sound (a) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture, and (b) between baseline (without gesture) and final performance (without gesture) conditions. Results of these acoustical measurements will be presented according to the particular singer gesture employed (low, circular arm gesture; arched hand gesture; pointing gesture). Within that structure, macro-results (behaviors of this group of participants on the whole) precede micro-results (behaviors of individual singers).

Low, circular arm gesture ("Over the Rainbow"): Measures of Intonation. Figure 32 illustrates the data points used for pitch measures during each participant's performances of "Over the Rainbow."

Figure 32. Data points used for intonation comparison for low, circular arm gesture ("Over the Rainbow").

At each of these data points, I extracted a steady state portion of the sung /i/ vowel for analysis with Praat (version 5.3.12) software. For *Fo* measures, I compared these data to the target pitches indicated in the score. In order to do so, I first converted data from Herz to cents, to facilitate analysis of intonation differences on a non-logarithmic scale. For this process, I took a frequency measurement (Hz) of each sung pitch of interest using Praat. I then converted each measurement of Hertz to cents by comparing the frequency of the target pitch to the actual sung frequency, using an online frequency conversion calculator *(*www.sengpielaudio.com/calculator-centsratio.htm). Finally, I entered each resulting number (deviation in cents) into an Excel spreadsheet for subsequent analysis.

For calculation of mean cents deviation per each participant (*N* = 35) and for each iteration (*N* = 7) of each song (*N* = 3), I measured three ("Singin' in the Rain") or four pitches ("Over the Rainbow" and "Hawaiian Rainbows") at predetermined data acquisition points in each song excerpt. For baseline and posttest conditions, I then averaged the cents differences between scored and sung pitches at each data point to report baseline and posttest condition intonation.

To arrive at a grand mean of the five gestural iterations, I averaged the means acquired from data point measurements during each iteration. For purposes of interpreting results, a difference of ± 7 cents (Lindgren & Sundberg, 1972; Sundberg, 1982; Sundberg, Prame & Iwarrson, 1996) constituted a just noticeable difference in intonation.

Low, Circular Arm Gesture ("Over the Rainbow"): Overall Intonation Trends. Figure 33 illustrates participants' deviation in cents from target frequency for (a) baseline, (b) grand mean of the five gestural iterations, and (c) posttest during participants' performances of "Over the Rainbow."

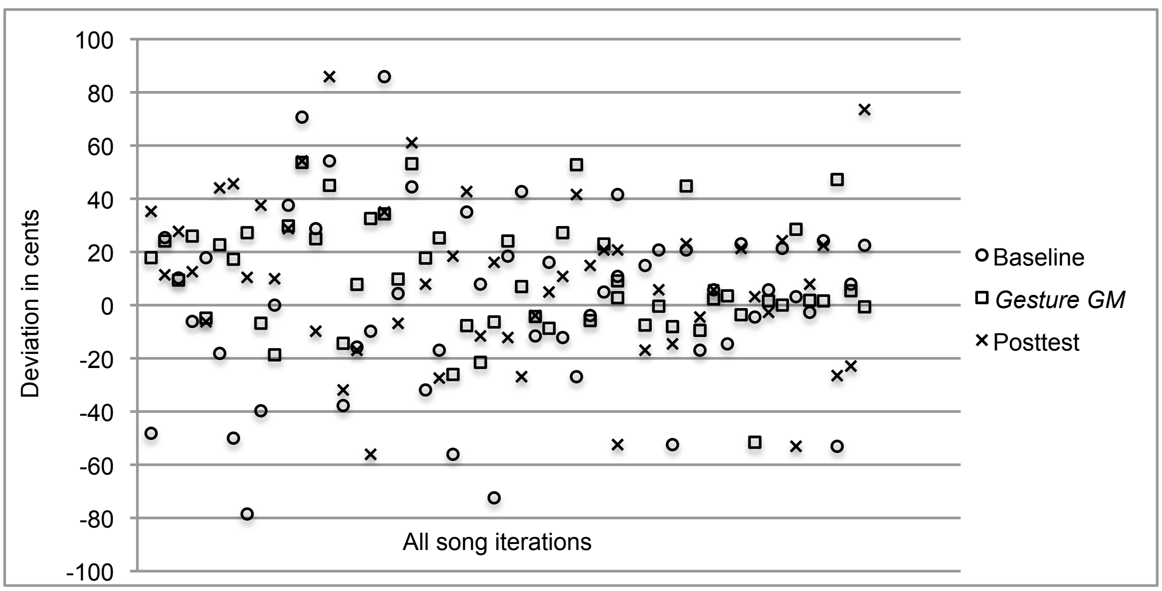

Figure 33. Deviation in cents from target frequency in baseline, gesture, and posttest conditions – Low, circular gesture ("Over the Rainbow") *Note*: *GM* = grand mean.

Baseline (range: -155 – 95 cents; variation: 250 cents;) and posttest (range: -127 – 100 cents; variation: 227 cents) conditions showed greater deviation in cents from target frequency than the grand mean of the gestural conditions (range: -112 – 72; variation: 184 cents) sung with the low, circular arm gesture. That is, on the whole participants tended to sing more in tune during gestural iterations overall than they did without employing the low, circular arm gesture.

Figure 34 displays cents deviation means for each iteration (*N* = 5) of the low, circular arm gesture compared to the means of baseline and posttest (without gesture) conditions. Singers were furthest below the target frequency (*M* = -5.85 cents) during the baseline condition and closest to the target frequency during the first gestural iteration (*M* = 2.75 cents). While these mean deviations were within ± 7 cents, there was a difference of 8.60 cents between the means of the baseline and first gestural iteration conditions, and a difference of 12.79 cents between the means of the baseline and posttest conditions. From baseline through posttest conditions, singers tended to raise the pitch slightly.

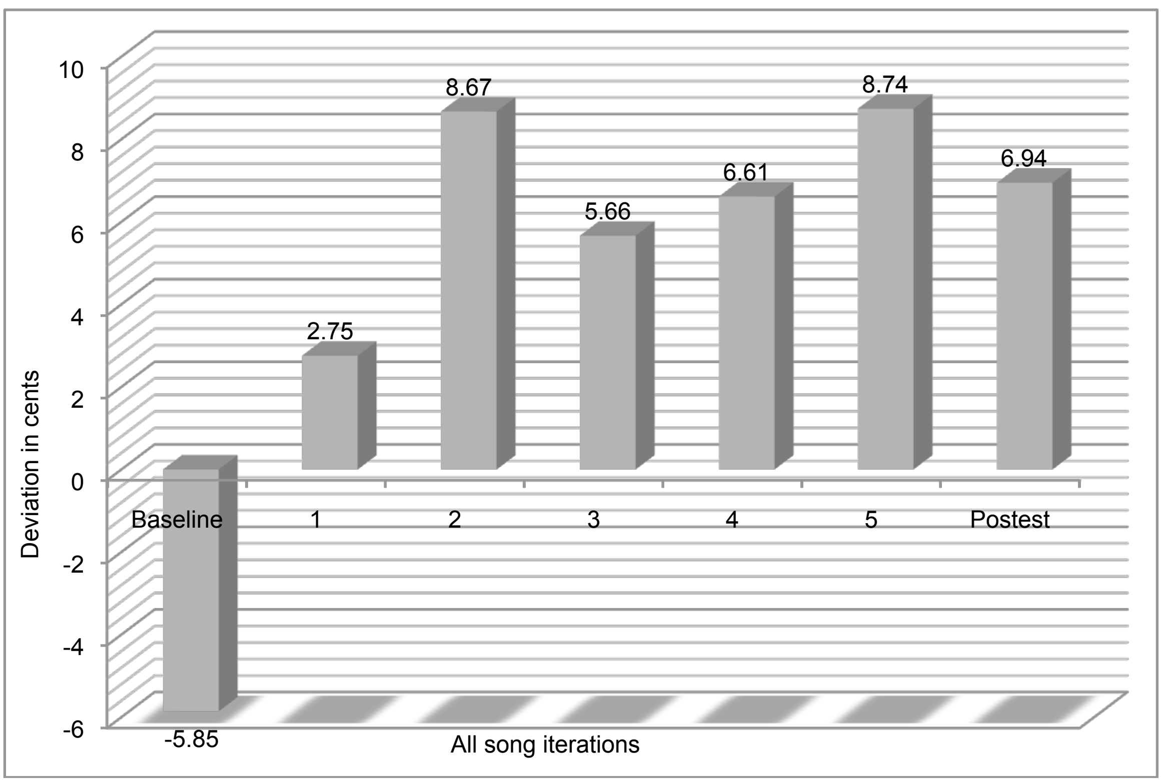

Figure 34. Fo deviation means for each iteration (*N* = 7) of the low, circular arm gesture compared to the means of baseline and posttest (without gesture) conditions.

Low, Circular Arm Gesture ("Over the Rainbow"): Gross Intonation Deviation. Although it does not take into consideration whether overall intonation measured as cents deviation tended to be sharp or flat in relation to target frequencies, converting data to absolute values affords another view of the data in terms of gross intonation deviation and permits ANOVA testing. A Repeated Measures ANOVA found no significant main effect for intonation between the baseline, gestural, and posttest conditions of "Over the Rainbow," (F [2,51] = 1.699, p = .193).

Low, circular arm gesture ("Over the Rainbow"): Pitch trends per each participant. Table 6 shows pitch trends per individual participant. Because soloists, by definition, sing alone, these data may be instructive from a pedagogical perspective. In other words, if a teacher requested each of these particular individuals to sing "Over the Rainbow" using the same protocol employed for this investigation, the following intonation behaviors might occur.

Table 6

Deviation in cents from target frequency per participant between baseline, gestural iterations and posttest conditions – Low, circular arm gesture ("Over the Rainbow")

Participant	Sex	Experience	Gesture compared to baseline	Posttest compared to baseline
1	F	2	*	*
2	F	2	*	
3	F	1	*	*
4	M	1	*	*
5	M	2	*	*
6	M	2	*	*
7	M	1	*	*
8	F	2	*	
9	F	1	*	*
10	F	1	*	*
11	M	2		
12	F	1		
13	F	1	*	
14	F	2	*	*
15	M	1		*
16	F	2		*
17	F	2		*

18	F	1		
19	F	1	*	
20	F	1	*	*
21	F	2		
22	F	2	*	
23	M	1		
24	M	1	*	
25	M	1		
26	M	1		
27	M	2	*	*
28	M	2		*
29	M	2	*	*
30	F	2	@*	
31	F	2		*
32	M	1	@	
33	M	1	*	*
34	M	1	*	
35	M	2	*	*
Total *			21 *(60.00%)*	19 *(54.29%)*
Total @*			1 *(2.86%)*	0 *(0.00%)*
Grand Total: Improvement			**22** ***(62.87%)***	**20** ***(57.14%)***
Total @			1 *(2.86%)*	0 *(0.00%)*
Total blank			12 *(34.29%)*	15 *(42.86%)*
Grand Total: Stasis or No Improvement			**13** ***(37.14%)***	**15** ***(42.86%)***

Note: Experience (1 = less experience, 2 = more experience). Comparison of conditions (@ = within + 7 cents of target frequency at baseline and remained so; @ = achieved target frequency; * = came closer to target frequency, blank cell = moved further from target frequency)*

Compared to baseline, only one participant's gestural iteration mean was within ± 7 cents of target pitch. Another participant, whose baseline iteration mean was already within ± 7 cents of target pitch, maintained it during excerpts sung with the low, circular arm gesture. However, of the remaining 33 participants, 22 of them (66.67%) moved closer to target pitch while employing the low, circular arm gesture.

Overall, Table 6 data appeared to suggest that the pitch tendencies of these solo singers varied idiosyncratically. That is, while majorities of participants (62.87% in baseline-gestural comparison, 57.14% in baseline-posttest comparison) moved closer to target frequency, not every singer responded in similar ways to employment of the low, circular arm gesture in “Over the Rainbow” with respect to intonation. Thirteen participants (37.14%) evidenced stasis or no improvement in the gestural iterations compared to their baseline performances. Fifteen participants (42.86%) evidenced no improvement in the baseline-posttest comparison.

Summary: Deviations from target frequencies in “Over the Rainbow.” According to the measurements of intonation used for this investigation, employment of the low, circular arm gesture while singing “Over the Rainbow” did not appear to offer a “magic” or “one size fits all” strategy for bringing this particular group of participants, on the whole, to within ±7 cents of the scored target frequencies. However, participants on the whole, regardless of sex or singing experience, trended toward more in tune singing both while employing the gesture and during the posttest condition (Figure 34). A primary contributor to this trend appeared to be that singers on the whole sang slightly sharper in the gestural iterations compared to baseline (Figure 34). This factor was particularly evident in the 8.60 cents difference between baseline and the first iteration sung with the low, circular arm gesture, rendering it the most in tune of the five gestural iterations. Moreover, while few singers achieved target range (±7 cents of scored pitch) in either baseline-gestural or baseline-posttest comparisons (Table 7), majorities of singers moved closer to target range in both comparisons.

Low, Circular Arm Gesture (“Over the Rainbow”): Mean Formant Frequencies. Formant frequency data provide an indication of voice timbre or color. Because participants sang an /i/ vowel throughout, formant frequency means acquired from the four data points in the

"Over the Rainbow" excerpt can provide a credible indication of voice timbre or color. For formant frequency extraction, Praat applied a Guassian-like window to compute linear predictive coefficients through the Burg algorithm integrated in the software. I used these computations to obtain frequency readings for the first four formants as produced at the steady state portion of the /i/ vowel sung at each of the four data points. Because males and females differ in average vocal tract length, which impacts vocal tract dependent formant frequencies, formant frequency data are presented according to participant sex.

As indicated in Table 7, female participants, on the whole, exhibited lowered frequencies in all four examined formants in the gestural condition compared with baseline, and in the posttest condition compared with the gestural iterations. When disaggregated according to individual participants, a majority of the eighteen female singers exhibited lowered frequencies in all four formants during both the gestural (n = 13, 72.22%) and posttest (n = 13, 72.22%) conditions of "Over the Rainbow."

Table 7

Overall Frequency Means and Standard Deviations in Hertz for the Low, Circular Arm Gesture in "Over the Rainbow" (N =35 Singers)

Female	Baseline *M* (*SD*)	5 Gestural Iterations *GM* (*SD*)	Posttest *M* (*SD*)
Fo	289.94 (±4.23)	293.95 (±3.56)	293.02 (±3.48)
F1	610.05 (±22.46)	601.74 (±33.60)	596.28 (±21.97)
F2	1786.57 (±63.23)	1733.25 (±65.78)	1736.58 (±84.19)
F3	2698.22 (±160.40)	2668.09 (±98.10)	2626.68 (±102.17)
F4	3749.88 (±234.57)	3739.27 (±177.89)	3725.35 (±218.06)
Male			
Fo	221.12 (±5.31)	221.58 (±3.12)	221.76 (±4.29)
F1	373.78 (±16.98)	372.33 (±21.10)	364.77 (±21.80)
F2	1856.31 (±79.20)	1839.50 (±83.32)	1886.66 (±53.98)
F3	2538.44 (±97.18)	2501.39 (±101.30)	2466.91 (±86.20)
F4	3572.53 (±213.07)	3552.26 (±217.19)	3556.90 (±166.09)

Group means for male participants (*N* = 17), on the other hand, presented a mixed picture (Table 7). On the whole, these male singers, like the females, exhibited a lowering of F1 and F3 frequencies in the gestural condition compared with baseline, and in the posttest condition compared with gestural iterations. While males on the whole exhibited lowered F2 and F4 frequencies between baseline and gestural conditions, however, they exhibited higher F2 and F4 frequencies in the posttest condition. When disaggregated according to individual participants, a majority of male participants exhibited lowered frequencies in all four examined formants during the gestural (*n* = 13, 76.47%) and posttest (*n* = 12, 70.59%) conditions.

Lowered formant frequencies may indicate the presence of articulation maneuvers (e.g., lips, tongue, velum) and larynx positioning that would lengthen the vocal tract, resulting in a slightly "darker" or perhaps, depending upon aesthetic and other preferences, a somewhat "richer" vocal timbre. Overall, the low, circular arm gesture appeared to be associated with changes in vocal timbre for over 70% of both female and male participants during their performances of "Over the Rainbow."

Low, Circular Arm Gesture ("Over the Rainbow"): Measures of Relative Amplitude (Δ dB). For considerations of overall sung amplitude, decibel (dB) levels were acquired via Praat software at each of the four data points for each participant during all iterations of "Over the Rainbow." On the basis of these data, I calculated per participant the difference between an individual's mean dB across all iterations and her or his sung dB in each performance. This procedure yielded a Δ dB used for within participant amplitude comparisons. For this investigation, a 1 dB variance in complex, vocal sound constituted, for interpretation purposes, a just noticeable difference (Howard & Angus, 2006).

Table 8 illustrates overall relative amplitude (Δ dB) means and standard deviations for the low, circular arm gesture in “Over the Rainbow.” Participants overall exhibited a just noticeable increase (1.06 dB) in Δ dB while employing the low, circular arm gesture, likely attributable to a mean increase of 1.41 dB among males during the gestural iteration conditions.

Table 8

Overall Relative Amplitude (Δ dB) Means and Standard Deviations for the Low, Circular Arm Gesture in "Over the Rainbow" (N =35 Singers)

	Baseline *M* (*SD*)	5 Gestural Iterations *M* (*SD*)	Posttest *M* (*SD*)
Female Δ dB *M*	69.87 (± 9.41)	70.59 (± 6.37)	69.62 (± 8.74)
Male Δ dB *M*	69.87 (± 9.45)	71.28 (±11.68)	69.82 (±10.27)
Overall *M*	69.87	70.93	69.72

Figure 35 illustrates Δ dB deviations from individual mean amplitude for (a) baseline, (b) grand mean of the five gestural iterations, and (c) posttest during participants' performances of "Over the Rainbow." Participants, on the whole, appeared to sing with increased energy (+1 dB or more) during the gestural iterations. Participants, moreover, evidenced less Δ dB deviation from individual mean amplitude during their sung iterations with the low, circular arm gesture.

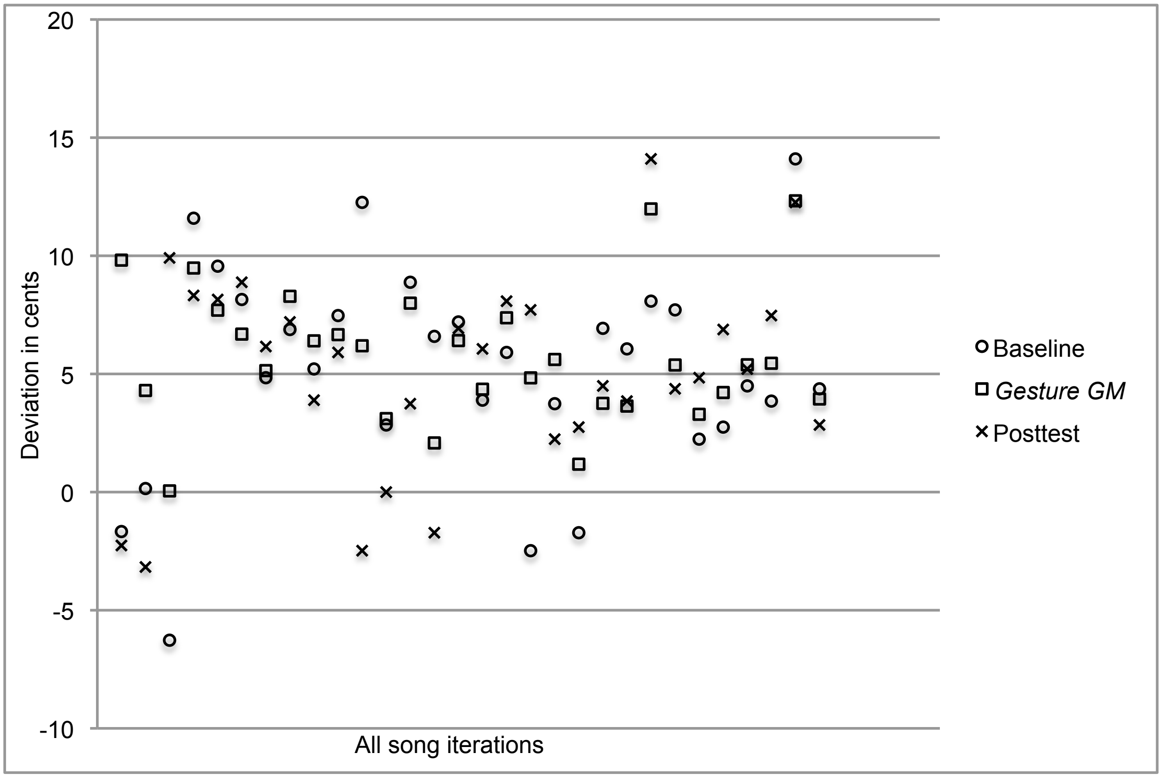

Figure 35. Δ dB deviation from individual mean amplitude in baseline, gestural, and posttest conditions – Low, circular gesture ("Over the Rainbow") *Note: GM* = grand mean.

Range of baseline measures was -6.5 - 13 Δ dB (19.5 dB variance) from individual mean amplitude. Posttest measures indicated a range of – 4 – 14 Δ dB (18 dB variance**)** from individual mean amplitude. Grand mean of gestural iteration measures fell within a range of .22 – 12.5 Δ dB (12.72 dB variance) from individual mean amplitude. That is, participants overall exhibited the most deviation from individual mean amplitudes in the baseline and posttest conditions.

Amplitude variance: gestural iterations. I also calculated variances in Δ dB from individual mean amplitudes for each iteration (N = 7) of the low, circular gesture compared to the means of baseline and posttest (without gesture) conditions (See Figure 36).

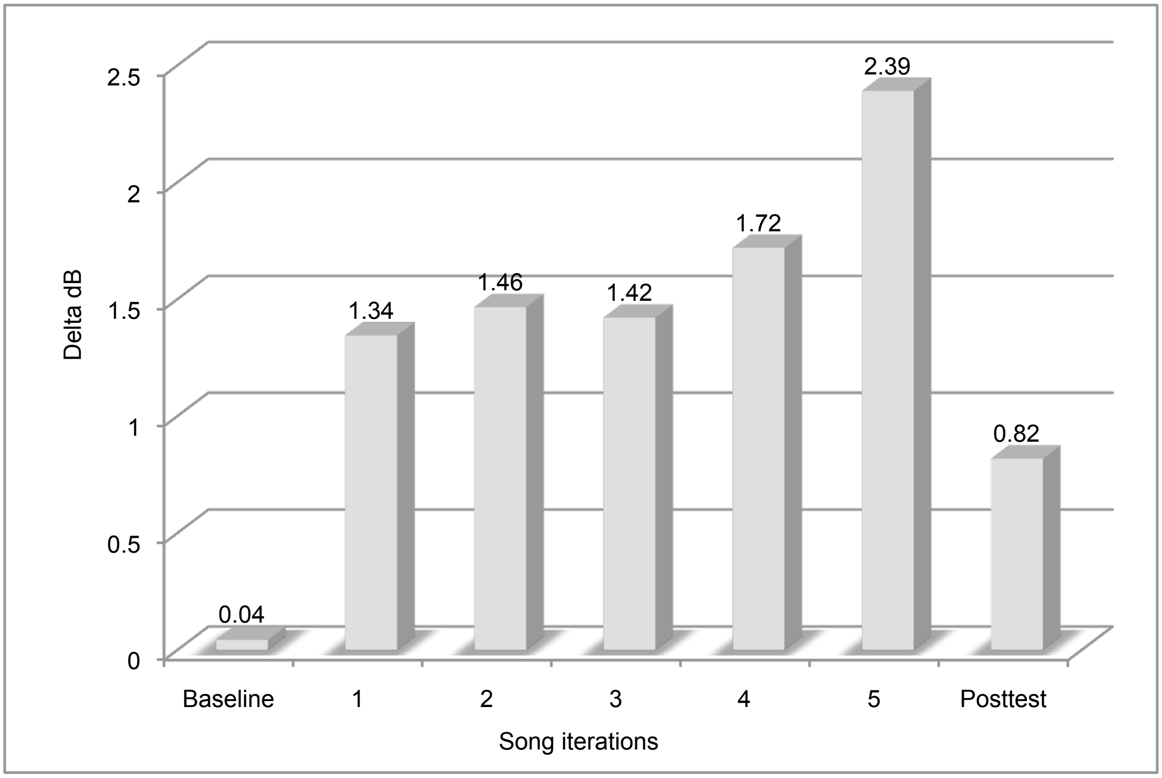

Figure 36. Δ dB from individual mean amplitudes for each iteration of "Over the Rainbow."

The largest variance from individual mean amplitude occurred during the fifth gestural iteration (*M* = 2.39 Δ dB). A potentially audible (± 1 dB or more) difference was observed between baseline (.04 Δ dB) and all gestural iterations (*M* = 1.77 Δ dB). Although, not an audible difference, there was an increase in amplitude in the posttest (*M* = .82 Δ dB) as compared to the baseline (.04 Δ dB).

Low, circular arm gesture ("Over the Rainbow"): Amplitude trends per each participant. Table 9 shows amplitude trends per individual participant.

Table 9

Amplitude trends per individual participant between baseline, gestural iterations and posttest conditions – Low, circular arm gesture ("Over the Rainbow")

Participant	Sex	Experience	Gestural M Compared to Baseline	Posttest Compared to Baseline
1	F	2	+	+
2	F	2	+	+
3	F	1	-	+
4	M	1	-	-
5	M	2	-	-
6	M	2	-	+
7	M	1	-	-
8	F	2	+	-
9	F	1	+	+
10	F	1	+	+
11	M	2	-	-
12	F	1	+	+
13	F	1	+	+
14	F	2	+	+
15	M	1	-	-
16	F	2	-	-
17	F	2	+	+
18	F	1	+	-
19	F	1	+	+
20	F	1	-	-
21	F	2	+	+
22	F	2	+	+
23	M	1	-	-
24	M	1	-	-
25	M	1	+	+
26	M	1	+	+
27	M	2	+	-
28	M	2	+	+
29	M	2	-	-
30	F	2	+	+
31	F	2	+	+
32	M	1	-	-
33	M	1	-	-
34	M	1	-	-
35	M	2	+	+
Total + (louder)			20 *(57.14%)*	16 *(45.71%)*
Total – (softer)			15 *(42.85%)*	19 *(52.28%)*

Grand Total: Audible difference	**35** ***(100.00%)***	**35** ***(100.00%)***
Grand Total: Stasis/No audible difference	0 *(0.00%)*	0 *(0.00%)*

Note: Experience (1 = less experience, 2 = more experience), Comparison of conditions (- = -1 db or more*,* + = +1 dB or more)*, blank cell = within 1 dB (no audible change)*

Participants 30, 31, and 35 evidenced greater overall energy in gestural iterations compared to baseline and posttest measures compared to baseline. Three participants (8.57%) evidenced increased amplitude when comparing their means of the gestural iterations to their baseline amplitudes, but a decrease in amplitude in the posttest to baseline comparison. Two participants (5.71%) evidenced decreased amplitude in the gesture to baseline comparisons, but increased amplitude in the posttest to baseline comparisons. Seventeen participants (48.57%) showed increased amplitude in the posttest and gesture comparisons.

Overall, Table 9 data appeared to suggest that, while the amplitude tendencies of these solo singers varied idiosyncratically, a majority of participants displayed increased amplitude (+ 1 dB or more) over baseline in both the gestural and posttest conditions.

Disaggregation of amplitude data by sex and experience. Disaggregation of amplitude results by participant sex, and singing experience indicated no significant interactions attributable to these variables (sex: F [2,51] = .164, p = .849, and experience: F [2,51] = 2.22, p = .802).

Summary of amplitude data results: Low, circular arm gesture ("Over the Rainbow"). According to measurements of delta dB, participants overall exhibited a just noticeable mean increase (+1.06 dB) in Δ dB while employing the low, circular arm gesture (Table 9). Assessments of deviations from individual mean amplitudes showed more variance during baseline and posttest conditions, and less variance during gestural iterations (Figure 36).

Participants exhibited a mean Δ dB variance of +1.77 dB with the low, circular arm gesture compared to baseline condition. A majority of singers (*N* = 20, 57.14%) evidenced increased amplitude in the gestural condition compared to baseline. A majority of singers (*N* = 19,54.29%) evidenced increased amplitude in the posttest condition compared to baseline (Table 9).

Overall Summary: Acoustic Measures (Low, Circular Arm Gesture – "Over the Rainbow"). Overall measures of Fo, amplitude (Δ dB), and formant behaviors indicated that while employing the low, circular arm gesture during sung iterations of "Over the Rainbow," participants, on the whole, tended to (a) move closer to (though not achieve) target frequency range (+7 cents of scored pitches examined), (b) sing with increased energy (+1 dB or more) while employing the gesture, and (c) change the timbre or color of their tone, largely through a tendency toward lowered formant frequencies. Individual singers, however, varied in their intonation, amplitude, and formant behaviors, and thus with respect to these summarized group tendencies.

Pointing gesture ("Singin' in the Rain"): Measures of Intonation. Figure 37 illustrates the data points used for pitch measures during each participant's performances of "Singin' in the Rain."

Figure 37. Data points used for intonation comparison - Pointing gesture ("Singin' in the Rain").

Pointing gesture ("Singin' in the Rain"): Overall Intonation Trends. Figure 38 illustrates participants' deviation in cents from target frequency for (a) baseline, (b) grand mean of the five gestural iterations, and (c) posttest during participants' performances of "Singin' in the Rain." Baseline (range: -75 – 78 cents; variation: 153 cents;) and posttest (range: -55 – 76 cents; variation: 130 cents) conditions showed greater deviation in cents from target frequency than the grand mean of the gestural conditions (range: -50 – 52; variation: 102 cents) sung with the pointing gesture. That is, on the whole participants tended to sing more in tune during gestural iterations overall than they did without employing the pointing gesture.

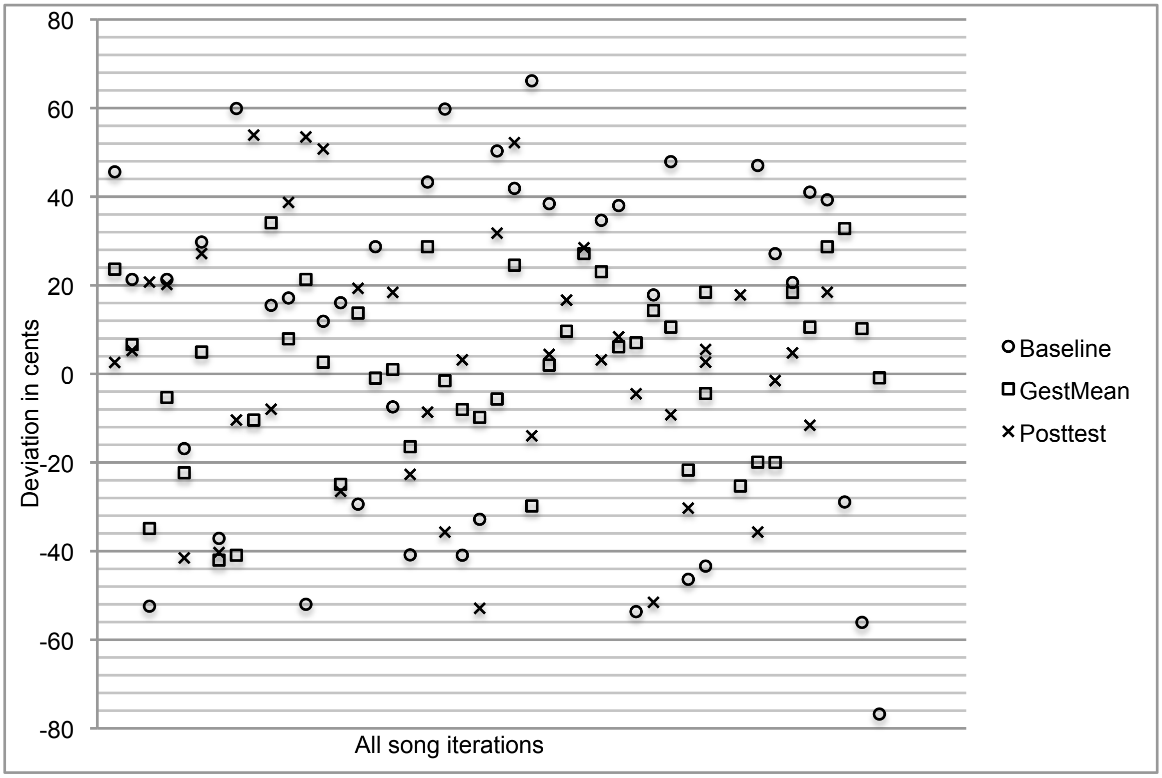

Figure 38. Deviation in Cents from target frequency in baseline, gesture, and posttest conditions – Pointing gesture ("Singin' in the Rain") *Note*: *GM* = grand mean.

Figure 39 displays cents deviation means for each iteration ($N = 5$) of the pointing gesture compared to the means of baseline and posttest (without gesture) conditions. Singers were furthest below the target frequency ($M = -14.65$ cents) during the baseline condition and closest to the target frequency during the first gestural iteration ($M = 3.91$ cents). While these mean deviations were within ± 7 cents, there was a difference of 18.56 cents between the means of the baseline and first gestural iteration conditions, and a difference of 1.19 cents between the means of the baseline and posttest conditions. From baseline through posttest conditions, singers tended to raise the pitch slightly.

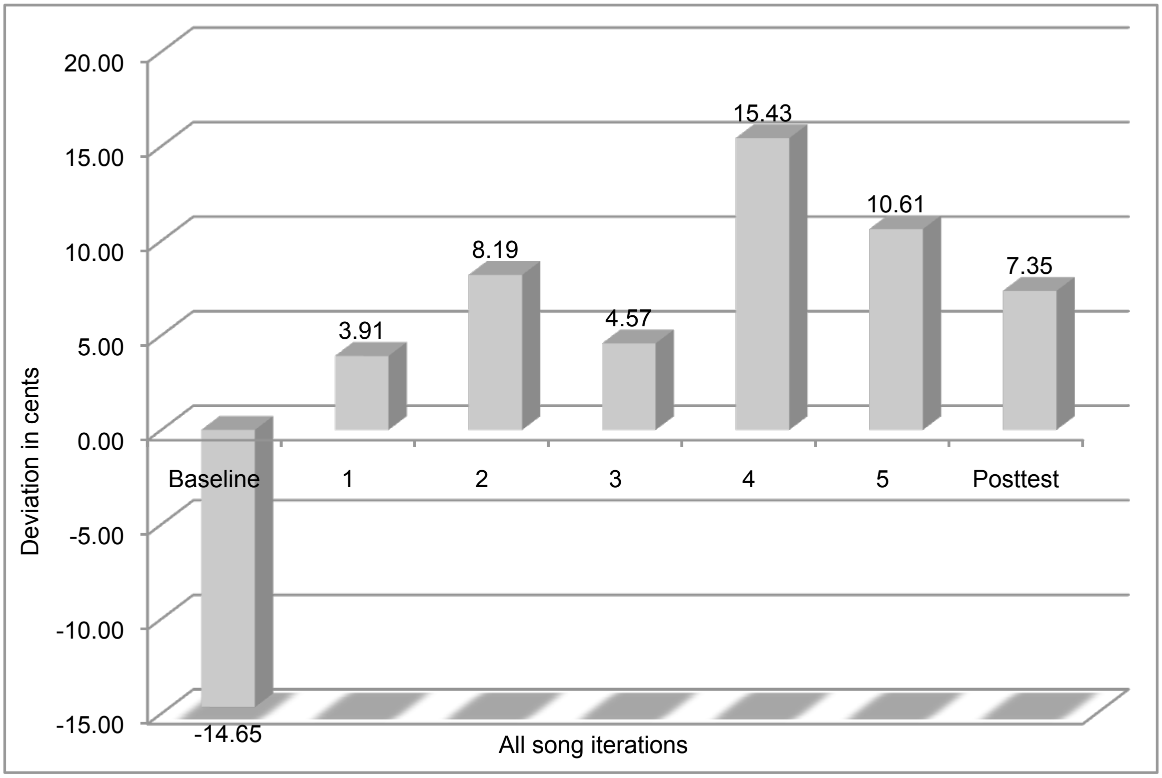

Figure 39. Fo deviation means for each iteration ($N = 7$) of the pointing gesture compared to the means of baseline and posttest (without gesture) conditions.

Pointing gesture ("Singin' in the Rain"): Gross Intonation Deviation. A Repeated Measures ANOVA found a significant main effect for intonation between the baseline, gestural, and posttest conditions of "Singin' in the Rain," (F [2,51] = 1.699, $p = .001$) between baseline, gestural iteration, and posttest conditions. Follow-up paired t – tests (two-tailed) measure specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance ($p = .05/3 = .017$). *T*-test results indicated significant differences between mean of gestural iterations and posttest measures ($p < .001$) and between baseline and mean of gestural iteration measures ($p < .005$). No significant differences were found between baseline and posttest measures ($p = .563$).

Pointing gesture ("Singin' in the Rain"): Pitch trends per each participant. Table 10 shows pitch trends per individual participant.

Table 10

Deviation in cents from target frequency per participant between baseline, gestural iterations and posttest conditions – Pointing gesture

Participant	Sex	Experience	Gesture compared to baseline	Posttest compared to baseline
1	F	2	*	*
2	F	2	*	
3	F	1	*	*
4	M	1	*	*
5	M	2	*	
6	M	2	*	
7	M	1	*	*
8	F	2	*	*
9	F	1	*	*
10	F	1		
11	M	2	*	
12	F	1	*	*
13	F	1		*
14	F	2		
15	M	1	*	
16	F	2	*	*
17	F	2		
18	F	1	*	*
19	F	1		*
20	F	1	*	*
21	F	2	*	*
22	F	2	*	
23	M	1	*	*
24	M	1		
25	M	1		
26	M	1	*	*
27	M	2		
28	M	2		*
29	M	2	*	*
30	F	2		@*
31	F	2		*
32	M	1	@	
33	M	1	@	
34	M	1	*	*
35	M	2	*	

Total *	21 *(60.00%)*	19 *(54.29%)*
Total @*	0 *(0.00%)*	1 *(2.87%)*
Grand Total: Improvement	**21** ***(60.00%)***	**20** **(57.14%)**
Total @	2 *(5.87%)*	0 *(0.00%)*
Total blank	11 *(31.43%)*	15 *(42.86%)*
Grand Total: Stasis or No Improvement	**13** ***(37.14%)***	**15** ***(42.86%)***

Note: Experience (1 = less experience, 2 = more experience). Comparison of conditions (@ = within + 7 cents of target frequency at baseline and remained so; @ = achieved target frequency; * = came closer to target frequency, blank cell = moved further from target frequency)*

Compared to baseline, no participant's gestural iteration mean was within ± 7 cents of target pitch. Two participants, whose baseline iteration means were already within ± 7 cents of target pitch, maintained it during excerpts sung with the pointing gesture. However, of the remaining 33 participants, 21 of them (60.00%) moved closer to target pitch while employing the pointing gesture.

Overall, Table 10 data appeared to suggest that the pitch tendencies of these solo singers varied idiosyncratically. That is, while majorities of participants (60.00% in baseline-gestural comparison, 57.14% in baseline-posttest comparison) moved closer to target frequency not every singer responded in similar ways to employment of the pointing gesture in "Singin' in the Rain" with respect to intonation. Thirteen participants (37.14%) evidenced stasis or no improvement in the gestural iterations compared to their baseline performances. Fifteen participants (42.86%) evidenced no improvement in the baseline-posttest comparison.

Summary: Deviations from target frequencies in "Singin' in the Rain." According to pitch measurements used for this investigation, employment of the pointing gesture while singing “Singin’ in the Rain” did not appear to bring this particular group of participants, on the whole, to within ±7 cents of the scored target frequencies. However, participants on the whole, regardless of sex or singing experience, trended toward more in tune singing both while employing the gesture and during the posttest condition (Figure 39). A primary contributor to this trend appeared to be that singers on the whole sang slightly sharper in the gestural iterations compared to baseline (Figure 34). This factor was particularly evident in the 18.56 cents difference between baseline and the first iteration sung with the pointing gesture, rendering it the most in tune of the five gestural iterations. Moreover, while few singers achieved target range (±7 cents of scored pitch) in either baseline-gestural or baseline-posttest comparisons (Table 9), majorities of singers moved closer to target range in both comparisons.

Pointing gesture (“Singin’ in the Rain”): Mean Formant Frequencies. As indicated in Table 11, female participants, on the whole, exhibited lowered frequencies in all four examined formants in the gestural condition compared with baseline, but not in the posttest condition compared with the gestural iterations. When disaggregated according to individual participants, a majority of the eighteen female singers exhibited lowered frequencies in all four formants during both the gestural (*n* = 12, 75.00%) and posttest (*n* = 13, 72.22%) conditions of “Singin’ in the Rain.”

Table 11

Overall Frequency Means and Standard Deviations in Hertz for the Pointing Gesture in “Singin’ in the Rain” (N =35 Singers)

Female	Baseline *M* (*SD*)	5 Gestural Iterations *M* (*SD*)	Posttest *M* (*SD*)
Fo Deviation	289.94 (± 4.23)	293.95 (± 3.56)	293.02 (± 3.48)
F1	612.47 (± 21.42)	598.15 (± 20.17)	612.55 (± 14.61)
F2	1570.13 (±127.43)	1553.07 (± 82.38)	1701.42 (± 76.83)
F3	2569.03 (±159.45)	2565.17 (±100.36)	2539.57 (± 94.81)
F4	3581.29 (±233.58)	3350.88 (±216.25)	3551.92 (±210.70)

Male			
Fo Deviation	221.12 (± 5.31)	221.58 (± 3.12)	221.76 (± 4.29)
F1	369.23 (± 23.34)	378.34 (± 17.65)	379.84 (± 14.89)
F2	1761.28 (± 55.53)	1830.58 (±123.62)	1896.75 (± 47.08)
F3	2475.57 (± 87.74)	2481.32 (±155.63)	2583.35 (± 79.29)
F4	3484.73 (±167.64)	3566.34 (±229.77)	3612.92 (±159.18)

Group means for male participants ($N = 17$), on the other hand, presented a different picture (Table 11). On the whole, these male singers, unlike the females, exhibited a raising of formant frequencies in the gestural condition compared with baseline, and in the posttest condition compared with gestural iterations. When disaggregated according to individual participants, a majority of male participants exhibited heightened frequencies in all four examined formants during the gestural ($n = 11$, 73.33%) and posttest ($n = 12$, 70.59%) conditions.

Lowered formant frequencies may indicate the presence of articulation maneuvers (e.g., lips, tongue, velum) and larynx positioning that would lengthen the vocal tract, resulting in a slightly "darker" or perhaps, depending upon aesthetic and other preferences, a somewhat "richer" vocal timbre. Higher formant frequencies may indicate the opposite maneuvers. Overall, the pointing gesture appeared to be associated with changes in vocal timbre for over 70% of both female and male participants during their performances of "Singin' in the Rain."

Pointing gesture ("Singin' in the Rain"): Measures of Relative Amplitude (Δ dB). Table 12 illustrates overall relative amplitude (Δ dB) means and standard deviations for the pointing gesture in "Singin' in the Rain." Participants overall exhibited a noticeable increase (3.34 dB) in Δ dB while employing the pointing gesture, likely attributable to a mean increase of 6.08 dB among males during the gestural iteration conditions.

Table 12

Overall Relative Amplitude (Δ dB) Means and Standard Deviations for the Pointing Arm Gesture in "Singin' in the Rain" (N =35 Singers)

	Baseline *M* (*SD*)	5 Gestural Iterations *M* (*SD*)	Posttest *M* (*SD*)
*Female*Δ dB	68.72 (±9.46)	69.33 (±7.25)	68.99 (± 8.31)
Male Δ dB	63.68 (±8.45)	69.76 (±9.83)	66.28 (±10.26)
Total	66.20	69.54	67.64

Figure 40 illustrates Δ dB deviations from individual mean amplitude for (a) baseline, (b) grand mean of the five gestural iterations, and (c) posttest during participants' performances of "Singin' in the Rain." Participants, on the whole, appeared to sing with increased energy (+1 dB or more) during the gestural iterations. Participants, moreover, evidenced greater Δ dB deviation from individual mean amplitude during their sung iterations with the pointing gesture.

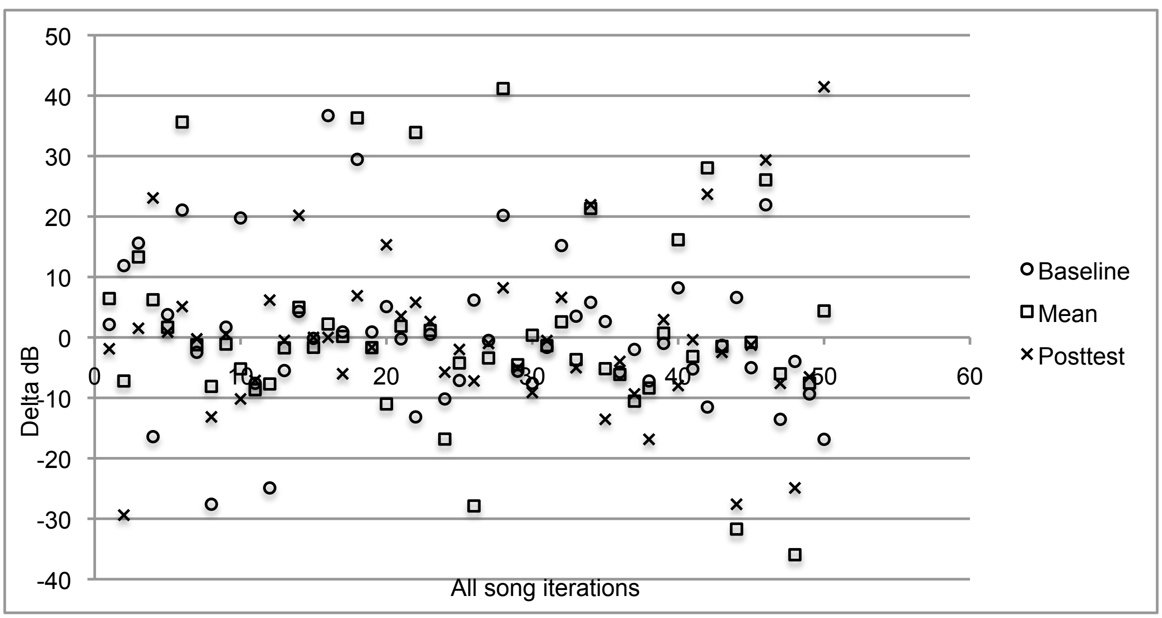

Figure 40. Δ dB deviation from individual mean amplitude in baseline, gesture, and posttest conditions – Pointing gesture ("Singin' in the Rain") *Note: GM* = grand mean.

Range of baseline measures was -28.50 – 37.57 Δ dB (66.07 dB variance) from individual mean amplitude. Posttest measures indicated a range of – 29.14 – 41.45 Δ dB (70.59 dB variance) from individual mean amplitude. Grand mean of gestural iteration measures fell within a range of -36.03 – 42.36 Δ dB (78.39 dB variance) from individual mean amplitude. That is, participants overall exhibited the most deviation from individual mean amplitudes in the gestural iterations and posttest conditions.

Amplitude variance: gestural iterations. I also calculated variances in Δ dB from individual mean amplitudes for each iteration (*N* = 7) of the low, circular gesture compared to the means of baseline and posttest (without gesture) conditions (See Figure 41). The largest variance from individual mean amplitude occurred during the third and fourth gestural iterations (*M* = 1.95 Δ dB). A potentially audible (+ 1 dB or more) difference was observed between baseline (.14 Δ dB) and all gestural iterations (*M* = 1.86 Δ dB). Another audible difference was found in amplitude in the posttest (*M* = 1.38 Δ dB) as compared to the baseline (.04 Δ dB).

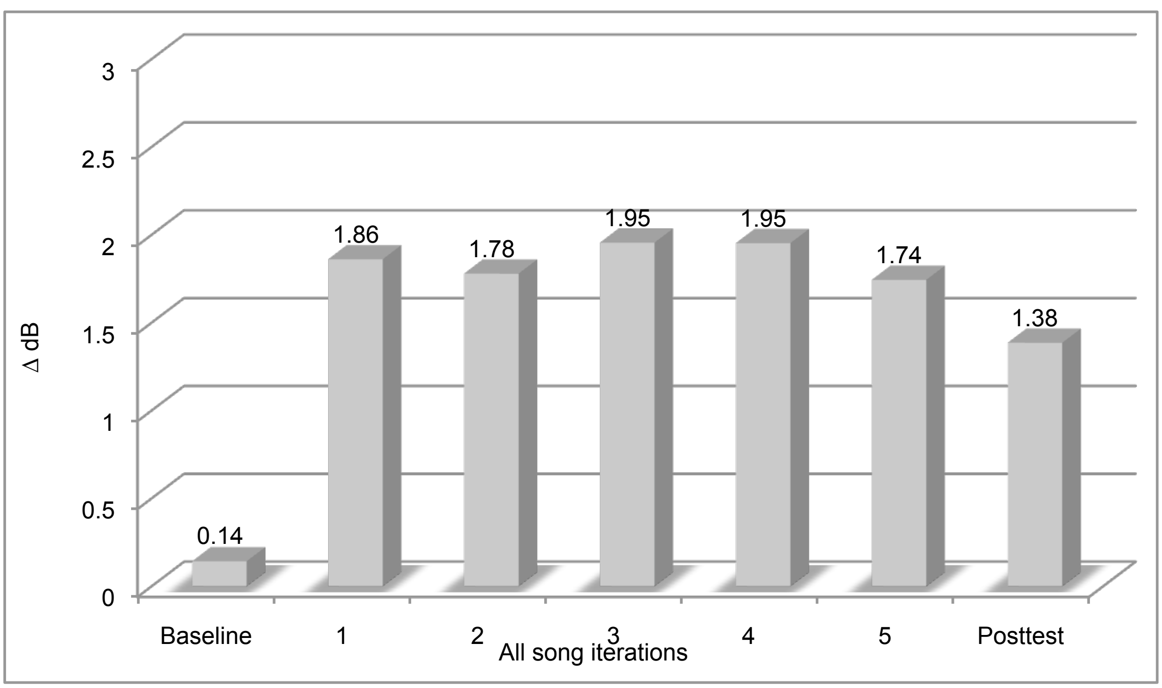

Figure 41. Δ dB from individual mean amplitudes for each iteration of “Singin’ in the Rain.”

Pointing gesture ("Singin' in the Rain"): Amplitude trends per each participant.

Table 13 shows amplitude trends per individual participant.

Table 13

Amplitude trends per individual participant between baseline, gestural iterations, and posttest conditions – Pointing gesture ("Singin' in the Rain").

Participant	Sex	Experience	Gestural M Compared to Baseline	Posttest Compared to Baseline
1	F	2		+
2	F	2	+	+
3	F	1		+
4	M	1		+
5	M	2		+
6	M	2	-	
7	M	1	-	-
8	F	2		+
9	F	1	+	+
10	F	1	+	
11	M	2	+	+
12	F	1	+	+
13	F	1	+	+
14	F	2		
15	M	1	+	+
16	F	2	+	
17	F	2	+	+
18	F	1		+
19	F	1	+	+
20	F	1	+	-
21	F	2	+	+
22	F	2	+	+
23	M	1	+	
24	M	1	+	
25	M	1	+	+
26	M	1	+	+
27	M	2	+	+
28	M	2	+	
29	M	2	+	+
30	F	2	+	
31	F	2	+	+
32	M	1	+	+
33	M	1	+	
34	M	1	+	+
35	M	2	+	+

Total + (louder)	26 *(74.28%)*	24 *(68.57%)*
Total – (softer)	2 *(5.71%)*	2 *(5.71%)*
Grand Total: Audible difference	**28** ***(80.00%)***	**26** ***(74.28%)***
Grand Total: Stasis/No audible difference	7 *(20.00%)*	9 *(25.71%)*

*Note: Experience (1 = less experience, 2 = more experience), Comparison of conditions (- = -*1 db or more*, + = +*1 dB or more*), blank cell = within 1 dB (no audible change)*

Twenty-eight participants (80.00%) evidenced increased amplitude when comparing their means of the gestural iterations to their baseline amplitudes. Two participants (5.71%) evidenced decreased amplitude in the gesture to baseline comparisons. Twenty-six participants (74.28%) showed increased amplitude in the posttest and gesture comparisons.

Overall, Table 13 data appeared to suggest that, while the amplitude tendencies of these solo singers varied idiosyncratically, a majority of participants displayed increased amplitude (+ 1 dB or more) over baseline in both the gestural and posttest conditions.

Disaggregation of amplitude data by sex and experience. Disaggregation of amplitude results by participant sex, and singing experience indicated no significant interactions attributable to these variables (sex: F [2, 51] = 1.139, p = .328, and experience: F [2,51] = .468, p = .629).

Summary of amplitude data results: Pointing gesture ("Singin' in the Rain"). According to measurements of delta dB, participants overall exhibited a clearly noticeable mean increase (+1.86 dB) in Δ dB while employing the pointing gesture (Table 14). The greatest deviation in Δ dB was seen during the 3^{rd} and 4^{th} gestural iterations with the least change from amplitude means during the baseline condition (Figure 41). Participants exhibited a mean Δ dB variance of +1.82 dB with the pointing gesture compared to baseline condition. A majority of singers (N = 2, 80.00%) evidenced increased amplitude in the gestural condition compared to baseline. A majority of singers (N = 26, 74.28%) evidenced increased amplitude in the posttest condition compared to baseline (Table 13).

Overall Summary: Acoustic Measures (Pointing gesture – "Singin' in the Rain"). Overall measures of Fo, amplitude (Δ dB), and formant behaviors indicate that while employing the pointing gesture during sung iterations of "Singin' in the Rain," participants, on the whole, tended to (a) move closer to (though not achieve) target frequency range (+7 cents of scored pitches examined), (b) sing with increased energy (+1 dB or more) while employing the gesture, and (c) change the timbre or color of their tone. Individual singers, however, varied in their intonation, amplitude, and formant behaviors, and thus with respect to these summarized group tendencies.

Arched hand gesture ("Hawaiian Rainbows"): Measures of Pitch. Figure 42 illustrates the data points used for pitch measures during each participant's performances of "Hawaiian Rainbows."

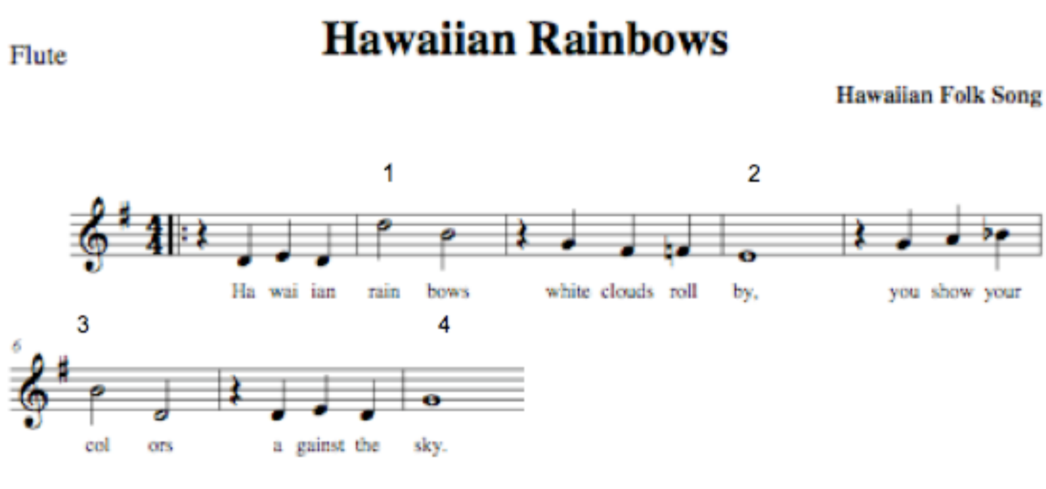

Figure 42. Data points used for intonation comparison for arched hand gesture.

Arched hand gesture ("Hawaiian Rainbows"): Overall Intonation Trends. Figure 43 illustrates participants' deviation in cents from target frequency for (a) baseline, (b) grand mean of the five gestural iterations, and (c) posttest during participants' performances of "Hawaiian Rainbows." Baseline (range: -50 – 68 cents; variation: 118 cents;) and posttest (range: -69 – 58 cents; variation: 127 cents) conditions showed greater deviation in cents from target frequency than the grand mean of the gestural conditions (range: -79 – 35; variation: 114 cents) sung with the arched hand gesture. That is, on the whole participants tended to sing more in tune during gestural iterations overall than they did without employing the arched hand gesture.

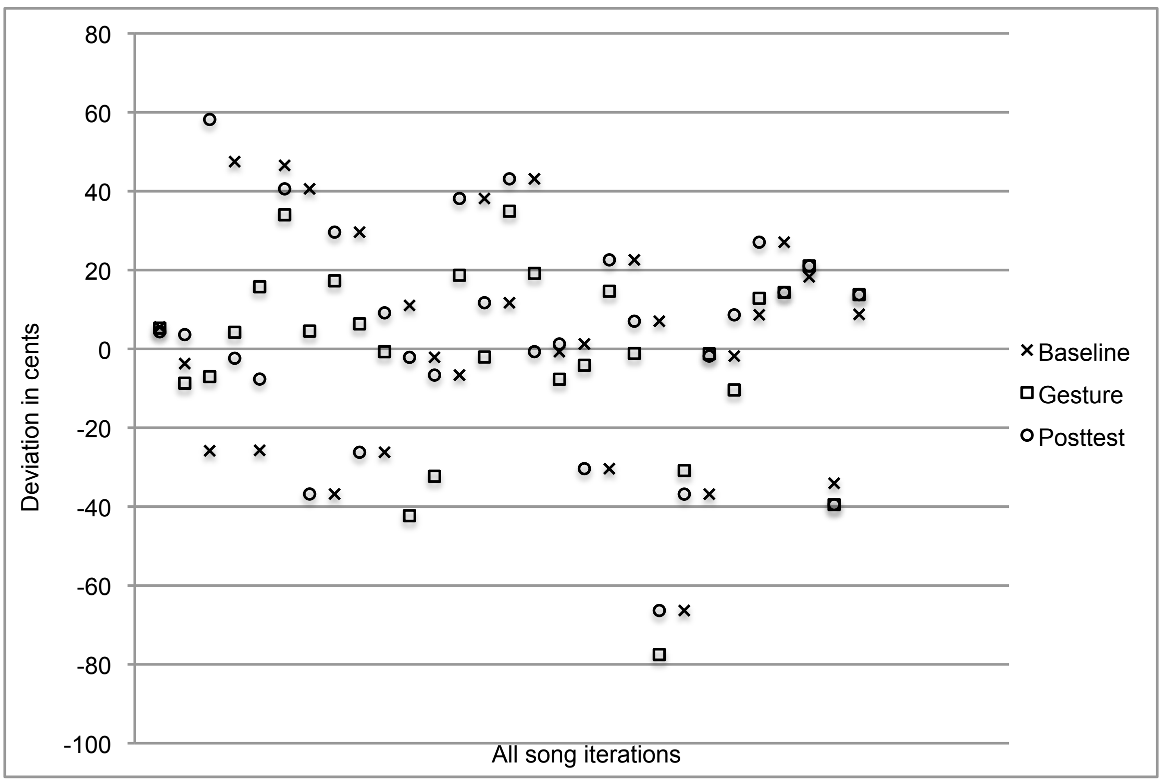

Figure 43. Deviation in Cents from target frequency in baseline, gesture, and posttest conditions – Arched hand gesture ("Hawaiian Rainbows") *Note*: *GM* = grand mean.

Figure 44 displays cents deviation means for each iteration ($N = 5$) of the arched hand gesture compared to the means of baseline and posttest (without gesture) conditions. Singers were furthest below the target frequency (*M* = -6.76 cents) during the baseline condition and closest to the target frequency during the first gestural iteration (*M* = -1.20 cents). While these mean deviations were within ± 7 cents, there was a difference of 5.56 cents between the means of the baseline and second gestural iteration conditions, and a difference of 10.08 cents between the means of the baseline and posttest conditions. From baseline through posttest conditions, singers tended to raise the pitch slightly.

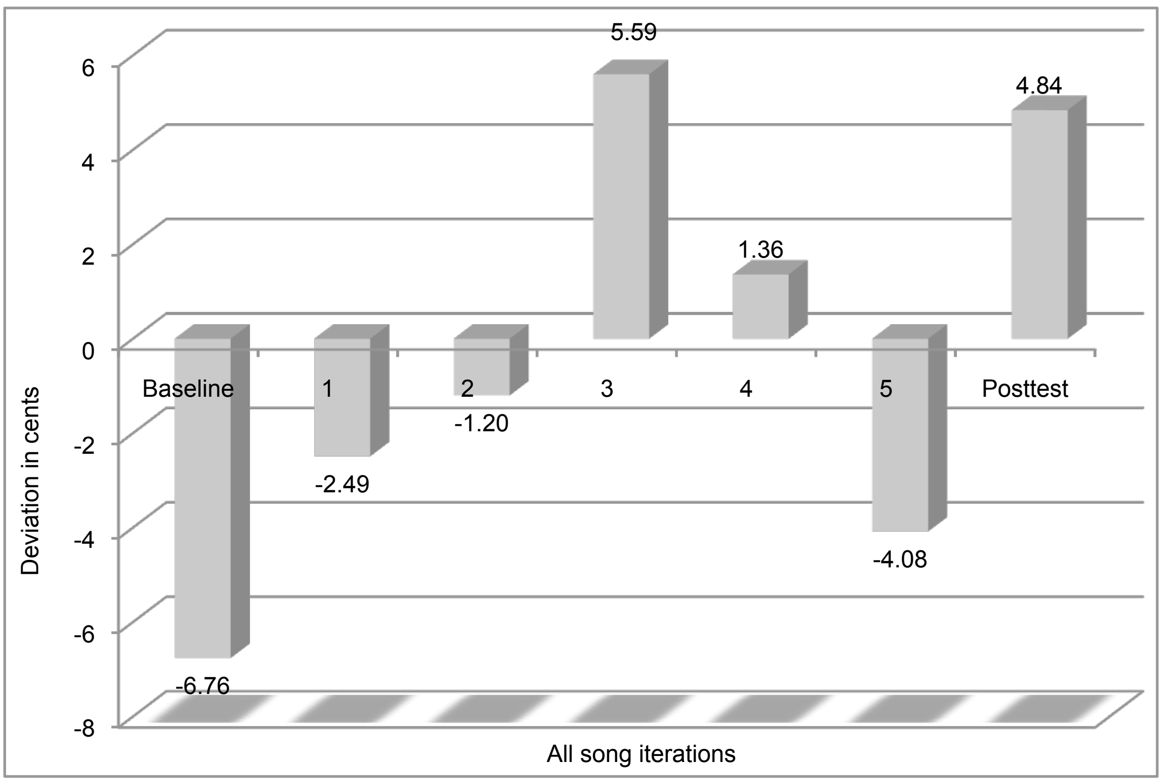

Figure 44. Fo deviation means for each iteration (*N* = 7) of the arched hand gesture compared to the means of baseline and posttest (without gesture) conditions.

Arched hand gesture ("Hawaiian Rainbows"): Gross Intonation Deviation.

A Repeated Measures ANOVA found no significant main effect for pitch between the baseline, gestural, and posttest conditions of "Hawaiian Rainbows," (F [2,51] = .096, *p* = .91).

Arched hand gesture ("Hawaiian Rainbows"): Pitch trends per each participant.

Table 14 shows pitch trends per individual participant.

Table 14

Deviation in cents from target frequency per participant between baseline, gestural iterations and posttest conditions – Arched hand gesture ("Hawaiian Rainbows").

Participant	Sex	Experience	Gesture compared to baseline	Posttest compared to baseline
1	F	2	@*	
2	F	2	@*	
3	F	1	*	*
4	M	1	*	*
5	M	2	*	
6	M	2		
7	M	1	*	
8	F	2	@*	
9	F	1	*	*
10	F	1	*	@*
11	M	2	@*	@*
12	F	1	@*	@*
13	F	1	*	@*
14	F	2	*	*
15	M	1	*	
16	F	2		
17	F	2	*	*
18	F	1	*	*
19	F	1		*
20	F	1	*	
21	F	2	*	*
22	F	2		
23	M	1	*	*
24	M	1		
25	M	1		
26	M	1	*	@*
27	M	2	*	@*
28	M	2	*	@*
29	M	2	*	*
30	F	2	*	
31	F	2		
32	M	1	*	*
33	M	1	*	*
34	M	1		*
35	M	2	*	
Total *			22	13

	(62.86%)	*(37.14%)*
Total @*	5 *(14.29%)*	7 *(20.00%)*
Grand Total: Improvement	**27** ***(77.14%)***	**20** ***(57.14%)***
Total @	0 *(0.00%)*	0 *(0.00%)*
Total blank	8 *(22.86%)*	15 *(42.86%)*
Grand Total: Stasis or No Improvement	**8** ***(22.86%)***	**15** ***(42.86%)***

Note: Experience (1 = less experience, 2 = more experience). Comparison of conditions (@ = within + 7 cents of target frequency at baseline and remained so; @ = achieved target frequency; * = came closer to target frequency, blank cell = moved further from target frequency)*

Compared to baseline, five participants' gestural iteration means were within ± 7 cents of target pitch. However, of the remaining 26 participants, 22 of them (66.86%) moved closer to target pitch while employing the arched hand gesture.

Overall, Table 14 data appeared to suggest that the pitch tendencies of these solo singers varied idiosyncratically. That is, while majorities of participants (77.14% in baseline-gestural comparison, 57.14% in baseline-posttest comparison) moved closer to target frequency not every singer responded in similar ways to employment of the arched hand gesture in "Hawaiian Rainbows" with respect to intonation. Eight participants (22.86%) evidenced stasis or no improvement in the gestural iterations compared to their baseline performances. Fifteen participants (42.86%) evidenced no improvement in the baseline-posttest comparison.

Summary: Deviations from target frequencies in "Hawaiian Rainbows." According to the measurements of pitch used for this investigation, employment of the arched hand gesture while singing "Hawaiian Rainbows" did bring this particular group of participants, on the whole, to within ±7 cents of the scored target frequencies. However, participants on the whole, regardless of sex or singing experience, trended toward more in tune singing both while employing the gesture and during the posttest condition (Figure 43). A primary contributor to this trend appeared to be that singers on the whole sang both sharper and flatter in the gestural iterations compared to baseline (Figure 44). This factor was particularly evident in the 4.56 cents difference between baseline and the first iteration sung with the arched hand gesture, rendering it the most in tune of the five gestural iterations. Moreover, while few singers achieved target range (±7 cents of scored pitch) in either baseline-gestural or baseline-posttest comparisons (Table 14), majorities of singers moved closer to target range in both comparisons.

Arched hand gesture ("Hawaiian Rainbows"): Mean Formant Frequencies. As indicated in Table 15, female participants, on the whole, exhibited lowered frequencies in all four examined formants in the gestural condition compared with baseline, but not in the posttest condition compared with the gestural iterations. When disaggregated according to individual participants, a majority of the eighteen female singers exhibited lowered frequencies in all four formants during both the gestural (n = 14, 87.50%) condition of "Hawaiian Rainbows."

Table 15

Overall Frequency Means and Standard Deviations in Hertz for the Arched Hand Gesture in "Hawaiian Rainbows" (N =35 Singers)

Female	Baseline *M* (*SD*)	5 Gestural Iterations *M* (*SD*)	Posttest *M* (*SD*)
Fo Deviation	348.36 (± 6.28)	350.37 (± 7.31)	351.16 (± 7.57)
F1	580.89 (± 15.03)	577.97 (± 11.33)	589.91 (± 13.48)
F2	1706.26 (± 47.21)	1700.26 (±117.30)	1731.83 (± 45.67)
F3	2725.73 (± 79.43)	2606.85 (±149.31)	2621.51 (± 77.88)
F4	3691.79 (±159.32)	3391.27 (±223.45)	3579.82 (±157.78)
Male			
Fo Deviation	245.19 (± 9.21)	251.25 (± 6.17)	249.36 (± 5.72)
F1	389.39 (± 14.01)	386.40 (±22.12)	378.43 (± 13.84)
F2	1807.34 (±119.90)	1719.21 (±54.31)	1922.93 (±119.81)
F3	2540.75 (±151.95)	2503.32 (± 86.52)	2559.94 (±151.82)
F4	3577.17 (±226.13)	3503.76 (±166.42)	3629.07 (±225.96)

Group means for male participants (*N* = 17), on the other hand, presented a mixed picture (Table 15). On the whole, these male singers, like the females, exhibited a lowering of formant frequencies in the gestural condition compared with baseline, but showed varied tendencies in the posttest condition compared with gestural iterations. While males on the whole exhibited lowered formant frequencies between baseline and gestural conditions, however, they exhibited higher F2, F3, and F4 frequencies in the posttest condition. When disaggregated according to individual participants, a majority of male participants exhibited lowered frequencies in all four examined formants during the gestural (*n* = 15, 80.00%).

Lowered formant frequencies may indicate the presence of articulation maneuvers (e.g., lips, tongue, velum) and larynx positioning that would lengthen the vocal tract, resulting in a slightly "darker" or perhaps, depending upon aesthetic and other preferences, a somewhat "richer" vocal timbre. Overall, the arched hand gesture appeared to be associated with changes in vocal timbre for over 80% of both female and male participants during their performances of "Hawaiian Rainbows."

Arched hand gesture ("Hawaiian Rainbows"): Measures of Relative Amplitude (Δ dB). Table 16 illustrates overall relative amplitude (Δ dB) means and standard deviations for the arched hand gesture in "Hawaiian Rainbows." Participants overall exhibited a just noticeable decrease (1.17 dB) in Δ dB while employing the arched hand gesture, likely attributable to a mean decrease of more than 1 dB among males and females during the gestural iteration conditions.

Table 16

Overall Relative Amplitude (Δ dB) Means and Standard Deviations for the Arched Hand Gesture in "Hawaiian Rainbows" (N =35 Singers)

	Baseline *M* (*SD*)	5 Gestural Iterations *M* (*SD*)	Posttest *M* (*SD*)
*Female*Δ dB	69.52 (±6.38)	68.34 (±5.27)	69.92 (±7.23)
Male Δ dB	69.54 (±7.53)	68.38 (±8.29)	69.29 (±6.92)
Total	69.53	68.36	69.61

Figure 45 illustrates Δ dB deviations from individual mean amplitude for (a) baseline, (b) grand mean of the five gestural iterations, and (c) posttest during participants' performances of "Hawaiian Rainbows." Participants, on the whole, appeared to sing with decreased energy (+1 dB or more) during the gestural iterations. Participants, moreover, evidenced less Δ dB deviation from individual mean amplitude during their sung iterations with the arched hand gesture.

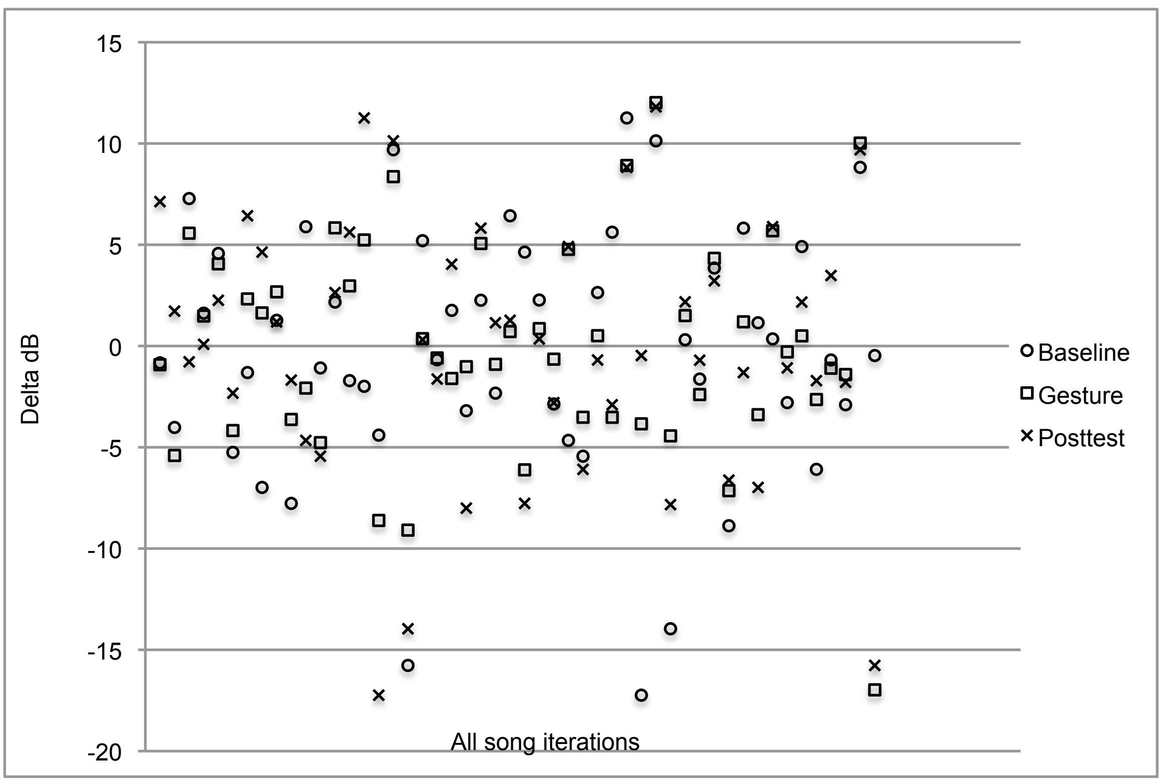

Figure 45. Δ dB deviation from individual mean amplitude in baseline, gesture, and posttest conditions – Arched hand gesture ("Hawaiian Rainbows") *Note: GM* = grand mean.

Range of baseline measures was -17.02 – 12.57 Δ dB (29.59 dB variance) from individual mean amplitude. Posttest measures indicated a range of -17.38 – 12.12 Δ dB (29.50 dB variance) from individual mean amplitude. Grand mean of gestural iteration measures fell within a range of -17.02 – 12.44 Δ dB (29.46 dB variance) from individual mean amplitude. That is, participants overall exhibited the most deviation from individual mean amplitudes in the baseline and posttest conditions.

Amplitude variance: gestural iterations. I also calculated variances in Δ dB from individual mean amplitudes for each iteration ($N = 7$) of the arched hand gesture compared to the means of baseline and posttest (without gesture) conditions (See Figure 46). The largest variance from individual mean amplitude occurred during the baseline measure ($M = 0.75$ Δ dB). A potentially audible (± 1 dB or more) difference was observed between baseline (.75 Δ dB) and all gestural iterations ($M = -.23$ Δ dB). Although, not an audible difference, there was a decrease in amplitude in the posttest ($M = -.45$ Δ dB) as compared to the baseline (.75 Δ dB).

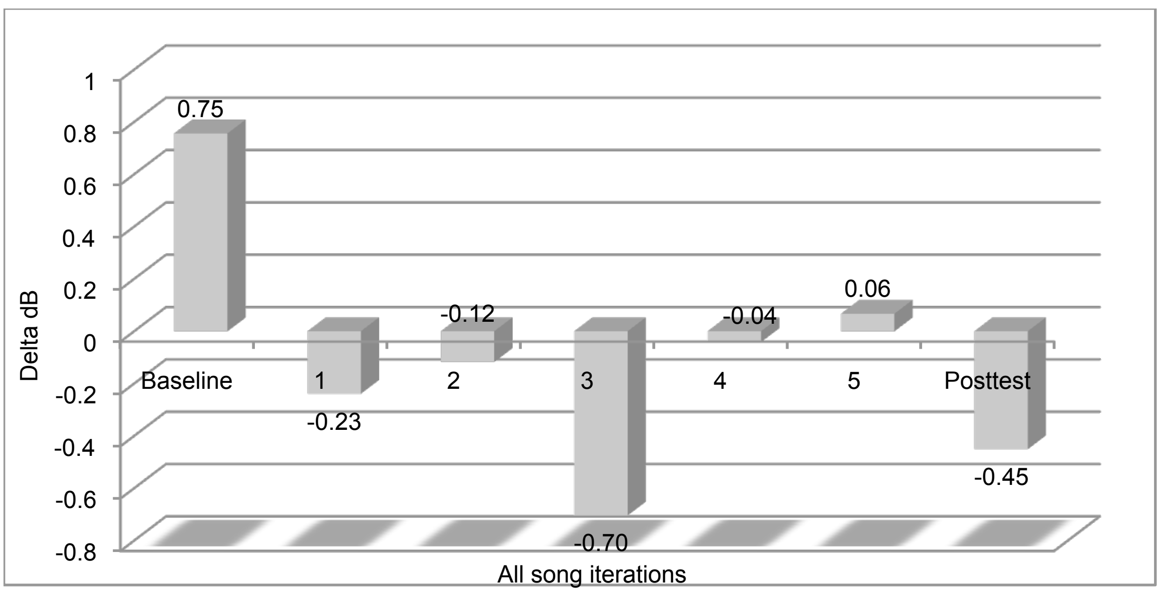

Figure 46. Δ dB from individual mean amplitudes for each iteration of “Hawaiian Rainbows.”

Arched hand gesture ("Hawaiian Rainbows"): Amplitude trends per each participant. Table 17 shows amplitude trends per individual participant.

Table 17

Amplitude trends per individual participant between baseline, gestural iterations and posttest conditions – Arched hand gesture ("Hawaiian Rainbows")

Participant	Sex	Experience	Gestural M Compared to Baseline	Posttest Compared to Baseline
1	F	2	+	-
2	F	2	+	+
3	F	1	-	-
4	M	1	-	-
5	M	2	-	-
6	M	2	-	-
7	M	1	+	+
8	F	2	-	-
9	F	1	+	
10	F	1		
11	M	2		-
12	F	1		-
13	F	1	-	-
14	F	2	+	+
15	M	1	+	+
16	F	2	+	+
17	F	2	-	-
18	F	1	-	-
19	F	1		
20	F	1	-	-
21	F	2	-	
22	F	2	+	+
23	M	1	-	-
24	M	1		
25	M	1	-	-
26	M	1	-	
27	M	2	+	-
28	M	2	+	
29	M	2		
30	F	2		
31	F	2	-	-
32	M	1		
33	M	1	-	+
34	M	1	-	
35	M	2	+	-
Total + (louder)			11	7

	(31.43%)	*(20.00%)*
Total – (softer)	16 *(45.71%)*	17 *(48.57%)*
Grand Total: Audible difference	**27** ***(77.14%)***	**24** ***(68.57%)***
Grand Total: Stasis/No audible difference	8 *(22.86%)*	11 *(31.43%)*

Note: Experience (1 = less experience, 2 = more experience), Comparison of conditions (- = -1 db or more*,* + = +1 dB or more)*, blank cell = within 1 dB (no audible change)*

Eleven participants (31.43%) evidenced increased amplitude when comparing their means of the gestural iterations to their baseline amplitudes. One participant (2.87%) evidenced decreased amplitude in the gesture to baseline comparisons, but increased amplitude in the posttest to baseline comparisons. Seven participants (20.00%) showed increased amplitude in the posttest and gesture comparisons.

Overall, Table 17 data appeared to suggest that, while the amplitude tendencies of these solo singers varied idiosyncratically, a majority of participants displayed decreased amplitude (+ 1 dB or more) over baseline in both the gestural and posttest conditions.

Disaggregation of amplitude data by sex and experience. Disaggregation of amplitude results by participant sex, and singing experience indicated no significant interactions attributable to these variables (sex: F [2,51] = .311, p = .743, and experience: F [2,51] = .304, p = .739).

Summary of amplitude data results: Arched hand gesture ("Hawaiian Rainbows"). According to measurements of delta dB, participants overall exhibited a just noticeable mean decrease (-1.17 dB) in Δ dB while employing the arched hand gesture (Table 17). Assessments of deviations from individual mean amplitudes showed more variance during baseline and posttest conditions, and less variance during gestural iterations (Figure 46). A majority of singers

($N = 16$, 45.71%) evidenced decreased amplitude in the gestural condition compared to baseline. A majority of singers ($N = 24$, 68.57%) evidenced increased amplitude in the posttest condition compared to baseline (Table 13).

Overall Summary: Acoustic Measures (Arched hand gesture – "Hawaiian Rainbows"). Overall measures of Fo, amplitude (Δ dB), and formant behaviors indicate that while employing the arched hand gesture during sung iterations of "Hawaiian Rainbows," participants, on the whole, tended to (a) move closer to (though not achieve) target frequency range (+7 cents of scored pitches examined), (b) sing with decreased energy (+1 dB or more) while employing the gesture, and (c) change the timbre or color of their tone, largely through a tendency toward lowered formant frequencies. Individual singers, however, varied in their intonation, amplitude, and formant behaviors, and thus with respect to these summarized group tendencies.

Gesture Intonation Comparisons: Negotiation of an ascending octave interval. Each of the three melodies sung for this investigation included a scored ascending octave leap on the same pitches (from D4 to D5 female voices; from D3 to D4 male voices). Because (a) participants sang the same vowel (/i/) throughout each melody and (b) this octave interval occurred at or very near the beginning of each melody, there is opportunity, as a matter of interest and within the limitations of the protocol followed in this investigation, to compare the three gestures (low, circular arm; pointing; arched hand) in terms of their respective potential effects on intonation as participants negotiated a particular singing task: execution of an ascending octave leap.

Table 18 presents, as a matter of broad context, the grand frequency means and standard deviations in Hertz while performing the ascending octave task. Scored target pitches for the higher pitch of this octave were 587 Hz (females) and 294 Hz (males).

Table 18

Overall Frequency Means and Standard Deviations in Hertz for the Ascending Octave Leap across all Gestures (N =35 Singers)

Female	Low, circular arm gesture *GM* (*SD*)	Pointing gesture *GM* (*SD*)	Arched hand gesture *GM* (*SD*)
Baseline	581.33 (± 9.45)	585.93 (± 7.48)	584.58 (± 8.93)
Gesture GM	580.38 (± 6.62)	584.58 (± 10.83)	583.14 (± 9.98)
Posttest	586.31 (± 22.01)	583.49 (± 20.41)	585.47 (± 15.11)

Male	Low, circular arm gesture *GM* (*SD*)	Pointing gesture *GM* (*SD*)	Arched hand gesture *GM* (*SD*)
Baseline	287.51 (± 9.46)	292.41 (± 9.32)	290.12 (± 10.27)
Gesture GM	286.36 (± 5.68)	291.16 (± 5.99)	289.58 (± 11.93)
Posttest	292.37 (± 15.98)	289.49 (± 22.36)	291.63 (± 14.27)

Participants, on the whole, sang below the scored frequency across all conditions. Among females, baseline to posttest comparisons indicated some posttest movement toward target frequency with the low, circular arm gesture (+14 cents) and the arched hand gesture (+ 2 cents). By contrast, posttest means with the pointing gesture indicated movement away from target frequency (- 19 cents). Among males, baseline to posttest comparisons indicated similar trends, with movement toward target frequency with the low, circular arm gesture (+ 29 cents) and with the arched hand gesture (+ 9 cents), but movement away from target frequency (- 17 cents) with the pointing gesture.

Group Tendencies (in cents) per gesture in negotiation of the octave. Figure 47 illustrates group deviation means in cents from target pitch per condition and iteration in the ascending octave task.

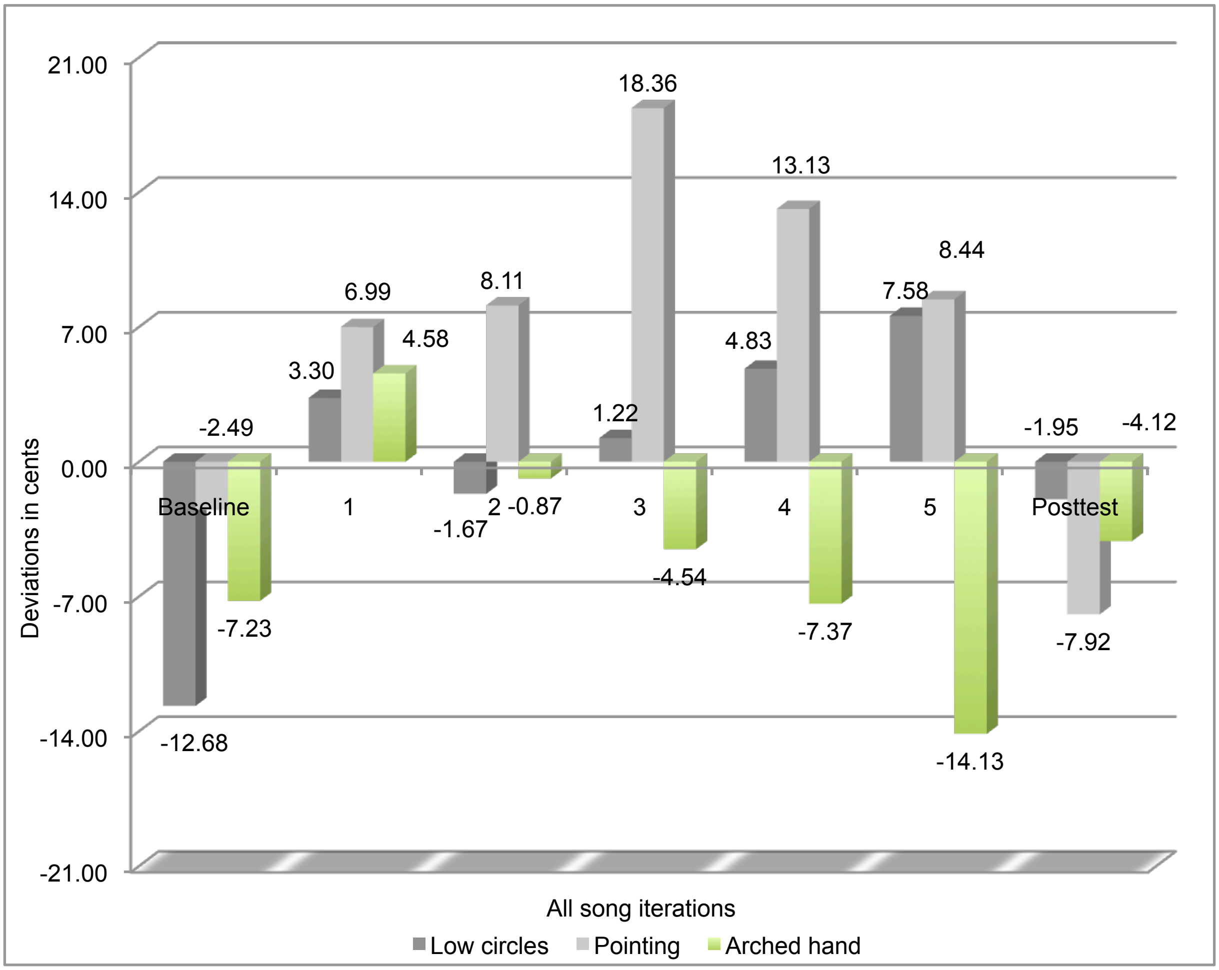

Figure 47. Singing an ascending octave: Group mean deviations in cents from target frequency across three gestural conditions.

As shown in Figure 47, the first iteration of each of the gestures appeared to move singers, on the whole, from slightly flat baseline intonation to slightly more sharp singing. From baseline to first gestural iteration of the octave, means of sung excerpts with the low, circular arm gesture displayed a variance of 15.98 cents. Excerpts sung with first use of the pointing gesture evidenced a variance of 9.48 cents from baseline, while excerpts performed with the arched hand gesture showed a variation of 11.81 cents between the baseline and first gesture conditions. Each of these mean variations exceeded ± 7 cents, suggesting that they could be perceptible variances.

The pointing gesture occasioned at the octave consistently more sharp mean singing (7 cents or more from target frequency) during its five iterations than either the low, circular arm or arched hand gestures. This trend was particularly robust during the second, third, and fourth gestural iterations, where the mean deviations of excerpts utilizing the pointing gesture consistently exceeded tendencies of the other gestures by more than 7 cents. By contrast, use of the arched hand gesture, with the exception of its first iteration, tended to decrease mean deviation slightly, until, by the fourth and fifth iterations, the arched hand gesture conditions displayed a perceptible (-7 cents or more) flatting.

Mean group deviations for all but one of the conditions that employed the low, circular arm gesture remained consistently within plus/minus cents of target frequency. The single exception occurred in the fifth iteration of this gesture, where mean deviation from target pitch was 7.58 cents. Moreover, the posttest group mean deviation following iterations of the circular arm gesture was also within ± 7 cents, and closer (-1.95 cents) to target pitch than the posttest deviation means of the other gestures.

Considered solely from the perspective of overall group tendencies, then, the low, circular arm gesture appeared to be more beneficial for intonation during an ascending octave leap than the pointing or arched hand gestures.

Gross Deviation Assessment. A Repeated Measures ANOVA, using positive numbers, found no significant main effect (F [2,51] = 1.87, p = .16) between baseline, gestural iteration, and posttest intonation measures of the octave leap across the three gestures.

Per Participant Gesture and Intonation Comparisons. Table 19 disaggregates individual participant *Fo* behaviors on the octave task according to sex, condition, type of gesture used, and intonation tendencies in cents.

Table 19

Deviation in cents from target frequency per participant and gesture type between baseline, gestural iterations and posttest conditions of a sung, ascending octave

		Low, circular arm gesture		**Pointing gesture**		**Arched hand gesture**	
Participant	Sex	Gesture compared to baseline	Posttest compared to baseline	Gesture compared to baseline	Posttest compared to baseline	Gesture compared to baseline	Posttest compared to baseline
1	F	*	*	*	*	*	
2	F	*		*	*		
3	F	*	*	*	*	*	
4	M	*		*	*	*	*
5	M	*		*		*	*
6	M	*	*	*			
7	M	*		*	*	*	
8	F	*	*				
9	F	*	*	*		*	
10	F	*	*	*	*	*	
11	M				*	*	*
12	F	*		*			
13	F			*		*	*
14	F	*					*
15	M	*	*	*		@*	
16	F	*			*		
17	F	*	*	*	*		
18	F			*		*	*
19	F	*	*	*			
20	F	*	*			*	
21	F	*		*	*	*	*
22	F					*	
23	M			*	*		
24	M					*	*
25	M	*	*		*	*	*
26	M		*			*	*
27	M	*	*	*	*		
28	M	@*		*		*	*
29	M	@					
30	F	*	*	*	*		

31	F	*				*	*
32	M	*	*	*	*	*	
33	M	*	*				*
34	M	*	*		*		
35	M	@*		*		*	
Total *		25 (*71.43%*)	17 (*48.57%*)	22 (*62.86%*)	16 (*34.28%*)	20 (*57.14%*)	13 (*37.14%*)
Total @*		2 (*5.71%*)	0 (*0.00%*)	0 (*0.00%*)	0 (*0.00%*)	1 (*2.86%*)	0 (*0.00%*)
Grand Total: Improvement		**27 (*77.14%*)**	**17 (48.57%)**	**22 (*62.86%*)**	**16 (*34.28%*)**	**21 (60.00%)**	**13 (*37.14%*)**
Total @		1 (*2.86%*)	0 (*0.00%*)	0 (*0.00%*)	0 (*0.00%*)	0 (*0.00%*)	0 (*0.00%*)
Total blank		7 (*20.00%*)	18 (*51.43%*)	13 (*37.14%*)	19 (*52.29%*)	14 (*40.00%*)	22 (*62.86%*)
Grand Total: Stasis or No Improvement		**8 (*22.86%*)**	**18 (*51.43%*)**	**13 (*37.14%*)**	**19 (*52.29%*)**	**14 (*40.00%*)**	**22 (*62.86%*)**

Note: Experience (1 = less experience, 2 = more experience). Comparison of conditions (@ = within + 7 cents of target frequency at baseline and remained so; @ = achieved target frequency; * = came closer to target frequency, blank cell = moved further from target frequency)*

When compared to their individual baselines, mean gestural iteration data acquired from these participants indicated that employment of each of the three gestures appeared to have some salutary effect on the octave intonation of the majority of them (77% of participants with use of the low, circular arm gesture; 63% with use of the pointing gesture; 60% with use of arched hand). The low, circular arm gesture appeared to move more singers toward target while it was being used during the ascending octave task, while the arched hand gesture appeared to assist comparatively fewer singers toward target.

However, in posttest-baseline comparisons with those singers who demonstrated improvement during the gestural conditions, there was little difference between the low, circular arm gesture and the pointing gesture. Of the 27 singers evidencing improvement with use of the low, circular arm gesture, 17 (62.96%) of them demonstrated improvement in the posttest-baseline comparison. Among the 22 singers who evidenced improvement with use of the pointing gesture, 16 of them (72.72%) showed improvement in their posttest-baseline comparisons.

According to Table 19 data, moreover, intonation behaviors varied by individual participants. That is, none of the gestures appeared to offer a "one size fits all" pedagogical treatment strategy for tuning the ascending octave leap. Some participants moved closer to target with the low, circular arm gesture, while others moved closer to target with the pointing or arched hand gestures. Participant 23, for example, evidenced improvement only with the pointing gesture. Participant 17 showed progress when using both the low, circular arm and pointing gestures, but no progress toward target with use of the arched hand gesture. By contrast, participant 22 evidenced improvement only with the arched hand gesture.

Table 19 data also make it apparent that the octave-task intonation tendencies of sizeable minorities of these solo singers did not improve while they used particular gestures. In gestural-baseline comparisons, for example, approximately 20% - 40% of singers evidenced no improvement when employing one or more of the gestures.

Summary: Intonation tendencies in performing the ascending octave interval. Both macro (group means) and micro (per participant) analyses suggested that use of each of the three gestures appeared to contribute somewhat to improved intonation of the ascending octave interval during the gestural conditions. Viewed from a macro perspective, the low, circular arm gesture appeared to offer assistance in moving toward target pitch for more singers than the arched hand and pointing gestures. However, micro results indicated that particular solo singers in a private voice-teaching context where a protocol similar to the one employed for this investigation might be used, could respond differently, and perhaps not at all, to use of a particular gesture in an ascending octave singing task. Although there were two or three exceptions among these participants, none of the gestures used for this investigation universally assisted singers to fully achieve target pitch in this ascending octave task during gestural iterations. At the same time, particular gestures appeared to assist particular singers in making progress toward target pitch.

Research Question Two: Perceptual Evaluations

The second research question for Experiment 2 inquired whether, according to expert listener (N =9) evaluations and singer (N = 35) survey responses, there were perceptual differences in solo sound (a) between baseline (without gesture) performance and each of five successive, intervening performances employing a particular gesture, and (b) between baseline (without gesture) and final performance (without gesture) conditions.

Expert Panel Evaluations. Expert listeners (N = 9) in a quiet room heard a stratified random sample of digital recordings of the last two measures of each song ("Over the Rainbow" – Low, circular arm gesture; "Singin' in the Rain" – Pointing gesture; "Hawaiian Rainbows" – Arched hand gesture) as played on a (Sony CDP-497 cd player) connected to a Pre-Sonus distribution amplifier through individual AKG (K240 Monitor, Austria) headphones. Playback volume remained consistent.

Because it was impractical for judges to listen to all 7 iterations of each song from each of 35 solo singers (735 excerpts), I used a random numbers table to choose 10 singers, 5 of whom were less experienced singers (two or fewer years of singing experience), and 5 who were more experienced singers (five or more years of singing experience). Experts listened to the baseline and posttest condition recordings as well as the middle, or third, gestural iteration condition in each song. Those procedures yielded a core of 90 excerpts for listening.

In order to assist reliability and to control for listener fatigue, a scaffolded approach was employed, such that each expert listener heard a total of 30 excerpts and no two judges heard the same 30 samples. Each judge spent a total of 20 minutes on the listening task. Figure 49 illustrates the approach utilized for the organization of excerpts heard by each expert.

Stimulus	Sound Files	Exp 1	Exp 2	Exp 3	Exp 4	Exp 5	Exp 6	Exp 7	Exp 8	Exp 9
A	1 – 10	x							x	x
B	11 – 20	x	x							x
C	21 – 30	x	x	x						
D	31 – 40		x	x	x					
E	41 – 50			x	x	x				
F	51 – 60				x	x	x			
G	61 – 70					x	x	x		
H	71 – 80						x	x	x	
I	81 - 90							x	x	x

Figure 49. Solo context expert listening panel plan.

As they listened, the judges evaluated each randomly ordered song excerpt by turning a Continuous Response Digital Interface (CRDI) dial to indicate “Less Pleasing” sound (0 – 122 on the dial) or “More Pleasing” sound (123-255 on the dial). For the gestural condition excerpts, I recorded expert ratings at data points corresponding to instances when participants utilized a particular gesture. These data were entered on an Excel spreadsheet for subsequent analysis.

Mean judges’ ratings were compared for each take of each song selection (Table 20). Results of a Cronbach’s Alpha procedure indicated good reliability, $\alpha = .86$.

Tables 20 - 22 show mean ratings across all experts for each song and condition. Experts rated lowest the sung baseline performances in each song. Only in "Hawaiian Rainbows" did the judges' mean rating of the baseline condition performances fall into the "More Pleasing" range on the CRDI dial.

Table 20

Mean expert CRDI ratings of extracted data points during phrases of "Over the Rainbow" with and without the low, circular arm gesture

	Baseline	Gesture	Posttest
	97.33	157.67	128.25
	84.92	113.08	143.50
	109.33	135.58	154.42
	109.33	138.50	131.00
	133.42	127.83	130.67
	127.67	136.83	149.17
	140.58	146.67	112.42
	122.08	76.33	149.08
	97.83	152.42	131.00
	99.17	117.00	134.50
GMean	*112.17*	*130.19*	*136.40*

A Repeated Measures ANOVA found a significant main effect (F [2, 8] = 4.732, $p < .05$) for expert ratings of "Over the Rainbow." Follow-up paired t-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance ($p = .05/3 = .017$). *T*-test results indicated significant differences ($p < .017$) between baseline and posttest mean measures with no significant differences between baseline and gesture measures or posttest and gesture measures.

Table 21

Mean expert CRDI ratings of extracted data points during phrases of "Singin' in the Rain" with and without pointing gesture

	Baseline	Gesture	Posttest
	104.25	109.92	110.72
	125.67	142.42	146.92
	99.58	106.08	135.92
	120.50	155.83	146.75
	133.58	138.17	125.50
	119.08	105.17	139.50
	116.75	137.92	149.75
	122.58	176.67	149.33
	117.25	139.00	110.33
	87.33	134.50	124.75
GMean	*114.66*	*134.57*	*133.95*

A Repeated Measures ANOVA found a significant main effect (F [2, 8] = 7.354, $p < .05$) for expert ratings of "Singin' in the Rain." Follow-up paired *t*-tests (two-tailed) measured specific differences in the model with a Bonferroni adjustment of alpha levels to provide conservative tests of significance (p = .05/3 = .017). *T*-test results indicated significant differences (p < .001) between baseline and gestural iterations as well as baseline and posttest mean measures, with no significant differences between gestural and posttest measures (p = .15).

Table 22

Mean expert CRDI ratings of extracted data points during phrases of "Hawaiian Rainbows" with and without the arched hand gesture

	Baseline	Gesture	Posttest
	128.75	119.83	109.25
	163.42	123.25	149.00
	130.83	136.50	132.75
	126.33	139.25	166.67
	84.83	108.67	96.25
	96.92	149.83	157.08
	108.67	121.50	154.83
	108.83	145.42	125.00
	103.00	150.00	134.58
	126.92	146.33	144.42
GMean	*117.85*	*134.06*	*136.98*

A Repeated Measures ANOVA found no significant main effect for expert ratings of phrases from "Hawaiian Rainbows," (F [2, 8] = 21.85, p = .85).

The CRDI allowed judges simultaneously to listen to and rate each sung excerpt. Immediately thereafter, judges indicated on the Expert Listener Survey (Appendix G) factors (intonation, tone color, vibrato, other, and volume) may have contributed most to their rating of a particular sung excerpt. These terms were a list and each judge checked all factors that applied.

Table 23

Judges' Rating Ranges and Comments Checked

Judge	Range of ratings	Comment checked
1	60 – 200	intonation
2	0 – 211	breath
3	51 – 171	intonation
4	51 – 222	intonation
5	31 – 206	breath
6	49 – 167	tone color
7	40 – 231	breath
8	64 – 206	intonation
9	61 – 217	intonation

Summary. Experts expressed significant preference for the sound of "Singin' in the Rain" (pointing gesture) in gestural as compared to baseline condition, and in posttest as compared to baseline condition. Judges most often endorsed the terms " intonation" and " breath" to describe primary factors contributing to their evaluations. That these listeners did not perceive the vocal sound of the gestural conditions to be significantly more pleasing than the sound of the posttest conditions heard may suggest at least a temporary persistence of effects of the pointing gesture after withdrawal of the gesture.

Expert listeners significantly heard as more pleasing the posttest conditions of “Over the Rainbow” (low, circular arm gesture). Although a majority of judges rated the sound of the gestural conditions of “Hawaiian Rainbows” (arched hand gesture) as more pleasing, there were no statistically significant mean preferences for any of the sung conditions over other conditions in this song.

In several ways, the results of expert listener ratings mirrored tendencies and trends suggested by the acoustical data. For instance, the baseline condition of each of the song selections was furthest from target frequency. These were the same selections given the lowest expert ratings. Experts most often cited intonation as the factor they most often rated excerpts on. The differences found in deviation in cents from target frequency relates to these expert judgments.

Participant Perceptions. Upon completion of the recording session, solo singers (N = 35) responded to an exit questionnaire (Appendix F) that solicited overall thoughts and perceptions of singing with gestures in a solo singing context. Participants were asked to, “Please give your overall thoughts and perceptions of singing with gesture.” I employed quantitative content analysis procedures (Krippendorf, 2004) to analyze these comments.

Participants wrote a total of 61 discrete comments. After reading them, I first sorted the comments according the mutually exclusive and exhaustive categories of “positive” and “negative,” a process that yielded 58 (95.08%) positive comments and 3 (4.92%) comments.

Thereafter, I sorted the 58 positive comments into the exhaustive and mutually exclusive categories of "general comments" and "specific comments." There were 13 (22.41%) general and 45 (77.59%) specific positive comments. Among the general comments: "I think they work well," "I really think they helped," and "overall, I think they are effective."

I further sorted the specific positive comments (*N* = 45) into these exhaustive and mutually exclusive categories: (a) focus of attention, (b) ease of phonation, (c) intonation, (d) timbre, and (e) breath control. Most (*n* = 13, 28.89%) of the specific positive comments addressed breath control. Included in this category were comments such as "I feel and hear the most difference in myself when using gestures on long notes and in fluid passages to sustain and connect," "I felt the gestures helped me to sing the extended notes as well as carry through phrases better," "I thought all of them were helpful for air support on the high parts," "I think it keeps the breath energy flowing very well," and "I felt like some of the gestures helped with continuity of sound production and breath support."

The next most frequent comments addressed intonation (*n* = 10, 22.22%) and timbre (*n* = 10, 22.22%). Comments about intonation included, "the pointing gesture helped me to hit the leaps," "pointing and arched hand helped to reach an appropriate pitch," "the gestures helped with maintaining pitch from going flat," "helped with maintaining a sustained pitch correctly without flatting," and "I feel more in tune with the way I sing when gestures are present in comparison to when they are not." Comments that addressed timbre included such statements as "the pointing gesture made me feel more controlled and pinpointed in my sound production," and "the low arm circles made me feel like I had a 'richer' sound."

Among comments (*n* = 9, 20.00%) about focus of attention were "I focused more on the air I was using instead of being nervous about the sound I was producing" and "the gestures helped focus so your whole body can function as the instrument, not just your throat." Comments (*n* = 6, 13.33%) about ease of phonation included: "the gestures helped me sing freer," "made me feel like my vocal production was lighter and easier," "gesture helps relax areas of tension that get in the way of singing" and "my sounds become more smooth and not so forceful."

Participant comments referenced "breath control" over twice as much as "ease of phonation." However, chi square analysis revealed no significance in the overall distribution of the 45 positive comments into the five categories, $x^2 = 1.34$, $df = 4$, $p = 0.86$.

The three negative comments (4.92% of all comments) voiced by participants were "Pointing and arched hand helped to teach an appropriate pitch, but low circle did not," "I'm not sure they helped me very much," and "The gestures distracted me."

Research Question Three: Video Analyses of Participants' Gestural Mastery

The third research question for Experiment 2 asked how long it might take, according to video analyses of participant behaviors, for singers to master each of the three gestures in a studio voice or other solo singing pedagogy context.

Solo context video analysis. To answer this question, I first analyzed each singer video recording using a researcher-created rubric (Table 24). A research assistant then repeated the video analysis task and rating reliability was found to be .91 (Agreements/

Agreements + Disagreements). Singers were judged to have mastered the gesture when they successfully exhibited eight of the ten behaviors for each gesture on the rubric.

Tables 24 - 26 display the results of this process according to the gesture learned.

Table 24

Participants' (N = 35) Mastery of the Low, Circular Arm Gesture ("Over the Rainbow") According to Checklist Rubrics By Iteration

Specific Behavior: Iteration When Behavior Demonstrated:

	1	2	3
Both hands are used	34 (97%)	1 (3%)	
Fingers together	33 (94%)	1 (3%)	1 (3%)
Palms towards the midline of the body	34 (97%)	1 (3%)	
Arms, with elbows slightly bent	34 (97%)	1 (3%)	
Arms follow the upward and outward circular motion of the hands	34 (97%)	1 (3%)	
Hands move in circles in front of torso	34 (97%)	1 (3%)	
Hands are no lower than the hips and no higher than the sternum	32 (91%)	2 (5.7%)	1 (3%)
The circles are done fairly quickly, not necessarily in the tempo of the song.	34 (97%)	1 (3%)	

Table 25

Participants' (N = 35) Mastery of the Pointing Gesture ("Singin' in the Rain") According to Checklist Rubrics By Iteration

Specific Behavior: Iteration When Behavior Demonstrated:

	1	2	3
The index finger of your right hand points upward and outward	32 (91%)	3 (8.6%)	
Finger moving at a 45 degree angle from the torso	32, (91%)	3 (8.6%)	
Finger starting at height of sternum	32 (91%)	2 (5.7%)	1 (3%)
Finger/hand arches outward in front of the forehead	32 (91%)	3 (8.6%)	
Index finger leads, the arm follows.	32 (91%)	3 (8.6%)	
The arm begins with elbow slightly bent	32 (91%)	1 (3%)	2 (5.7%)
Arm extends from the shoulder	32 (91%)	3 (8.6%)	
Arm straightens as the point moves outward and upward	32 (91%)	3 (8.6%)	

Table 26

Participants' (N = 35) Mastery of the Arched Hand Gesture ("Hawaiian Rainbow") According to Checklist Rubrics By Iteration

Specific Behavior: Iteration When Behavior Demonstrated:

	1	2	3
Fingers arched (as if holding a tennis ball)	32 (91%)	3 (8.6%)	
Palm facing downward	35 (100%)		
The hand moves vertically upward	33 (94%)	2 (5.7%)	
Hand moves in front of the torso	33 (94%)	2 (5.7%)	

Hand moves from the level of the hip	33 (94%)	1 (3%)	1 (3%)
Hand moves up to level of eyebrows	32, (91%)	3 (8.6%)	
As the hand moves upward, the arm starts with elbow slightly bent	35 (100%)		
Arm follows with elbow slightly bent throughout the gesture	33 (94%)	2, (5.7%)	

As indicated by Tables 24-26, most singers (90% +) achieved gestural mastery during the first iteration, regardless of gesture or song. Fewer participants required subsequent iterations of particular gestural behaviors with the low, circular arm gesture, while more participants required subsequent iterations to master behaviors associated with the pointing gesture. No participant, however, took longer than the third iteration to master any of the gestures employed.

Experiment 2 Summary. Overall measures of *Fo*, amplitude (Δ dB), and formant behaviors indicate that the gestures employed in this investigation had an effect, although not universally, on the sound produced by the majority of singers in this study. While employing the low, circular arm gesture during sung iterations of "Over the Rainbow," participants, on the whole, tended to (a) move closer to target frequency range (b) sing with increased energy while employing the gesture, and (c) change the timbre or color of their tone, largely through a tendency toward lowered formant frequencies. The same measures indicate that while employing the pointing gesture during sung iterations of "Singin' in the Rain," participants, on the whole, tended to (a) move closer to target frequency range, (b) sing with increased energy while employing the gesture, and (c) change the timbre or color of their tone. For "Hawaiian Rainbows," acoustic findings indicate that while employing the arched hand gesture during sung iterations participants, on the whole, tended to (a) move closer to target frequency range, (b) sing with decreased energy while employing the gesture, and (c) change the timbre or color of their tone, largely through a tendency toward lowered formant frequencies. Across all song selections, individual singers, however, varied in their intonation, amplitude, and formant behaviors, and thus with respect to these summarized group tendencies.

The octave leap across gestures was also examined. The low, circular arm gesture appeared to offer assistance in moving toward target pitch for more singers than the arched hand and pointing gestures. However, results also indicated that particular solo singers could respond differently, and perhaps not at all, to use of a particular gesture in an ascending octave singing task. None of the gestures used for this investigation universally assisted singers to fully achieve target pitch in this ascending octave task during gestural iterations, however, particular gestures appeared to assist particular singers in making progress toward target pitch.

In several ways, the results of expert listener ratings and participant perceptions mirrored tendencies and trends suggested by the acoustical data. For instance, the baseline condition of each of the song selections was furthest from target frequency. These were the same selections given the lowest expert ratings. Experts most often cited intonation as the factor they most often rated excerpts on. The differences found in deviation in cents from target frequency relates to these expert judgments. Participants commented most frequently on intonation and timbre and achieved gestural mastery during the first iteration, regardless of gesture or song. Fewer participants required subsequent iterations of particular gestural behaviors with the low, circular arm gesture, while more participants required subsequent iterations to master behaviors associated with the pointing gesture.

CHAPTER SIX

Discussion

This investigation documents from multiple perspectives (acoustical, perceptual, and contextual) participant behaviors prior to, during, and after singing melodies with an array of singer gestures (low, circular arm; pointing; arched hand). Some choral (e.g., Eichenberger, 1994; Jordan, 1996) and some solo (Bailey, 2007; Thurman & Welch, 2000) voice teachers report anecdotally that particular singer gestures seem to make positive contributions in assisting overall vocal sound. Primary findings from this study suggest that such might be the case in particular circumstances. At the same time, however, results also indicate that the picture appears to be far more complex than the pedagogical literature tends to assume, and that these contributions may be relatively small in degree.

Singing is an intricate and multi-faceted human behavior entailing simultaneous coordination between and among a variety of physiological, cognitive, and acoustic components (Thurman & Welch, 2000). The teaching of singing, whether in choral or private studio contexts, is likewise a complicated undertaking. Voice teachers, whether in choral or studio contexts, must hear accurately, assess quickly, and make suggestions for improvement based on a holistic understanding of what may be happening with particular voices at particular points in time (Cooksey, 1992; Henderson, 1979).

Such considerations help to place in broad context the specific findings of this particular investigation. Because (a) this study appears to be the first to research on multiple levels the potential effects of a variety of singer gestures on vocal sound and (b) a scientific orientation to research is necessarily reductionist, involving the isolation of particular variables in order to assess them, some individual findings may appear unremarkable. A ± 7 cents variation in pitch, a ± 1 delta dB variance in relative amplitude, a slight lowering or raising of formant frequencies, or LTAS indications of decreased or increased signal amplitude in particular frequency regions, for example, can be construed as rather minor, “small potatoes” indeed when viewed in isolation.

Yet, as these variables combine and interact, as, of course, they do in human singing, perceptible nuances that either improve or detract from vocal sound may result. For the teaching of singing, nuances matter a lot. Incremental progress in sound production and propagation is just as important from a pedagogical perspective, perhaps even more so in some circumstances, as giant leaps forward. If some of that incremental progress can be achieved non-verbally, then so much the better from the perspective of efficient use of instructional time.

Given that singer gesture is an under-investigated phenomenon in the research literature to date, it seemed prudent first to investigate the matter tree by tree in order to ascertain what variables may be at play and chart possible directions for further research. The following discussion, therefore, considers the assorted individual variables and dependent measures of this study in terms of matters raised that may warrant reflection by the profession and inform ongoing research. It does so, however, by framing these matters within larger “forest” contexts, including (a) relationships between Experiment 1 (choral singing) and Experiment 2 (solo singing) results, (b) possible relationships between and among findings from measures of timbre, intonation, and amplitude, (c) convergences of acoustical and perceptual data, (d) pedagogical reflections for voice educators in choral and solo contexts, and (e) limitations of the study and suggestions for future research.

Findings are limited to the particular participants in this study, and likewise circumscribed by the particular methods, procedures, and dependent measures employed. Because singing is a widespread human behavior, it would be difficult to assemble truly random populations of solo and choral singers for this kind of study. Despite inclusion of like numbers of more experienced/less experienced and female/male participants in the convenience groups employed, results of this investigation should not be generalized to other singers or contexts.

Relation of the Two Experiments (Choral and Solo Contexts)

Experiments 1 and 2 were conducted with different groups of singers, largely because of an overall interest in testing assertions in the pedagogical literature that use of different singer gestures accomplish different things, and within that basic frame of interest whether or not context (choral or solo singing) might matter. Choir singing, by definition, is group singing. Yet, from an acoustical perspective, that is, beyond its basic sociological definition, choir singing also entails a chorusing effect. In order to have a naturalistic mixed choir singing context, one, for example, that features three rows of singers on risers with a sufficient number of singers per row to establish minimum requirements for a chorusing effect in each row (at least three females and at least three males singing the same scored pitches, according to Ternström, 2005), and to have a choir that contains both experienced and less experienced choristers, around 30 singers are required.

It is not impossible to attempt to isolate acoustic parameters of individual voices when they are singing with others. But doing so with around 30 singers while maintaining a naturalistic choral singing environment is not particularly feasible. The decision to employ a number of iterations of each melody for the gestural condition, in order to average results of several trials ($n = 5$) with a particular gesture rather than rely solely on a one-time iteration, further complicates the prospect, due to possible singer fatigue or loss of interest. Previous research (e.g., Rossing, Sundberg & Ternström, 1986, 1987), moreover, suggests that singers behave somewhat differently when singing chorally than they do when performing as soloists.

Thus, in order to gain a broad understanding of an under-investigated phenomenon, this particular study utilizes different groups of singers for its two experiments. A benefit of such a division is the possibility of two, naturalistic contexts for assessing singer vocal behaviors, one choral and the other solo. A corollary benefit is assessing from a pedagogical perspective what may happen with individual singers using various singer gestures while they are with a teacher one-on-one.

The primary research interests informing this particular study entail investigation of a variety of singer gestures in two distinct contexts using multiple measures appropriate to those contexts. Because its two experiments involve different groups of singers, although effort was made to balance the groups in terms of sex, experience level, and size, data from this study cannot directly address possible relationships between the two singing contexts, choral and solo. Yet findings from the solo context experiment may indirectly provide some insight on the "raw material," such as individual pitch, amplitude, and timbre behaviors that singers may bring to a choral context before experiencing additional variables (i.e., self to other ratio, the chorusing effect, and group dynamics) that ensue from the act of simultaneously listening to singing with other people.

Table 27 facilitates speculation on this score by summarizing primary findings of the study according to context, particular dependent measures, and convergence of data.

Table 27

Overall Singer Gesture Data Comparisons by Context and Measure (Choir and Solo)

	Timbre (LTAS)	*Pitch (MaxMSP)*	*Amplitude(NA)*	*Listeners*	*Convergence*
CHOIR	Circle*	Circle*		Circle*	√
	Point*	Point*		Point*	√
	Arched*	Arched*		Arched	√ -

	Timbre(Formant Freq)	*Pitch (Cents Dev)*	*Relative dB*	*Listeners*	*Convergence*
SOLO *M*	Circle^	Circle^	Circle^	Circle*	√
	Point^	Point*	Point^	Point*	√
	Arched^	Arched^	Arched^	Arched	√ -

Note: * = statistically significant difference among one or more condition comparisons (baseline-gesture, baseline-posttest, gesture-posttest; ^ = trends (directional change in all 4 formant frequencies, closer to target pitch, or plus-minus 1 dB) by majority of solo participants; √ = convergence of all the measurements; √ - = convergence of majority of the various measurements.

According to convergence of the various dependent measures as depicted in Table 26 "something" occurred in both contexts that seems to be attributable to employment of singer gestures. Measured differences are small ones, but they tend to occur consistently in both contexts but not across all singers.

For the sake of discussion, solo context results depicted in Table 27 rely more on interpretation of majority trends than robust tests of statistical significance. Yet, disaggregation of solo context results by individual participant painted a picture not only of majority trends, but also demonstrated that not all of the individual singers were alike. The individual singers in this study brought different established vocal habits to the gestural singing tasks, and they did not universally move in the same direction (e.g., flat or sharp singing, increased or decreased amplitude, uniform directional changes in formant frequencies) when employing the various singer gestures.

Some solo singers, for instance, evidenced progress toward desired pitch targets with one gesture, but not another. Some evidenced progress with all three gestures. For some, no gesture appeared to "work" as a nonverbal pedagogical strategy.

On this point, one message these data may convey is that with respect to using singer gestures in choral contexts, the whole may be more than a simple sum of each of its individual parts, especially when the individual parts are mistakenly presumed to be like units of measurement. That is, if sufficient numbers of individual choristers with similar proclivities evidence desirable nuances in one or more vocal production behaviors before singing in a group, the acoustical "chorusing" that occurs in choir-singing contexts may carry the day by providing more robust differences in group sound than would necessarily be the case with solo sound. Were that the case, it might help explain why the pedagogical literature to date appears to reflect more interest in singer gesture by choral conductors than on the part of private voice teachers. All of these speculations, of course, must be investigated by further research.

Measures of Pitch, Timbre, and Amplitude

Measures of timbre (LTAS for the choral context and formant frequencies for the solo context) indicated changes during implementation of gestural conditions. Formant frequencies, for example, lowered for a majority of solo singers across gestures. This finding may indicate that participants sang with a "darker" /i/ vowel. Some voice educators prefer this type of "darker" timbre as the vocal sound gets away from a lateral "cheese" sound. Lowered formant frequencies may also indicate the presence of articulation maneuvers (e.g., lips, tongue, velum) and larynx positioning that would lengthen the vocal tract, resulting in a somewhat "darker" or perhaps, depending upon aesthetic and other preferences, a somewhat "richer" vocal timbre. As Telfer comments, when singers move certain parts of the body "other parts of the body unconsciously react in certain ways" (In Brendell, 1997, p. 29). Thus, the presence of a somewhat darker tone could be related to physiological responses not directly involved in the gesture.

In both solo and choral contexts, the low, circular arm gesture appeared to be associated with changes in both timbre and relative amplitude. Interestingly, the greatest increase in signal amplitude was observed in both the solo and choral contexts during the third gestural iteration, the same point at which most singers stated they were comfortable with the gesture. Such congruence may indicate that this gesture contributed most at the point where singers felt most comfortable or most familiar with the movement.

The pointing gesture also seemed to produce a change in vocal timbre. Of the 35 solo participants, a lowering of formant frequencies between baseline and gestural iterations with the pointing gesture was observed in most solo context females ($N = 12$, 75%) and males ($N = 11$, 73.33%). Possible change in timbre was also seen in the choral context with significant differences in signal energy between all combinations of conditions (baseline to gesture mean, gesture mean to posttest, and baseline to posttest). These findings may suggest that the pointing gesture not only effects timbre of sound produced, but also influences singing done after gestures are performed, such as during the posttest in this study.

The arched hand gesture, overall, decreased signal amplitude during the choral context and lowered formant frequencies during the solo context. Overall, a lowering of formants was seen during the gestural iterations in female ($N = 14$, 87.50%) and male ($N = 15$. 80%) participants in the solo context. Such findings may indicate that the arched hand gesture contributes to changes in vocal timbre towards a “darker” or “more balanced” tone production on /i/ vowels for both choral and solo singers.

Expert listeners cited intonation more frequently than other terms as a factor in their ratings. Accuracy of pitch, of course, can be influenced by numerous variables, such as breath, vocal efficiency, and posture. The pitch analysis procedures in this investigation appear to indicate that singer gesture could also be a variable, given similarities between the choral context (Experiment 1) and solo context (Experiment 2) results using different dependent measures of pitch. Some pedagogues claim that intonation may improve with use of gesture because the singer's focus of attention shifts from an internal to an external focus (Eichenberger & Thomas, 1994; Con, 2002). Future studies might examine this possibility.

At the same time, however, measures of cents deviation from scored frequencies in the solo singing context indicate that employment of the low, circular arm gesture while singing "Over the Rainbow" did not appear to bring many solo singing participants to within ±7 cents of the scored target frequencies. Certainly, within the context of this particular study, that gesture does not appear to be a "magic bullet" in terms of addressing singer intonation.

Perhaps the relevant finding from a pedagogical perspective is that most solo participants (62.87%) did trend toward more in tune singing both while employing the low, circular arm gesture, and this trend persisted among some participants (57.14%) during the posttest condition after this gesture was withdrawn. This finding may support anecdotal claims that a low, circle will assist singers' pitch accuracy (Eichenberger, 1994; Jordan, 1996). Yet it also suggests that such assistance may be relatively small, or even absent in a substantial number of singers.

The pointing gesture was found to have possible impact as solo and choral singers sang "Singin' in the Rain" most in tune while performing this gesture and furthest from target frequency during the baseline condition. This finding may support claims that a pointing gesture makes the sung pitch better supported and clearer (Eichenberger, 1994; Jordan, 1996). Overall, however, 51.43% of solo singing participants sang closer to target frequency during the posttest condition of "Singin' in the Rain." This finding may suggest that for some singers the pointing gesture may enable more sharp singing, but when withdrawn enables singers to more nearly approach a desired target frequency. The iteration found to be most in tune (within ± 7 cents of target frequency) with this gesture was the first gestural iteration of the solo singers, possibly indicating that the pointing gesture had an effect on pitch when initially employing the gesture.

Solo singers also sang most in tune during “Hawaiian Rainbows” while performing with the arched hand gesture, indicating a possible beneficial effect on intonation of the arched hand gesture. According to measurements of fundamental frequency, solo singer participants in this investigation tended, overall, to sing slightly more in tune when singing with the arched hand gesture (68.57%) and also during the posttest condition (54.28%) after this gesture had been withdrawn. The iteration found to be most in tune (within $\pm$ 7 cents of target frequency) were the 2^{nd} and 4th gestural iterations, possibly indicating that there was an effect of employing the arched hand gesture once singers had some experience with the gesture.

Choral singers, on the other hand, although singing closer to pitch while employing the arched hand gesture, were more near target frequency during the posttest condition. For choral singers, then, one might surmise that singing with the arched hand gesture, which also produced significant changes in timbre, may be beneficial primarily in terms of its after effects.

Intonation tendencies in performing the ascending octave interval

Both macro (group means) and micro (per participant) analyses suggest that use of each of the three gestures appear to contribute somewhat to improved intonation of the ascending octave interval during the gestural conditions for solo and choral singer participants in this study. The low, circular arm gesture appears to offer assistance in moving toward target pitch for more solo singers than the arched hand and pointing gestures. This finding aligns with previous research employing a similar gesture (Brunkan, 2011) that found 67% of singers were closer to target pitch when singing with a low, circular arm gesture. Choral singers, by contrast, appear to move closer to target frequency on the octave singing tasks when using any of the gestures employed for this study.

None of the gestures used for this investigation universally assisted singers to fully achieve target pitch in this ascending octave task during gestural iterations. At the same time, particular gestures appeared to assist particular singers in making progress toward target pitch. These findings are similar to previous studies (Brunkan, 2010, 2011) on singer gesture, in that gestures seem to affect individual singers' tone production in a unique and individual fashion.

Eichenberger (1997) speculates that the low, circular arm gesture lends the sound more energy. This prediction seems to hold true in relation to the findings of this study. A majority of solo singers (57.14%) sang with increased energy when employing the low, circular arm gesture and the pointing gesture (74.28%) compared to baseline measures with the majority of solo singers (52.28%, low, circular gesture; 68.57%, pointing gesture) continuing to sing with increased energy during the posttest condition. Moreover, assessments of deviations from individual mean amplitudes show more variance during baseline and posttest conditions, and less variance during gestural iterations.

Singer Perceptions

Findings indicate a majority of participants in each context (97% choral context, 98% solo context) perceive that gestures positively affect vocal sound. This perceptual rating aligns with acoustical findings that indicate all three gestures in this study brought solo and choral singers closer to target pitch. Overall, participant perceptions indicate the low arm circles were most effective and easiest to do. Interestingly, both choral and solo singers in this study sang the octave leap most in tune while employing the low, circular gesture. Singing of the interval most in tune with the gesture cited as most effective and easiest may indicate that gestures are more effective when singers feel a level of comfort performing the motion.

Focus of attention has been extensively studied in research on motor tasks (i.e., Stoate & Wulf, 2011; Jackson & Holmes, 2011; Totsike & Wulf, 2003) as well as in music listening (i.e., Madsen, 2009; Madsen & Geringer, 1990; 1993) with fewer studies in musical motor task performance (Duke, Cash, & Allen, 2011). A majority of singers said they focused on the gesture instead of the sound. This finding might indicate that these gestures may function as an alternative focus during singing, and, perhaps, that such focus may impact the way in which singers' sound is produced. Future research may wish to examine singer gesture primarily from a focus of attention perspective.

Participant Learning and Mastery of the Three Singer Gestures

Most solo singers (97%, n = 34) and choral singers (97%, n = 29) were judged to have mastered the low circular gesture during the first iteration. Interestingly, the first iteration was also the most in tune overall (choral: -.001 from target frequency; solo: 2.75 cents from target frequency) and audibly more in tune in both contexts. Future research is needed to establish whether this phenomenon is primarily a novelty effect, such that any change in environment or practice could produce it, or to what extent it may be due to employment of a particular singer gesture.

A majority of solo singers (91%, n = 32) and choral singers (94%, n = 29) were also judged to have mastered the pointing gesture within the first iteration. Solo singing results indicate that the first gestural iteration was most in tune overall. The choir, however, sang audibly sharp on the first gestural iteration with the pointing gesture. These contradictory results between the contexts might be explained in terms of the conglomerate sound of the choir producing results based on group gesture. That is, context (solo or choral) may matter in terms of using particular singer gestures. This finding might inform pedagogical practice of choral directors and voice teachers in that certain gestures, while effective in one context, or with particular singers, may have a very different effect in another context.

According to video analysis, most solo singers (94%, *n* = 33) and choral singers (91%, *n* = 28) mastered the arched hand gesture during the first iteration as well. Pitch analysis results for the arched hand gesture show different trends than the other two gestures. The choral singers, for example, were much more in tune between the posttest and the first gestural condition, whereas, solo singers, more in tune in the first gestural iteration were closest to the target pitch on the second gestural iteration.

Video analyses also indicate that the particular gestures employed in this study are not difficult to learn. This fact is important to note. As a choral director or solo voice instructor, it is important to not only be inclusive of singers in any situation, but also to recommend singer gestures that are quickly and efficiently performed so that the focus of instruction may be on singing and not movement.

At the same time, acoustical measures of intonation in the solo context indicate that the most change from baseline occurred within the first three gestures. This factor suggests the possibility of an effect on sound production when singers first employed the gestures that did not necessarily hold true in later gestural iterations.

Pedagogical Reflections

It is important to view the data from this investigation from both macro and micro perspectives, because not all singers respond the same way, universally, to singer gestures. This consideration may be a less immediate concern in a group-singing context with sufficient numbers of singers to establish a chorusing effect. Nonetheless, choral teachers may wish to keep this point in mind, for, regardless of context, optimal development of individual singers is important.

Pedagogically, teachers frequently explain the goal of teaching strategies to their students depending upon the students' level of understanding, experience level, age, or teaching goals. This type of instruction can impact the outcome of the technique. Singers often employ their personal interpretation of strategies, therefore changing the outcome. Nonverbal gestures, also, may need to be tailored to a student's goals, needs, experience level, and learning styles. Future research might look at the use of gesture with groups at varying levels of development.

The gestures used in this study seem to have varying, generally small effects, according to certain individual dependent measures. The pointing gesture, for example, seemed to increase energy overall. Therefore, a choral director or voice teacher who aims for a more energized or perhaps, louder sound may want to employ such a gesture. If, however, the goal is pitch accuracy, the pointing gesture may not help all singers. The arched hand gesture, on the other hand, decreased energy and seemed to influence the timbre of the sound. Voice educators might wish to employ this gesture to evoke a tone that my blend more easily. The low, circular gesture seemed to have two main effects – more accurate pitch and increased energy. These effects occurred in both the choral and solo contexts. The low, circular gesture, therefore, might facilitate more accurate pitch or fuller sounds from singers in general.

Potential Confounding Variables

One of the challenges of researching phenomena associated with singer gesture is the need for controlling potential confounding variables. Therefore, three gestures recommended in the literature were chosen for this particular study. However, voice educators would normally choose gestures for singers that aim at a particular pedagogical goal. This type of individualized instruction was not utilized in this study, but it would be important to consider in practice and for future research.

It is possible that results could be attributed to a “novelty effect” for the first iteration of any gesture. In particular, the low, circular arm gesture was the first gesture performed by all singers. Thus, the acoustic and perceptual differences in measures of the low, circular arm gesture during the first iteration may be attributable to a shift in focus of attention, providing a distraction of sorts from the task of singing.

Further, counter-balancing of songs and gestures, although considered for this investigation, was not employed because the song selections, though similar, were not equivalent. The key, range, and tessitura of the melodies were consistent, but other inconsistencies such as order in which pitches occurred, rhythmic patterns, intervals, and length of phrases were not the same. Future research may wish to utilize one melody, or counter-balancing the order of multiple melodies to control for possible “novelty” and “ordering” effect.

The song selection, “Hawaiian Rainbows” proved to be a bit of a puzzle in terms of results. There may have been some confounding variables in the choral performances, particularly considering that the choir appeared to have more trouble negotiating some of its chromatic intervals. This situation might be ameliorated in future research by employing simpler melodies.

Yet another factor that may have influenced the findings on ‘Hawaiian Rainbows” was the fact that the choir was randomly assigned places on the choral risers. Many choral directors employ singer placement processes to facilitate optimum blending of voices. This type of process was not employed in this study. Therefore, one singer in this investigation, although not randomly assigned to the front of the choir, but on the outer edge of the second step, was consistently more audible on “Hawaiian Rainbows” than the other song selections. Future investigation may wish to employ choral voicing placement strategies in order to insure consistent blending of voices.

Other Considerations for Future Research

Future studies might measure intonation differently, e.g. using some sort of individual *Fo* standard derived by first subtracting from/adding to difference between initial baseline pitch and initial scored pitch. Although a similar procedure was done in this study with amplitude measures, frequency measures were not calculated in this fashion. Utilization of this method might enable researchers to examine changes in intonation based on an individual singer’s tonal center.

Future investigations that consider possible relationships between solo and choir-singing contexts where singer gesture is employed may well wish to incorporate different research decisions in this regard. For example, focusing on just one singer gesture, rather than three different gestures, might permit using the same group of singers, with half of them singing in the solo condition first and half of them singing in the solo condition after the choir singing portion of the study. Such a focus could also consider any possible transfer effects from one context to the other.

Eichenberger (1994) suggests that conductors incorporate the singer gestures employed in rehearsal into the conductor’s gestural vocabulary in performance. He posits that this integration of gesture causes singers to remember the effect they experienced when performing the gestures themselves. Future research might examine training with gesture, followed by conductor-led performance with same gestures in order to explore the possible lasting effects of training with singer gesture.

Three gestures recommended in the literature were employed in this study. Singers, however, sometimes adapt the gestures to their own needs. Singers might be afforded opportunity to suggest changes in gesture in order to achieve certain changes in sound. Future research may wish to explore chorister/singer-chosen gestures in relation to researcher-chosen gestures.

Previous research has indicated that singers may mirror non-verbal conductor behaviors (i.e., Manternach, 2009, 2011a, 2011b; Daugherty & Brunkan, 2009, 2011). Choral singers, therefore, may be impacted by behaviors of others in their environment, namely other singers in the choir. In the choral setting, singers not only performed each gesture as individuals, but they could also see others, even if just peripherally, doing the gestures. Future studies might investigate the degree to which singers alter their gestures on the basis of what they see other singers doing.

This study employed one gesture per song selection. Future studies might investigate the use of one song with a variety of gestures or a variety of song selections with one gesture employed.

Demographic variables of sex and experience, although not extensively reported for this study, may be of interest for future investigations of singer gesture. There have been claims that people with a certain level of experience may benefit more from certain types of instruction or attentional focus goals (i.e., Stoate & Wulf, 2011; Wulf, 2008). The gestures employed in this study may well have contributed to a shift in focus of attention for singers. Some participants in this study commented that singer gesture gave them an alternative focus – motion instead of sound. However, this possibility was only superficially examined, largely through singer survey responses. Many voice educators utilize teaching strategies that involve changing a singer's focus, whether it is through visualization exercises, asking singers to focus on an object in their environment, or directing singers to focus internally on things such as breathing or the velum. Future studies may wish to examine the effect of singer gesture on the singer's focus of attention. Past research, primarily in studies of athletic tasks (e.g., Beilock, Carr, MacMahon, & Starkes, 2002; Shafizadeh, McMorris, & Sproule, 2011; Zentgraf & Munzert, 2009), has posited that external versus internal focus of attention can influence the performance of motor tasks.

This investigation centers around one time, short-term data collection. It is possible, however, that longer-term exposure to certain strategies and techniques can impact their outcome. Therefore, future research might investigate how long it takes to get the most benefit from a technique such as singer gesture.

The three song selections in this study were sung in the key of D major. There were a variety of outcomes based on the pitches sung. For some singers singing in the key of D major was seemingly very comfortable, while for others, it was either too high or too low. Voice educators often choose literature for their singers, both choral and solo, based on key and tessitura. Key can play a major role in singer comfort, efficiency, and overall enjoyment. Therefore, future research might wish to utilize songs with different ranges or even in a singer chosen key.

As the anatomical structure of singers varies widely, some anatomical and physiological factors might be of interest to future research. These factors may also contribute to the magnitude of an individual's gesture. Therefore, future research may wish to examine the possible correlation of gesture magnitude to amount of change in frequency and amplitude. These findings might also be compared to length of an individual's arm structure. Among other possible measures for future research investigating singer gesture may be use of surface electromyography (sEMG) to assess electrical activity in muscle regions of interest or use of a motion capture system may enable synchronization of motion and acoustical data. Similarly, respiration bands worn by singers might enable measures of breathing behaviors.

Concluding Reflections

Findings of this investigation indicate that the singer gestures employed in this investigation apparently can affect intonation, amplitude, and timbre of sound produced in both choral and solo singing contexts. Overall perceptions of the expert listening panels and participants tend to confirm that such may be the case. However, these findings must be approached with both caution and discernment.

Results are limited to the contexts and procedures of this particular investigation. Even more importantly, from the perspective of vocal pedagogy, the findings of this study suggest that effects of singer gesture tend to be small ones, and that with particular individual singers there may be no effect. The possibility remains, moreover, that the use of many types of gesture could produce such nuances in vocal sound. More research is needed to ascertain whether small differences between particular gestures are “real,” or simply an artifact of the particular convenience groups of singers who participated in this study.

Research of singing phenomena across choral and solo singing contexts can assist voice educators to make informed, vocally friendly decisions about the pedagogical tools they may choose for particular singers in particular circumstances. Singer gesture may be one such tool. Results of the present study, the first to examine particular singer gestures with a variety of lenses (acoustical, perceptual, pedagogical) warrant continued research of a heretofore under-investigated area of keen interest to voice teachers and choir directors.

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Appendix A

KU RESEARCH & GRADUATE STUDIES
The University of Kansas

2/13/2012
HSCL #19905

Melissa Brunkan
1532 W. 22nd st.
Lawrence, KS 66046

The Human Subjects Committee Lawrence reviewed your research update application for project

19905 Brunkan/Daugherty (MEMT) The Effects of Three Singer Gestures on Acoustic and Perceptual Measures of Vocal Sound in Choral and Solo Singing Contexts

and approved this project under the expedited procedure provided in 45 CFR 46.110 (f) (7) Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies. As described, the project complies with all the requirements and policies established by the University for protection of human subjects in research. Unless renewed, approval lapses one year after approval date.

The Office for Human Research Protections requires that your consent form must include the note of HSCL approval and expiration date, which has been entered on the consent form sent back to you with this approval.

1. At designated intervals until the project is completed, a Project Status Report must be returned to the HSCL office.
2. Any significant change in the experimental procedure as described should be reviewed by this Committee prior to altering the project.
3. Notify HSCL about any new investigators not named in original application. Note that new investigators must take the online tutorial at http://www.rcr.ku.edu/hscl/hsp_tutorial/000.shtml.
4. Any injury to a subject because of the research procedure must be reported to the Committee immediately.
5. When signed consent documents are required, the primary investigator must retain the signed consent documents for at least three years past completion of the research activity. If you use a signed consent form, provide a copy of the consent form to subjects at the time of consent.
6. If this is a funded project, keep a copy of this approval letter with your proposal/grant file.

Please inform HSCL when this project is terminated. You must also provide HSCL with an annual status report to maintain HSCL approval. Unless renewed, approval lapses one year after approval date. If your project receives funding which requests an annual update approval, you must request this from HSCL one month prior to the annual update. Thanks for your cooperation. If you have any questions, please contact me.

Sincerely,

Jan Butin
HSCL Associate Coordinator
University of Kansas

cc: James Daugherty

Human Subjects Committee Lawrence
Youngberg Hall | 2385 Irving Hill Road | Lawrence, KS 66045 | (785) 864-7429 | HSCL@ku.edu | www.rcr.ku.edu/hscl

Appendix B

TEAR-OFF INFORMED CONSENT STATEMENT

TITLE: Characteristics of vocal sound (Experiment 1)

INTRODUCTION

The Department of Music Education/Music Therapy at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

The purpose of this study is to measure various characteristics of singing.

PROCEDURES

In this study, you will be asked to complete a brief demographic questionnaire and then sing three folksongs ("Somewhere Over the Rainbow," "Hawaiian Rainbows," and "Singin' in the Rain") on the syllable "me" with a choir of 30 singers You will perform the songs several times. You will engage in musical activities, some of which might include light movement. Your performance will be video and audio recorded. This process will take approximately thirty minutes. All audio and video material will be used by the researcher only and stored in a locked cabinet until completion of the study.

RISKS

This study involves no anticipated risk to you.

BENEFITS

Your participation in this study will benefit increased understanding of various characteristics of singing behaviors on the part of choir directors, voice teachers, and researchers in the field.

PAYMENT TO PARTICIPANTS

There is no payment to you for participating in this study.

PARTICIPANT CONFIDENTIALITY

Your name will not be associated in any way with the information collected about you or with the research findings from this study. The researcher(s) will use a study number or a pseudonym instead of your name. The researchers will not share information about you unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about you, in writing, at any time, by sending your written request to: Melissa Brunkan, Principal Investigator (address below). If you cancel permission to use your information, your information not be utilized and data will be destroyed. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

QUESTIONS ABOUT PARTICIPATION should be directed to:

Melissa Brunkan	Dr. James Daugherty
Principal Investigator	Faculty Supervisor
Music Education/Music Therapy	Music Education/Music Therapy
448 Murphy Hall	448 Murphy Hall
University of Kansas	University of Kansas
Lawrence, KS 66045	Lawrence, KS 66045
(785) 864- 9637	(785) 864 – 5094

If you have any questions about your rights as a research participant you may contact the Human Subjects Committee Lawrence Campus (HSCL) office at (785) 864-7429 or (785) 864-7385, write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email irb@ku.edu.

KEEP THIS SECTION FOR YOUR RECORDS. IF YOU WISH TO PARTICIPATE TEAR OFF THE FOLLOWING SECTION AND RETURN IT TO THE RESEARCHER(S).

Characteristics of Vocal Sound – Experiment 1

HSCL #19905

PARTICIPANT CERTIFICATION:

If you agree to participate in this study please sign where indicated, then tear off this section and return it to the investigator(s). Keep the consent information for your records.

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study and the use and disclosure of information about me for the study.

I agree to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

______________________________________ ________________________

Type/Print Participant's Name Date

____

Participant's Signature

Approved by the Human Subjects Committee University of Kansas, Lawrence Campus (HSCL). Approval expires one year from 2/13/2012. HSCL #19905

Appendix C

TEAR-OFF INFORMED CONSENT STATEMENT

TITLE: Characteristics of vocal sound (Experiment 2)

INTRODUCTION

The Department of Music Education/Music Therapy at the University of Kansas supports the practice of protection for human subjects participating in research. The following information is provided for you to decide whether you wish to participate in the present study. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw from this study, it will not affect your relationship with this unit, the services it may provide to you, or the University of Kansas.

PURPOSE OF THE STUDY

The purpose of this study is to measure various characteristics of singing.

PROCEDURES

In this study, you will be asked to complete a brief demographic questionnaire and then sing three folksongs ("Somewhere Over the Rainbow," "Hawaiian Rainbows," and "Singin' in the Rain") on the syllable "me." You will perform the phrases several times. You will engage in musical activities, some of which might include light movement. Your performance will be video and audio recorded. This process will take approximately fifteen minutes. All audio and video material will be used by the researcher only and stored in a locked cabinet until completion of the study.

RISKS

This study involves no anticipated risk to you.

BENEFITS

Your participation in this study will benefit increased understanding of various characteristics of singing behaviors on the part of choir directors, voice teachers, and researchers in the field.

PAYMENT TO PARTICIPANTS

There is no payment to you for participating in this study.

PARTICIPANT CONFIDENTIALITY

Your name will not be associated in any way with the information collected about you or with the research findings from this study. The researcher(s) will use a study number or a pseudonym instead of your name. The researchers will not share information about you unless required by law or unless you give written permission.

Permission granted on this date to use and disclose your information remains in effect indefinitely. By signing this form you give permission for the use and disclosure of your information for purposes of this study at any time in the future.

REFUSAL TO SIGN CONSENT AND AUTHORIZATION

You are not required to sign this Consent and Authorization form and you may refuse to do so without affecting your right to any services you are receiving or may receive from the University of Kansas or to participate in any programs or events of the University of Kansas. However, if you refuse to sign, you cannot participate in this study.

CANCELLING THIS CONSENT AND AUTHORIZATION

You may withdraw your consent to participate in this study at any time. You also have the right to cancel your permission to use and disclose information collected about you, in writing, at any time, by sending your written request to: Melissa Brunkan, Principal Investigator (address below). If you cancel permission to use your information, your information not be utilized and data will be destroyed. However, the research team may use and disclose information that was gathered before they received your cancellation, as described above.

QUESTIONS ABOUT PARTICIPATION should be directed to:

Melissa Brunkan	Dr. James Daugherty
Principal Investigator	Faculty Supervisor
Music Education/Music Therapy	Music Education/Music Therapy
448 Murphy Hall	448 Murphy Hall
University of Kansas	University of Kansas
Lawrence, KS 66045	Lawrence, KS 66045
(785) 864- 9637	(785) 864 – 5094

If you have any questions about your rights as a research participant you may contact the Human Subjects Committee Lawrence Campus (HSCL) office at (785) 864-7429 or (785) 864-7385, write the Human Subjects Committee Lawrence Campus (HSCL), University of Kansas, 2385 Irving Hill Road, Lawrence, Kansas 66045-7568, or email irb@ku.edu.

KEEP THIS SECTION FOR YOUR RECORDS. IF YOU WISH TO PARTICIPATE TEAR OFF THE FOLLOWING SECTION AND RETURN IT TO THE RESEARCHER(S).

Characteristics of Vocal Sound – Experiment 2

HSCL #19905

PARTICIPANT CERTIFICATION:

If you agree to participate in this study please sign where indicated, then tear off this section and return it to the investigator(s). Keep the consent information for your records.

I have read this Consent and Authorization form. I have had the opportunity to ask, and I have received answers to, any questions I had regarding the study and the use and disclosure of information about me for the study.

I agree to take part in this study as a research participant. By my signature I affirm that I am at least 18 years old and that I have received a copy of this Consent and Authorization form.

_______________________________________ ______________________

Type/Print Participant's Name Date

____

Participant's Signature

Approved by the Human Subjects Committee University of Kansas, Lawrence Campus (HSCL). Approval expires one year from 2/13/2012. HSCL #19905

Appendix D

Participant Number: ______________

PARTICIPANT QUESTIONNAIRE #1

NAME: ____

Your age: _____years

Circle One: MALE FEMALE

I am currently singing regularly in a choir (any kind). Circle One: YES NO

Please indicate previous years of regular, ongoing choir member ship in any kind of choir (including school, church/synagogue, and/or community choirs) at the following levels (If none, write zero. If less than one year, write less than 1 year):

CHILDHOOD/ELEMENTARY SCHOOL AGE Choir Participation: ____ years

EARLY ADOLESCENCE/MIDDLE OR JR HIGH SCHOOL AGE Choir Participation:
____ years

ADOLESCENT/HIGH SCHOOL AGE Choir Participation: ____ years

YOUNG ADULT AND/OR COLLEGE AGE Choir Participation ____ years

ADULT AND/OR POST COLLEGE AGE Choir Participation ____ years

Please indicate number of years of any regular, ongoing VOICE LESSONS with a private teacher (If none, write zero. If less than one year, write less than 1 year):
____ years

Please indicate number of years of any regular, ongoing DANCE LESSONS of any kind (If none, write zero. If less than one year, write less than 1 year):
____ years

Please indicate number of years of any regular, ongoing CONDUCTING experience (If none, write zero. If less than one year, write less than 1 year):
_____ years

Can you sing the following from memory? (circle one)

“Somewhere Over the Rainbow” YES NO
“Singin’ in the Rain” YES NO
“Hawaiian Rainbows” YES NO

Appendix E

Participant Survey – Experiment 1

1. Did you think singing with gestures affects the choir's overall vocal sound production? (check one)

_____ Yes, positively affects the choir's overall vocal sound production

If you answered yes, please rank the following gestures in order (1 = most effect to 3 = least effect) according to your perceptions of their possible contributions to the choir's overall vocal sound production. Write the numbers 1, 2, or 3 by each of the following gestures:

_____ Low arm circle
_____ Pointing
_____ Arched hand

_____Yes, negatively affected the choir's overall vocal sound production

If you answered yes, please rank the following gestures in order (1 = most effect to 3 = least effect) according to your perceptions of their possible negative contributions to the choir's overall vocal sound production. Write the numbers 1, 2, or 3 by each of the following gestures:

_____ Low arm circle
_____ Pointing
_____ Arched hand

_____ No, does not affect the choir's overall vocal sound production
_____ Not sure

2. When doing the gestures, did you focus most on the gestures or most on your vocal sound production?

3. Which gesture did you find easiest to do?

4. Which gesture did you find hardest to do?

5. Check below on which sung trial you first began to feel completely comfortable with doing the *low circular arm* gesture?
_____ Trial 1 _____ Trial 2 _____ Trial 3 _____ Trial 4 _____ Trial 5

6. Check below on which sung trial you first began to feel completely comfortable with doing the *pointing* gesture?
_____ Trial 1 _____ Trial 2 _____ Trial 3 _____ Trial 4 _____ Trial 5

7. Check below on which sung trial you first began to feel completely comfortable with doing the *arched hand* gesture?
_____ Trial 1 _____ Trial 2 _____ Trial 3 _____ Trial 4 _____ Trial 5

8. Please share below any *overall thoughts and perceptions* of about singing with gestures in choir rehearsals.

9. Have you had a choral singing experience before where singers were asked to employ gestures (hand and arm movements) while singing? (circle one) Yes No

If yes, please indicate how familiar you are with using gestures while singing:

_____ Not very familiar (done it once or twice)
_____ Somewhat familiar (done it 3- 10 times)
_____ Familiar (done it 11-20 times)
_____ Very Familiar (done it over 20 times)

Appendix F

Participant Number: _______

Participant Survey – Experiment 2

1. Did you think singing with gestures affects your overall vocal sound production? (check one)
_____ Yes, positively affects my overall vocal sound production

If you answered yes, please rank the following gestures in order (1 = most effect to 3 = least effect) according to your perceptions of their possible contributions to your overall vocal sound production. Write the numbers 1, 2, or 3 by each of the following gestures:

_____ Low arm circle
_____ Pointing
_____ Arched hand

_____Yes, negatively affected my overall vocal sound production

If you answered yes, please rank the following gestures in order (1 = most effect to 3 = least effect) according to your perceptions of their possible negative contributions to your overall vocal sound production. Write the numbers 1, 2, or 3 by each of the following gestures:

_____ Low arm circle
_____ Pointing
_____ Arched hand

_____ No, does not affect my overall vocal sound production
_____ Not sure

2. When doing the gestures, did you focus most on the gestures or most on your vocal sound production?

3. Which gesture did you find easiest to do?

4. Which gesture did you find hardest to do?

5. Check below on which sung trial you first began to feel completely comfortable with doing the *low circular arm* gesture?
_____ Trial 1 _____ Trial 2 _____ Trial 3 _____ Trial 4 _____ Trial 5

6. Check below on which sung trial you first began to feel completely comfortable with doing the *pointing* gesture?
_____ Trial 1 _____ Trial 2 _____ Trial 3 _____ Trial 4 _____ Trial 5

7. Check below on which sung trial you first began to feel completely comfortable with doing the *arched hand* gesture?
_____ Trial 1 _____ Trial 2 _____ Trial 3 _____ Trial 4 _____ Trial 5

8. Please share below any *overall thoughts and perceptions* of about singing with gestures in a solo singing setting.
9. Have you had a solo singing experience before where singers were asked to employ gestures (hand and arm movements) while singing? (circle one) Yes No

If yes, please indicate how familiar you are with using gestures while singing:

_____ Not very familiar (done it once or twice)
_____ Somewhat familiar (done it 3- 10 times)
_____ Familiar (done it 11-20 times)
_____ Very Familiar (done it over 20 times)

Appendix G

Expert Panel Participant Survey

Name: ____

Age: __________years

Sex (circle one): M F

Years of Teaching experience:

General Music: ___________ years

Choral Music: ___________ years

Studio Voice: ___________ years

In judging more or less pleasing overall sound, which factor(s) most contributed to your decision (please check all that apply)

______Intonation

______ Balance

______ Blend

______ Volume

______ OTHER: ____

Appendix H

Gesture Learning Checklist

Low circular gesture

Participant #: ____________

	1	2	3	4	5	6
Both hands are used						
Fingers together						
Palms towards the midline of the body						
Arms, with elbows slightly bent						
Arms follow the upward and outward circular motion of the hands						
Hands move in circles in front of the torso						
Hands are no lower than the hips and no higher than the sternum						
The circles are done fairly quickly, not necessarily in the tempo of the song.						

Pointing Gesture

	1	2	3	4	5	6
The index finger of your right hand points upward and outward						
Finger moving at a 45 degree angle from the torso						
Finger starting at the height of your sternum						
Finger/hand arches outward in front of the forehead						
Index finger leads, the arm follows.						
The arm begins with elbow slightly bent						
Arm extends from the shoulder						
Arm straightens as the point moves outward and upward						

Arched Hand Gesture

	1	2	3	4	5	6
Fingers arched (as if holding a tennis ball)						
Palm facing downward						
The hand moves vertically upward						
Hand moves in front of the torso						
Hand moves from the level of the hip						
Hand moves up to level of the eyebrows						
As the hand moves upward, the arm starts with elbow slightly bent						
Arm follows with elbow slightly bent throughout the gesture						

Appendix I

LTAS Charts of Each Song Selection

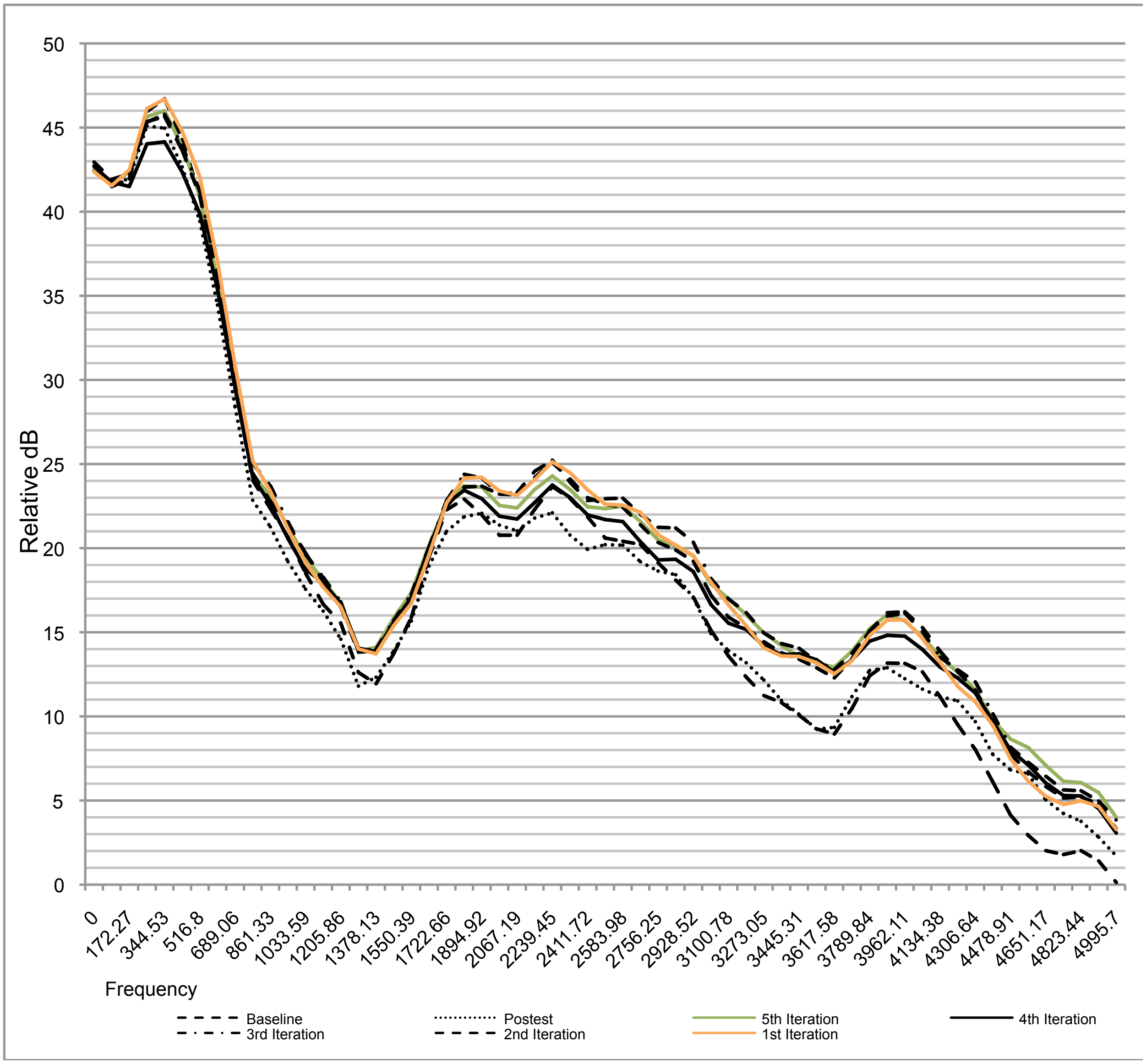

Figure I1. Entire Spectrum of all Iterations for "Over the Rainbow" – low, circular arm gesture.

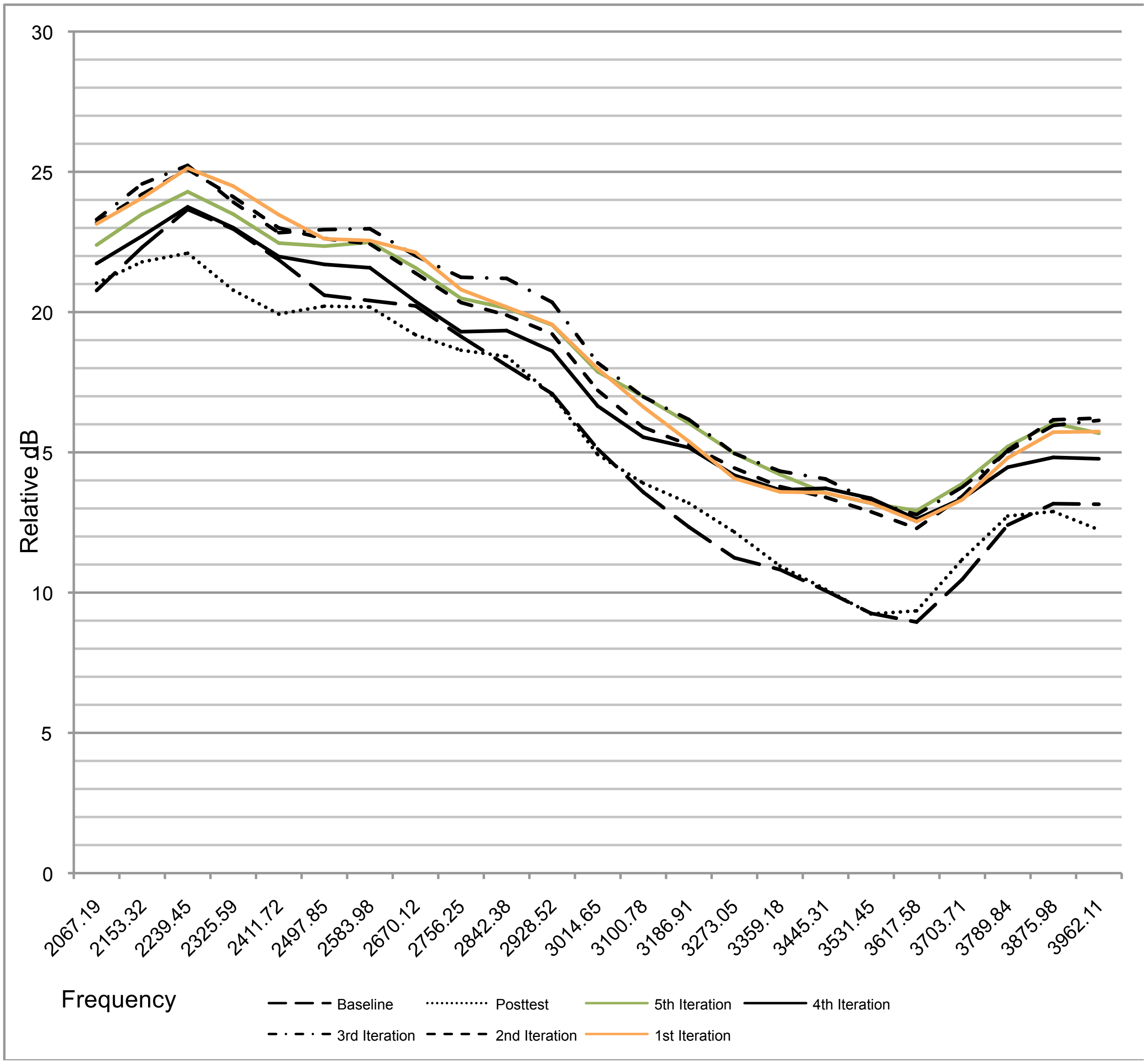

Figure I2. Singer's Formant Region (2 - 4kHz) for all Gestural Iterations of "Over the Rainbow" – low, circular arm gesture.

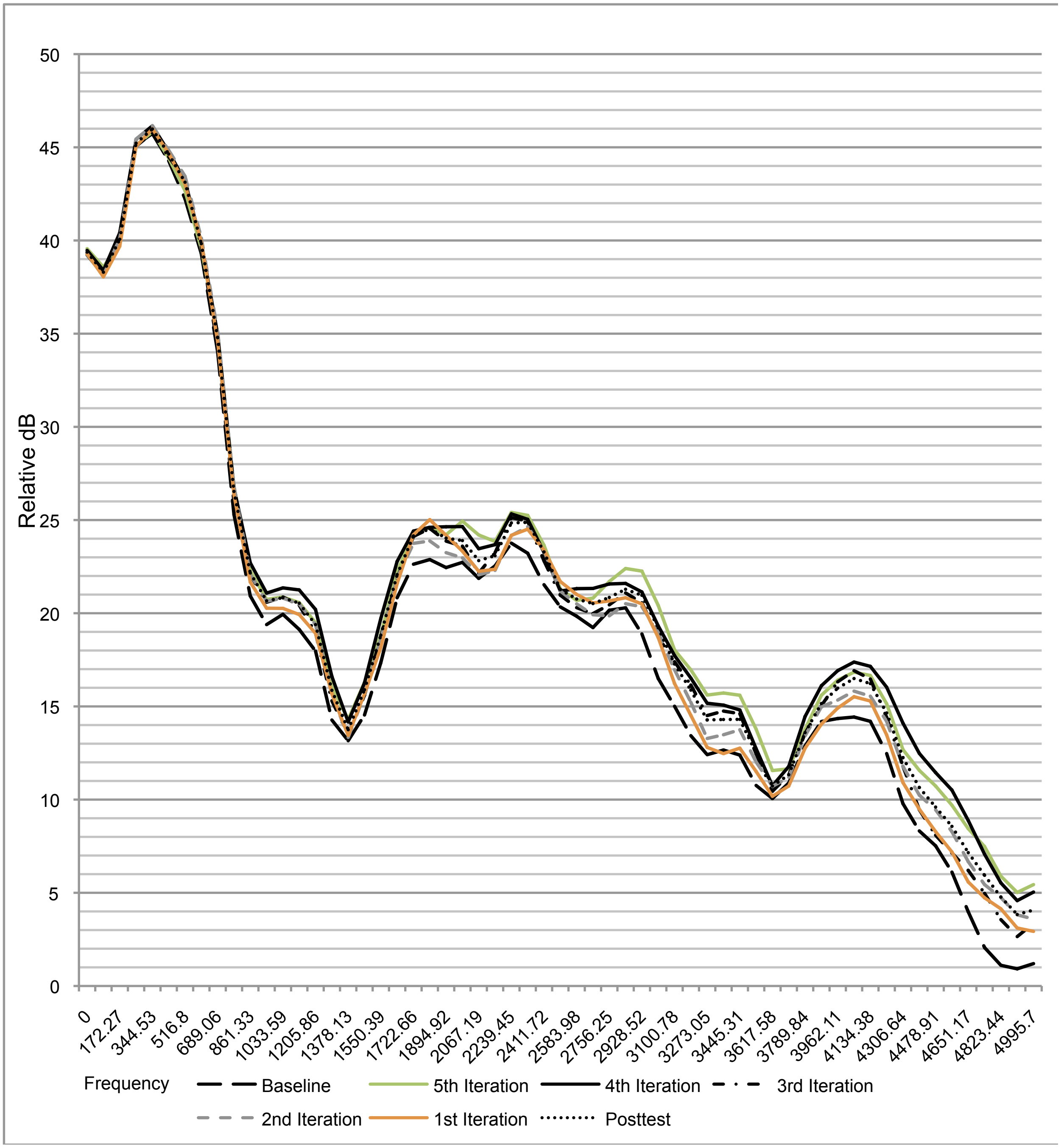

Figure I3. All iterations of "Singin' in the Rain" – entire spectrum – pointing gesture.

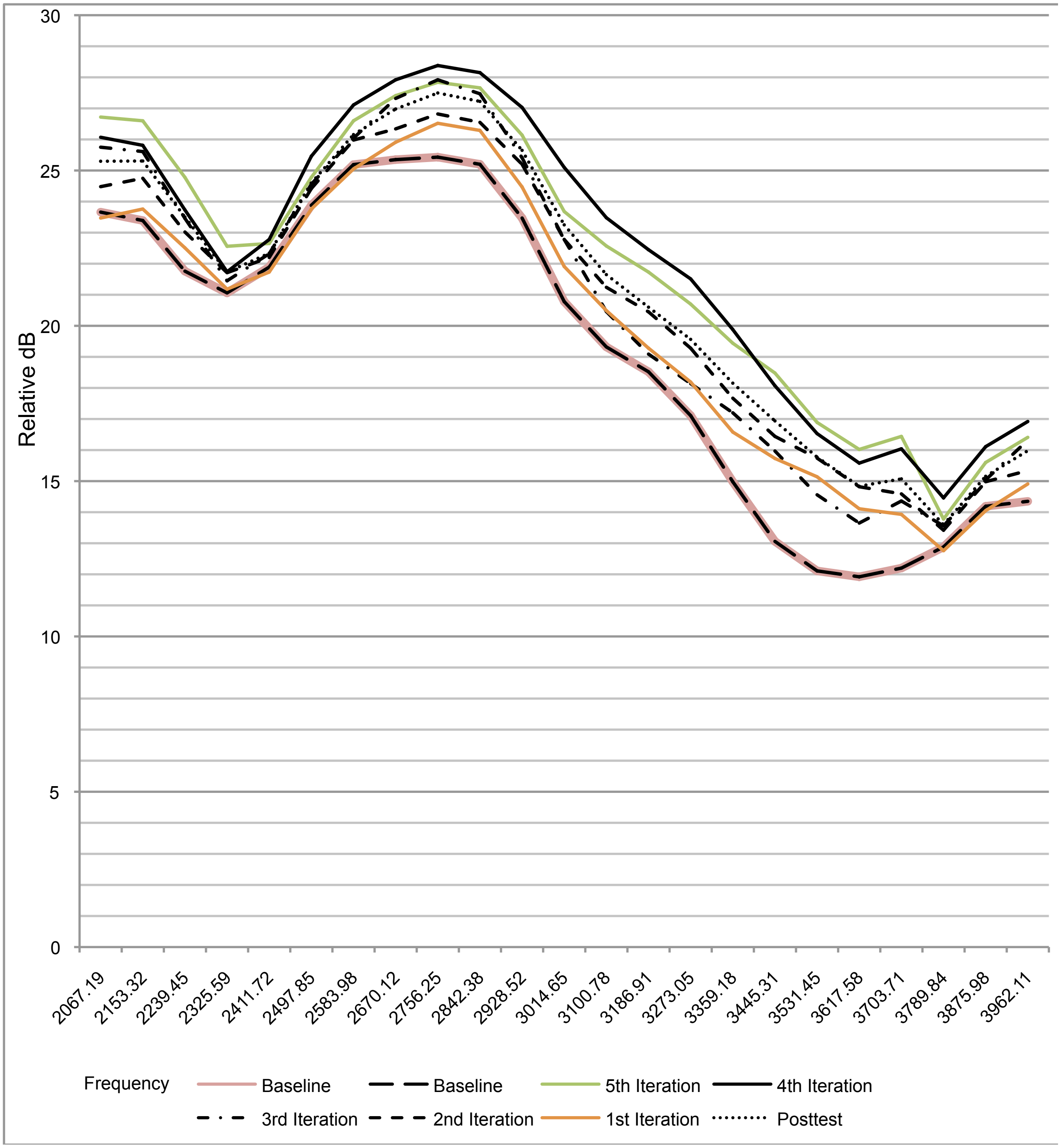

Figure I4. All iterations of "Singin' in the Rain" – singer's formant region – pointing gesture.

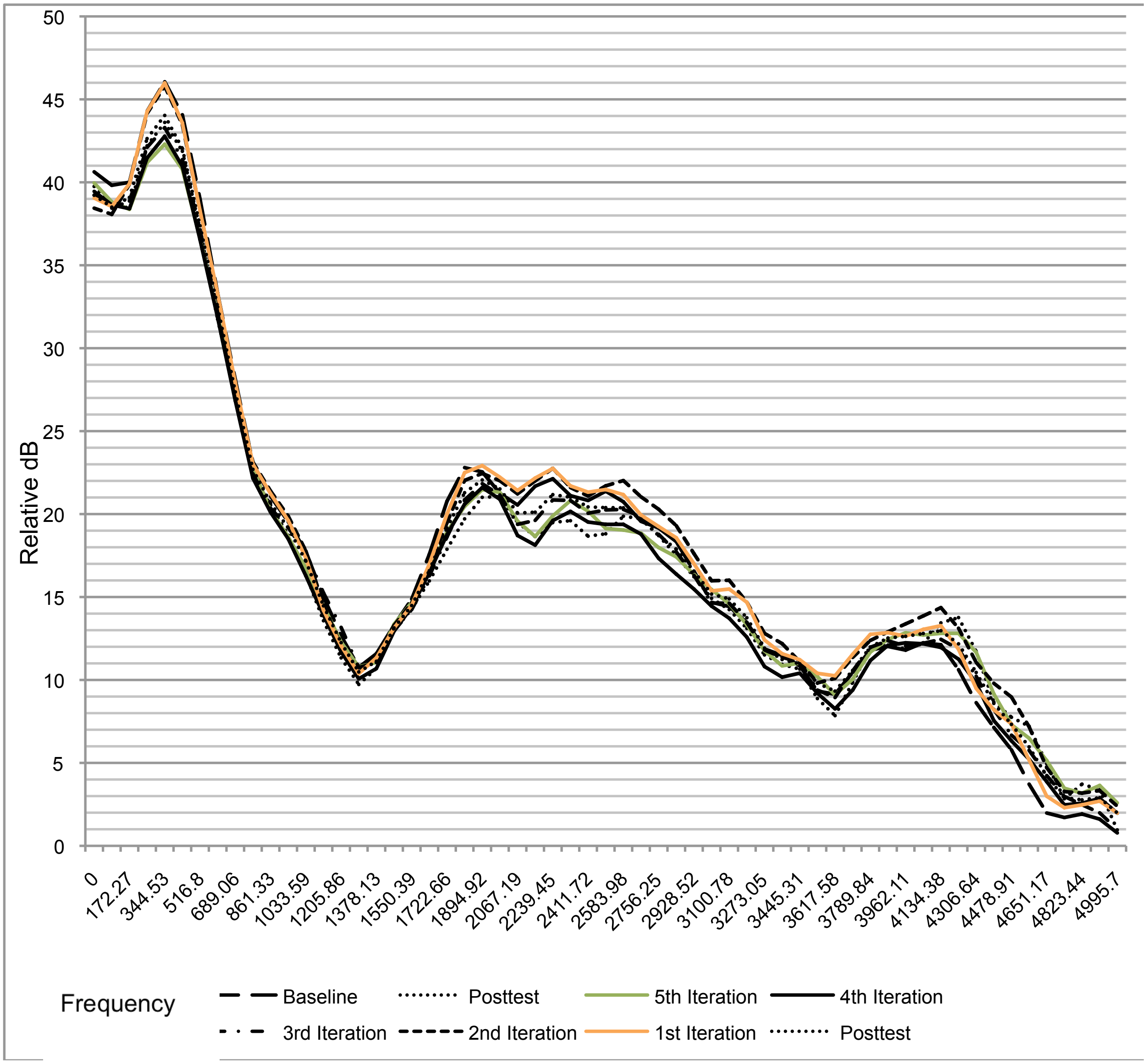

Figure I5. All iterations of "Hawaiian Rainbows" – entire spectrum – arched hand gesture.

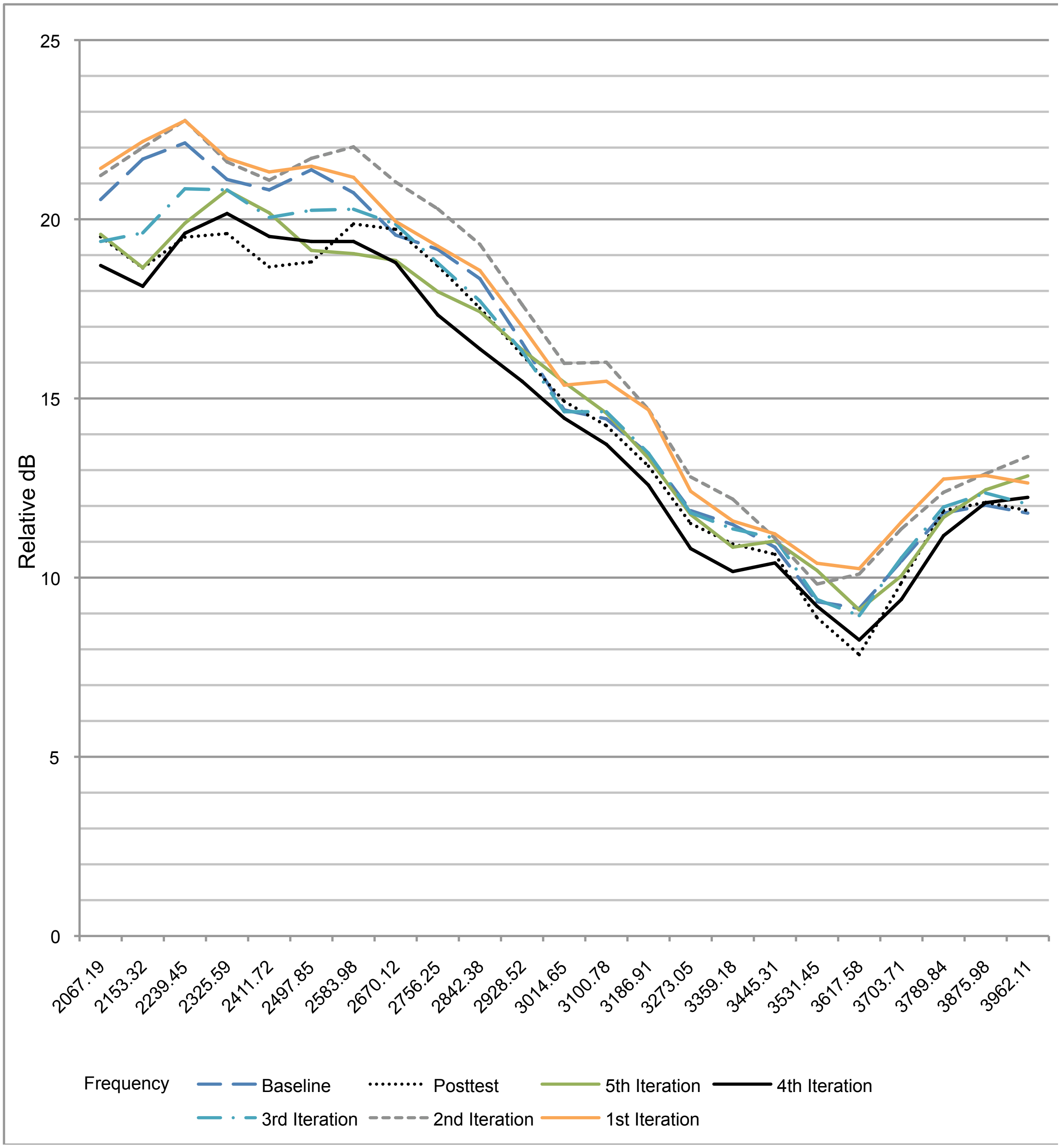

Figure I6. All iterations of "Hawaiian Rainbows" – singer's formant region – arched hand gesture.

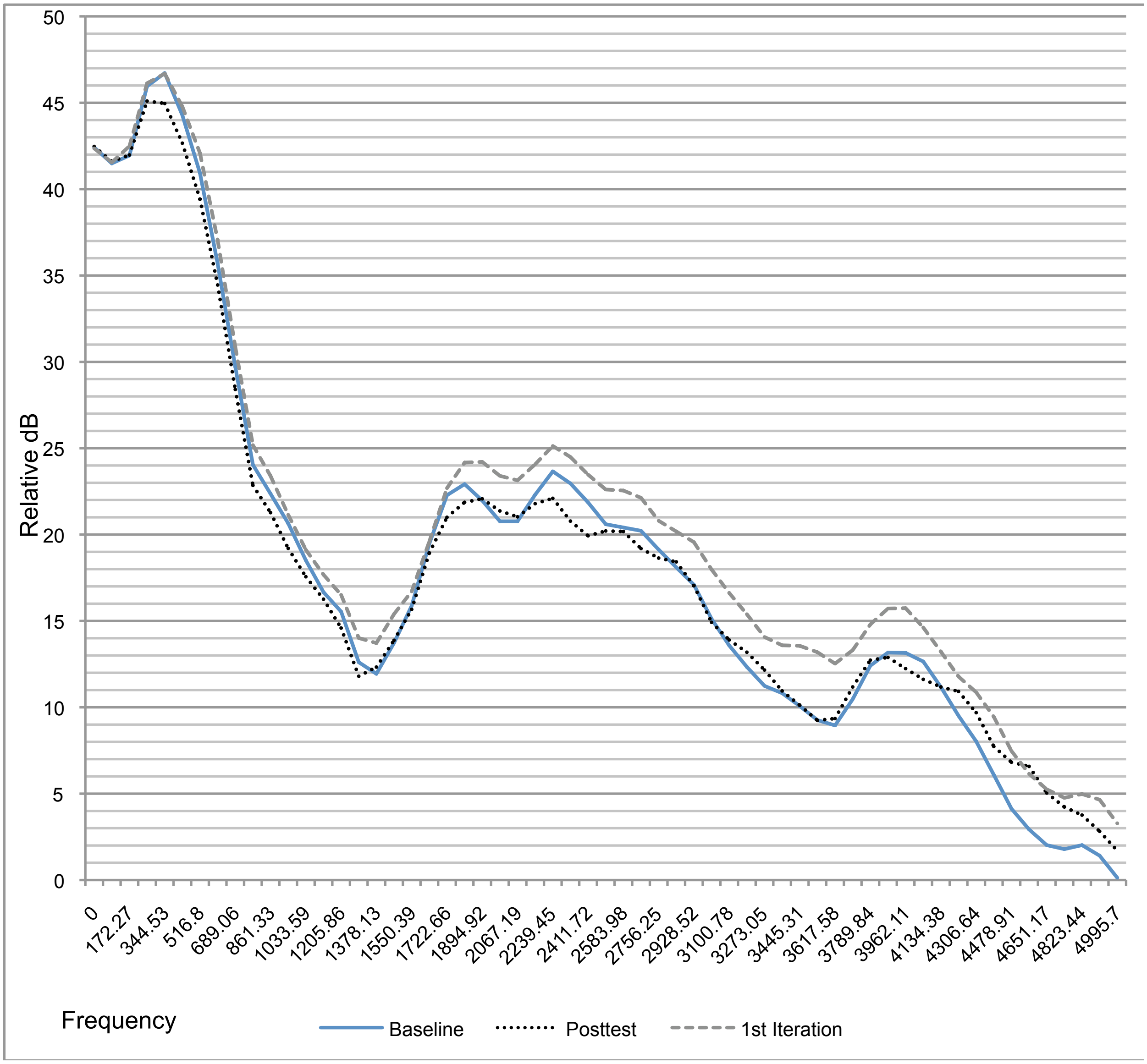

Figure I7. First gestural iteration entire spectrum – "Over the Rainbow" – low, circular arm gesture.

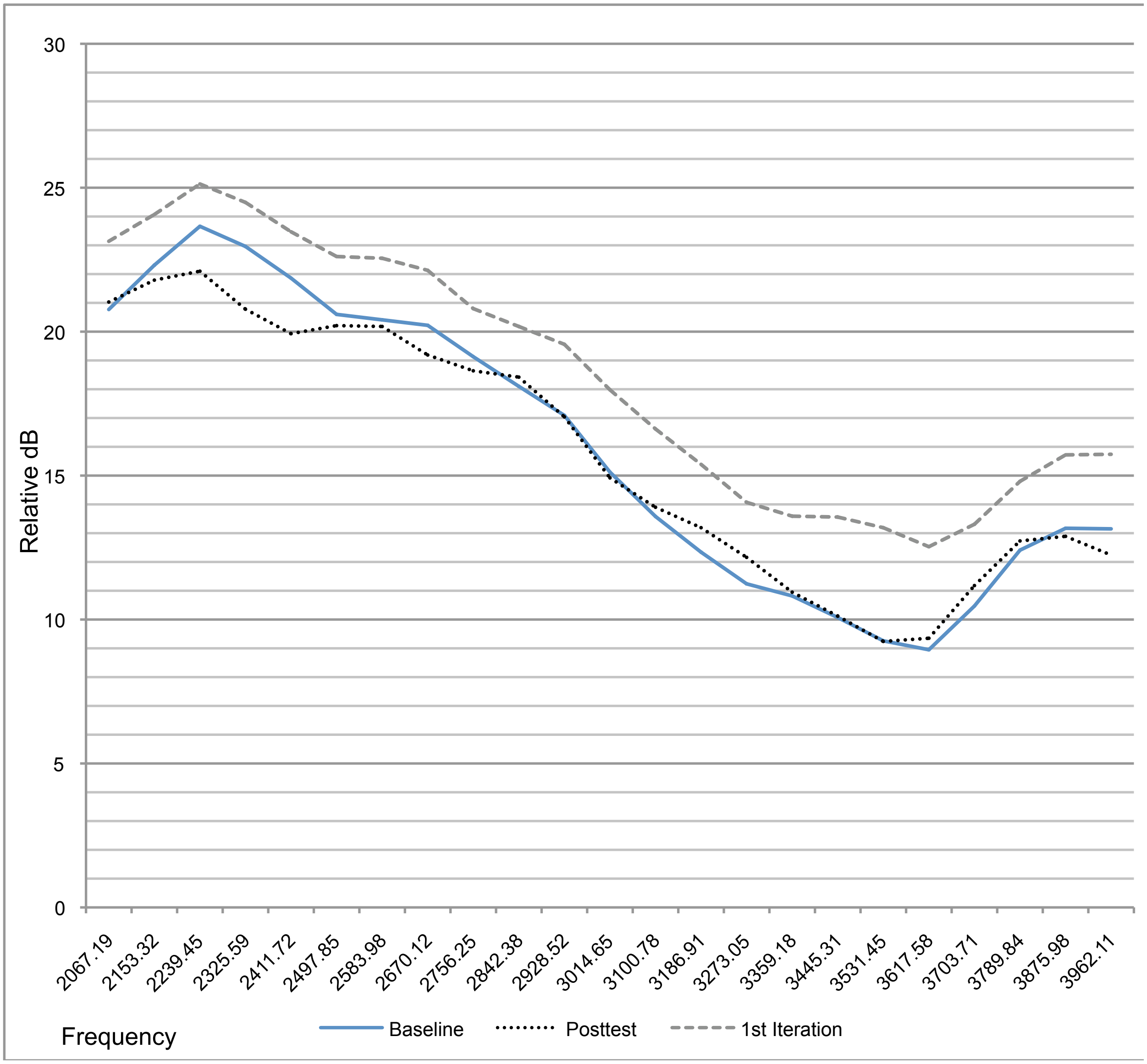

Figure I8. 1st gestural iteration of "Over the Rainbow" – singer's formant region – low, circular arm gesture.

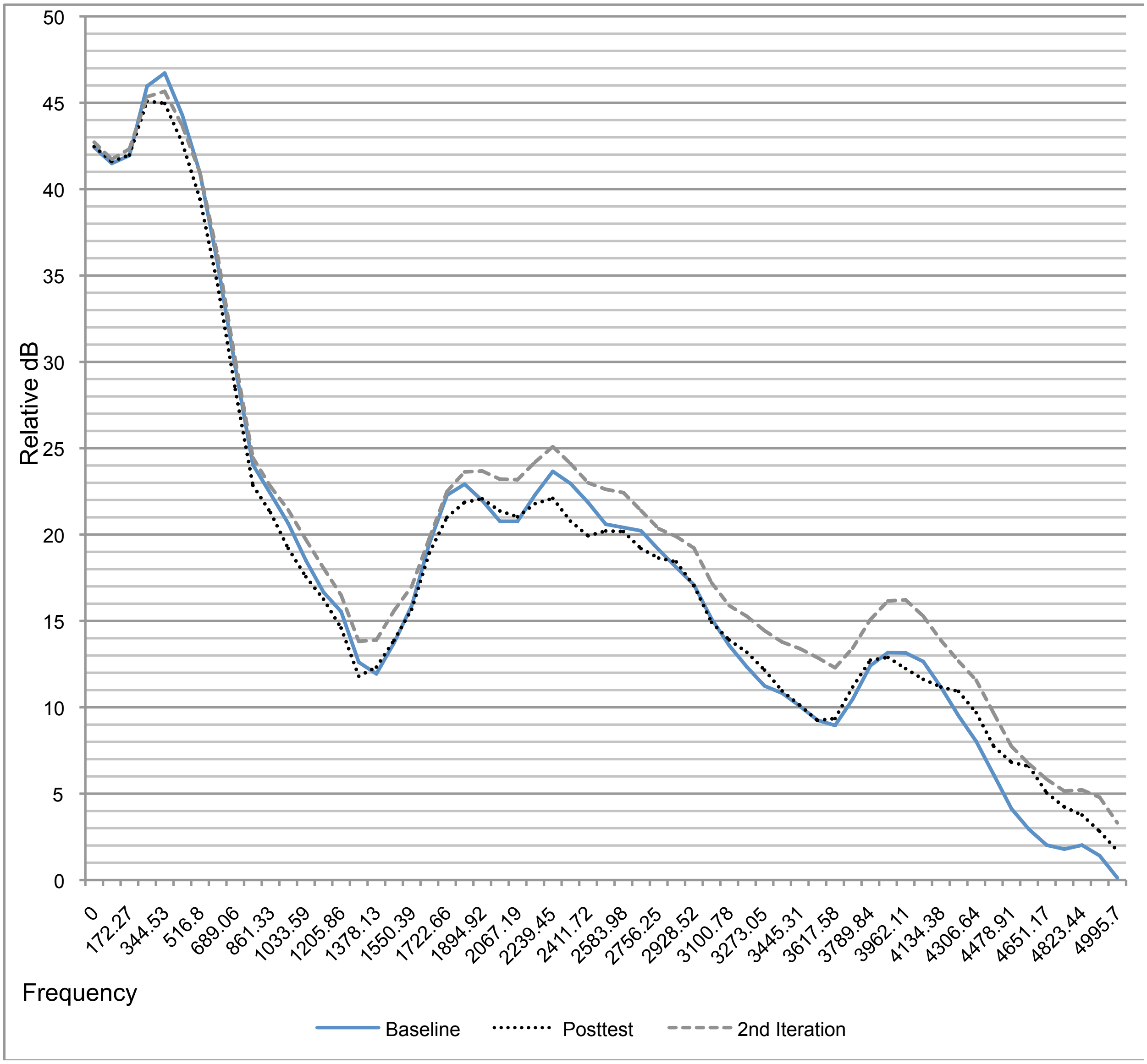

Figure I9. 2nd gestural iteration of "Over the Rainbow" – entire spectrum – low, circular arm gesture.

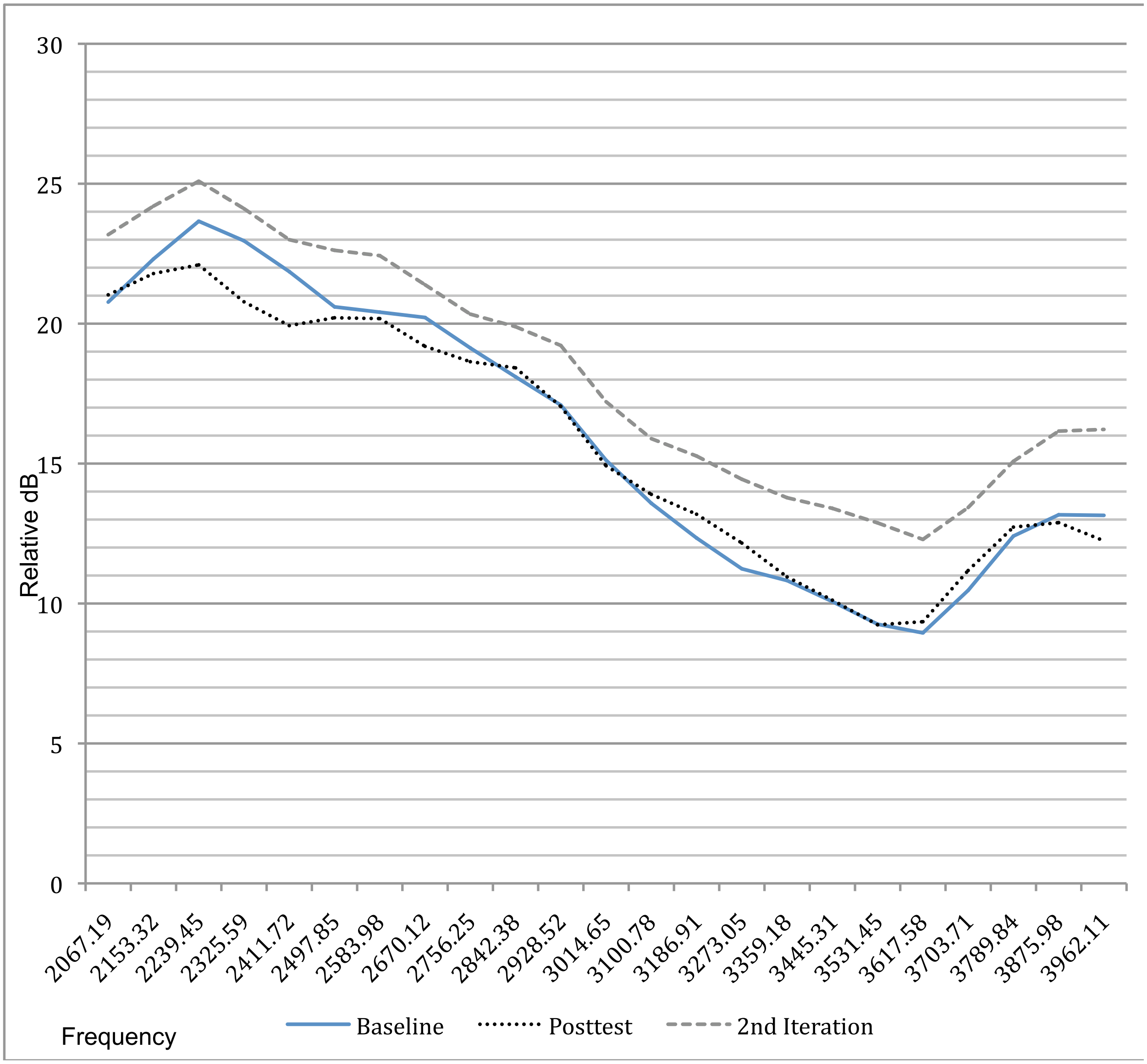

Figure I10. 2nd gestural iteration of "Over the Rainbow" – singer's formant – low, circular arm gesture.

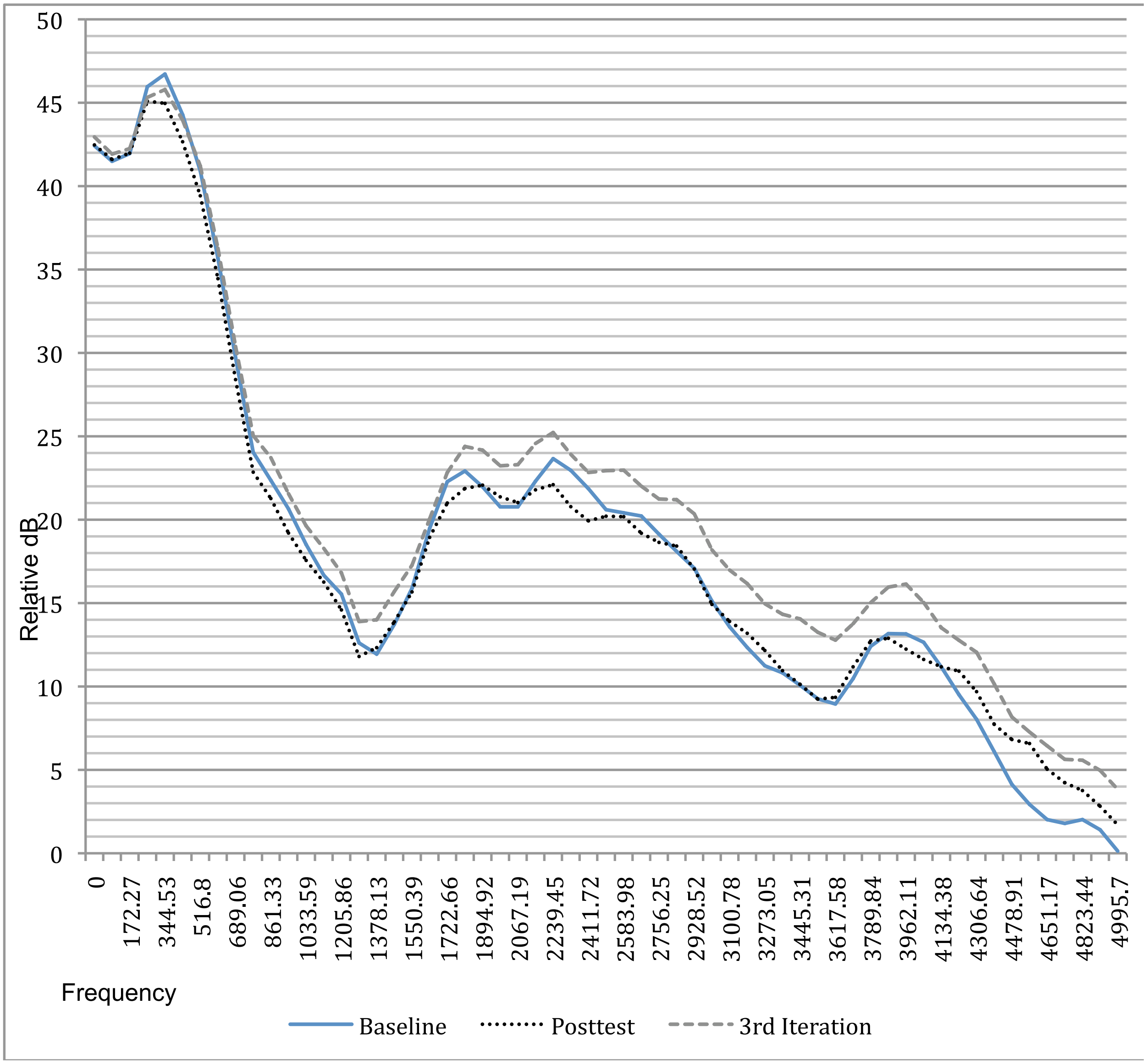

Figure I11. 3rd gestural iteration of "Over the Rainbow" – entire spectrum – low, circular arm gesture.

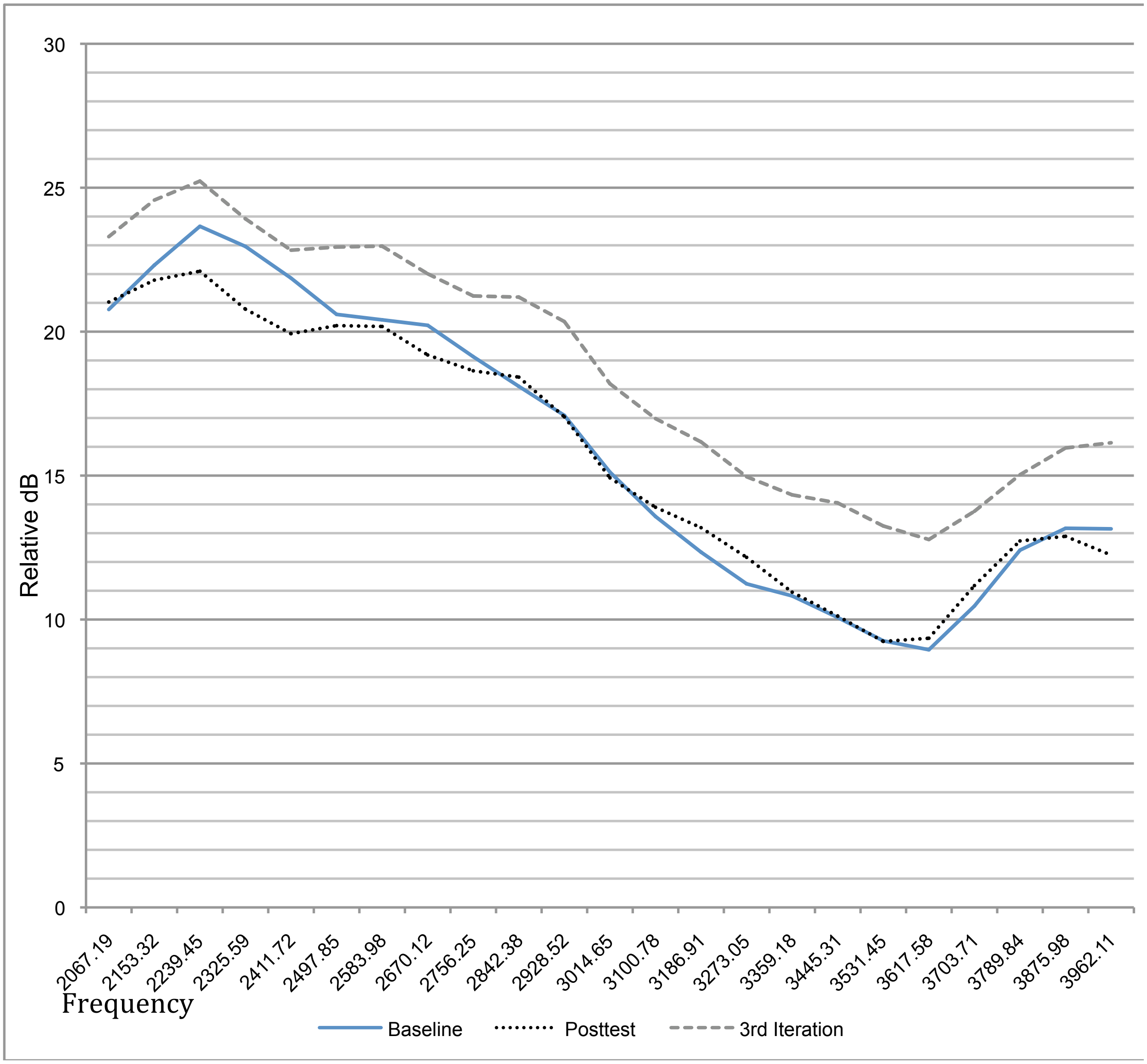

Figure I12. 3rd gestural iteration of "Over the Rainbow" – singer's formant – low, circular arm gesture.

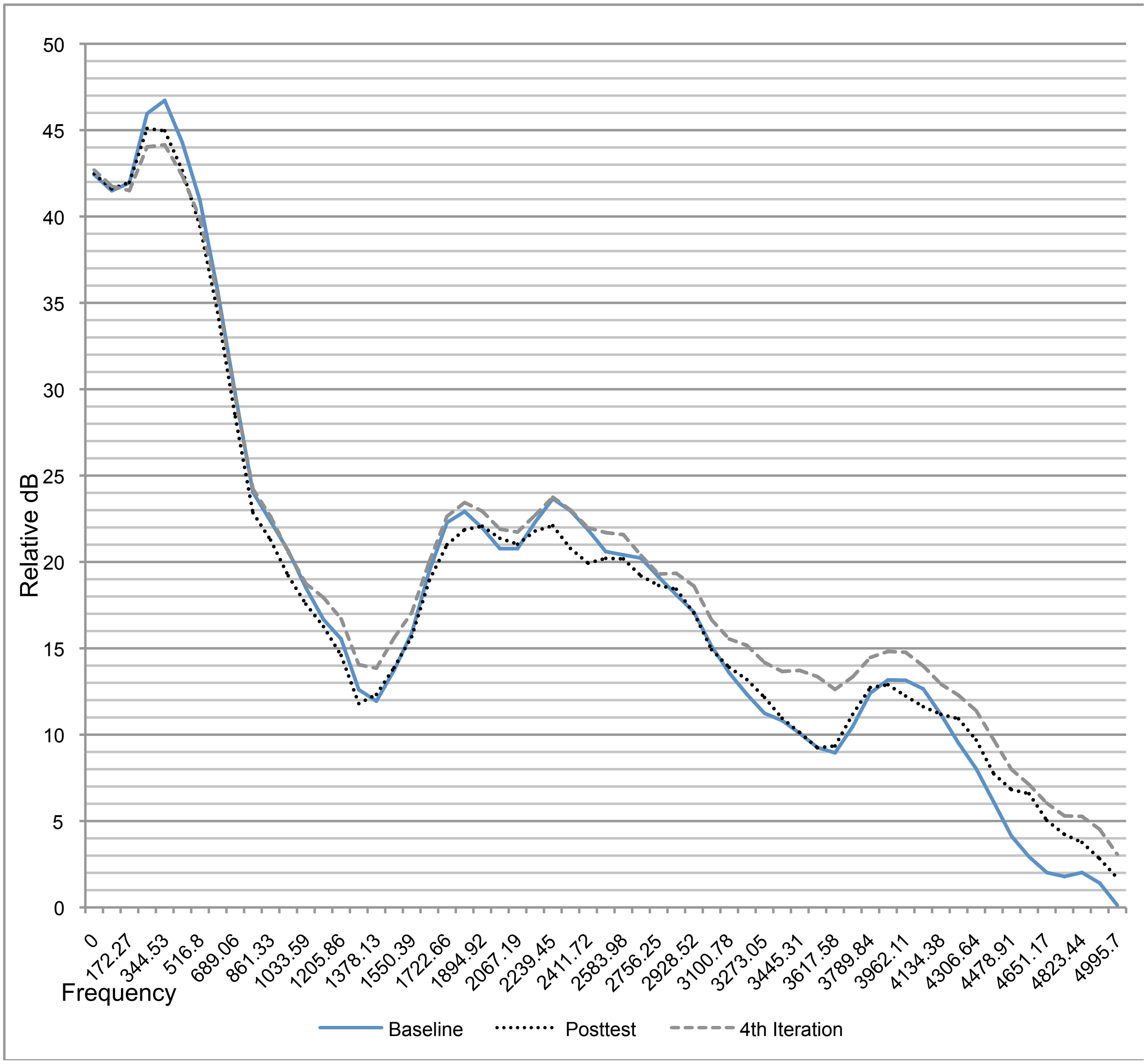

Figure I13. 4th gestural iteration of "Over the Rainbow" – entire spectrum – low, circular arm gesture.

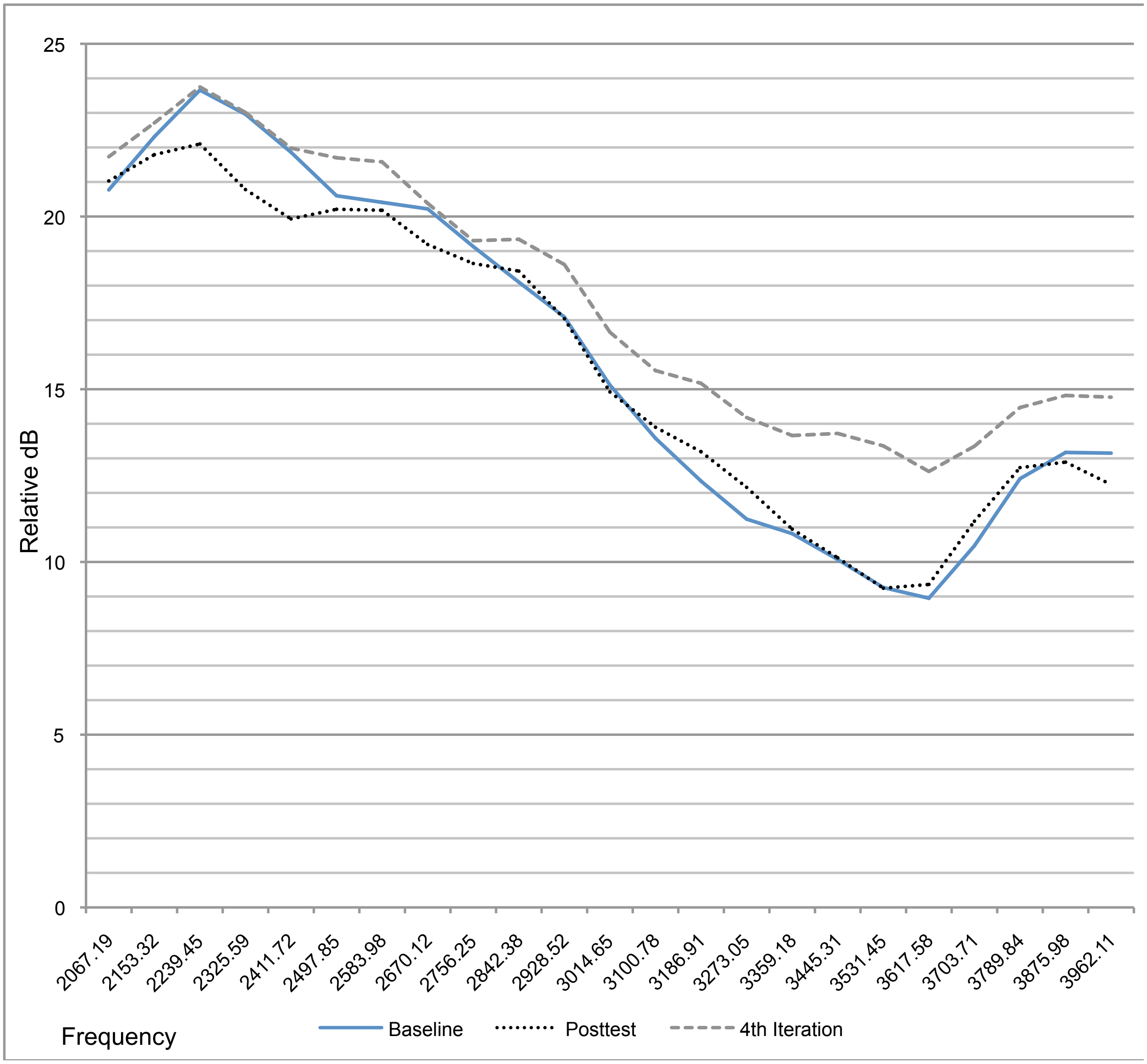

Figure I14. 4th gestural iteration of "Over the Rainbow" – singer's formant – low, circular arm gesture.

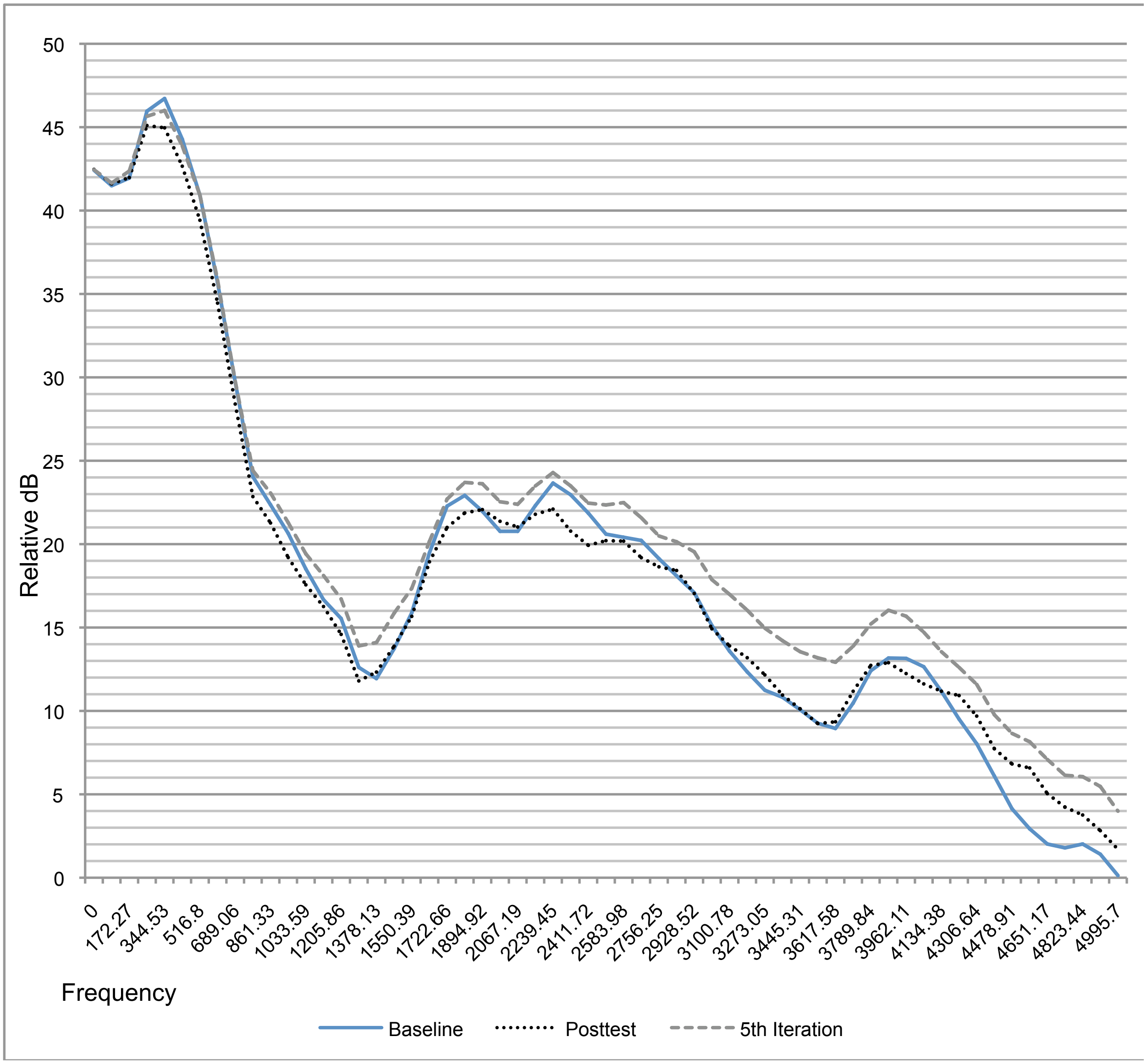

Figure I15. 5th gestural iteration of "Over the Rainbow" – entire spectrum – low, circular arm gesture.

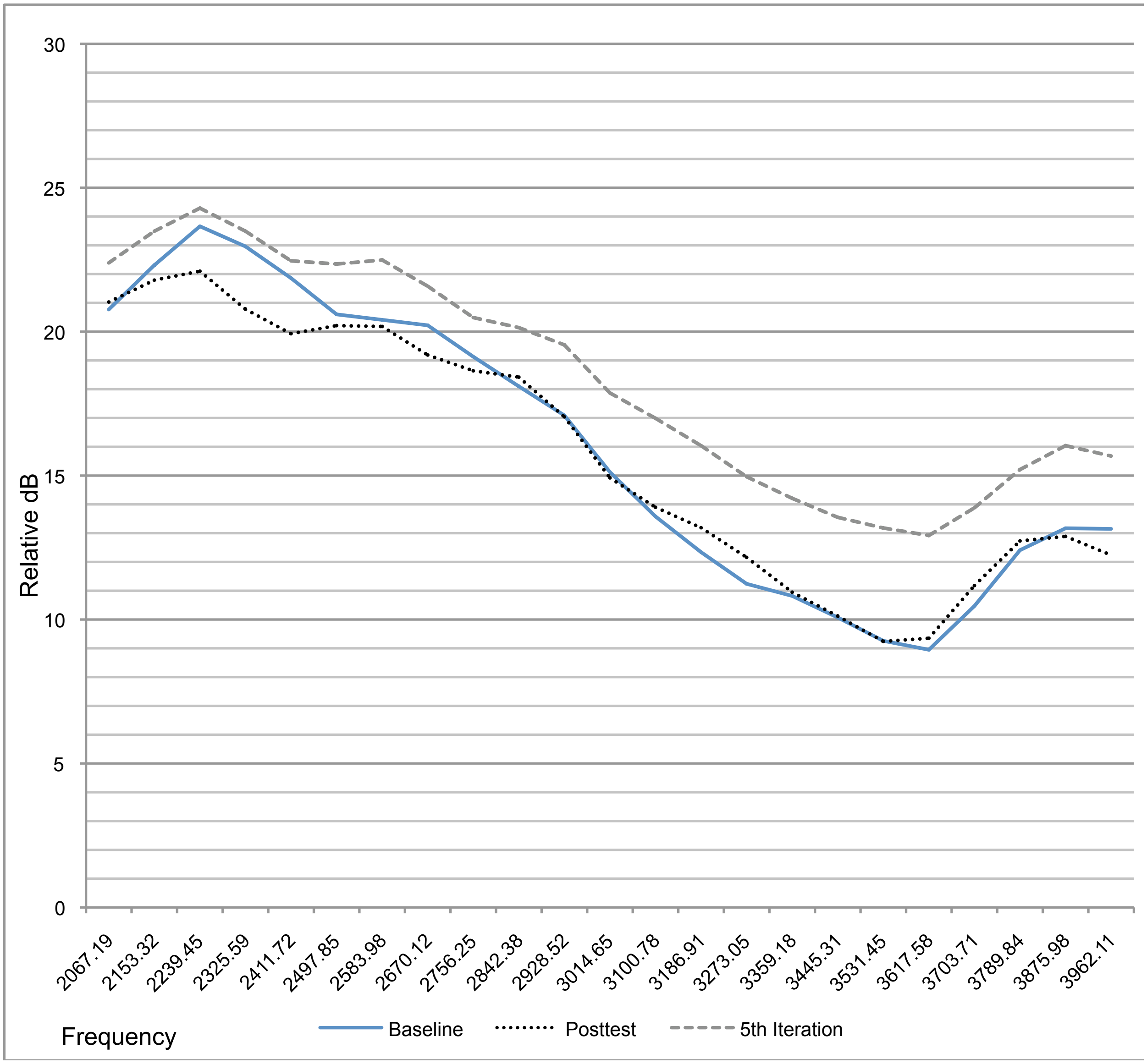

Figure I16. 5th gestural iteration of "Over the Rainbow" – singer's formant – low, circular arm gesture.

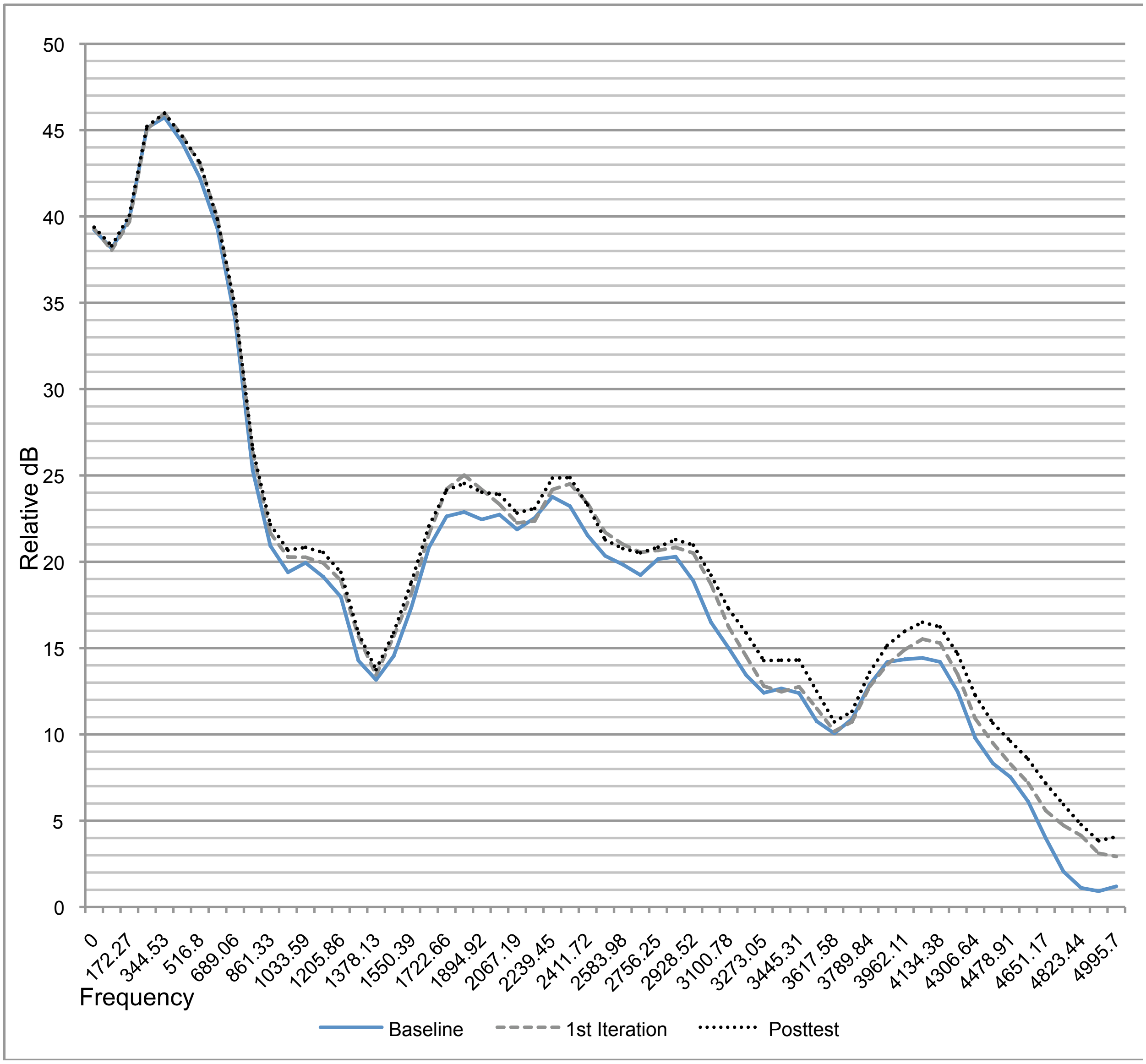

Figure I17. 1st gestural iteration of "Singin' in the Rain"- entire spectrum – pointing gesture.

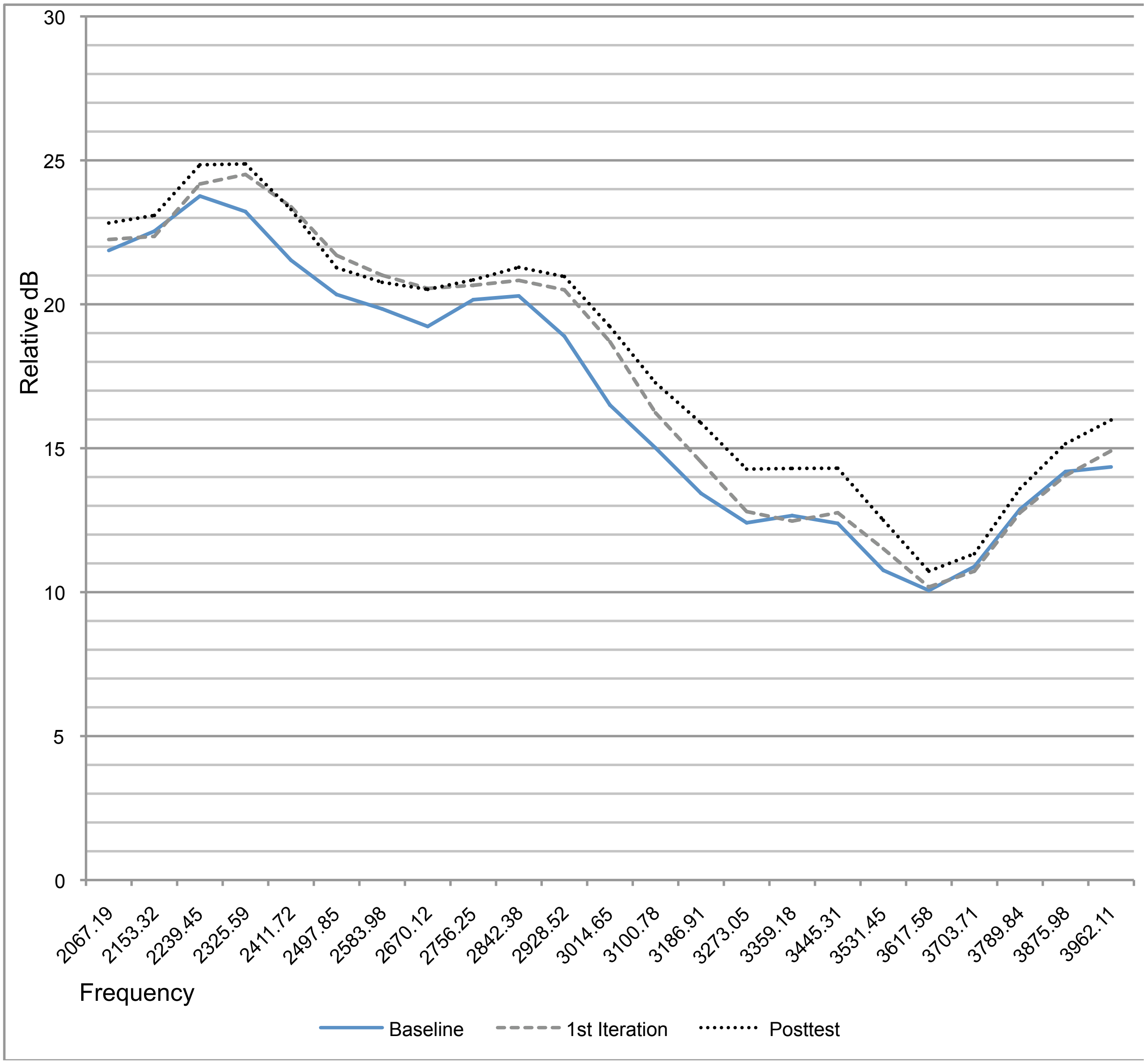

Figure I18. 1st gestural iteration of "Singin' in the Rain"- singer's formant region – pointing gesture.

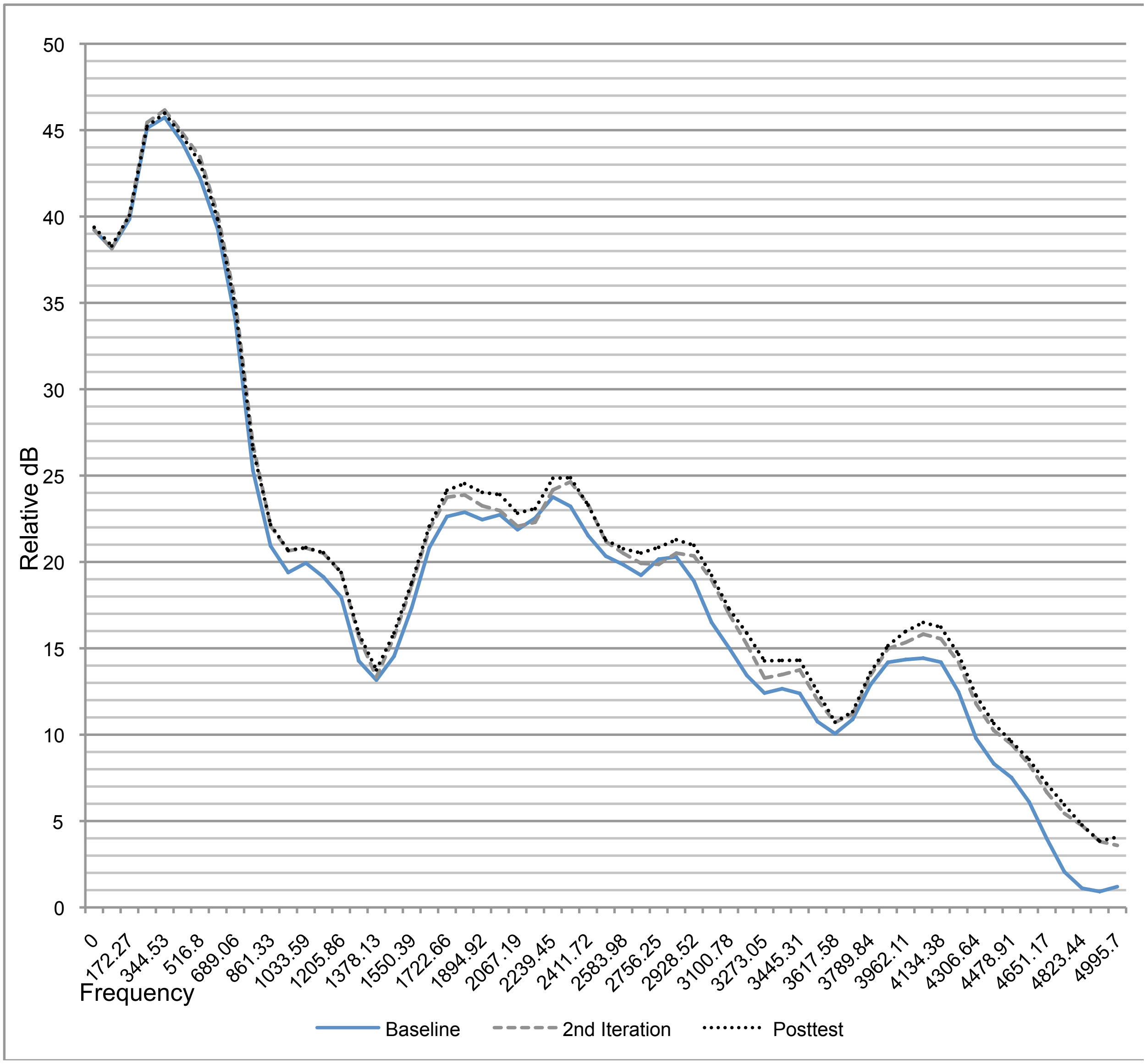

Figure I19. 2nd gestural iteration of "Singin' in the Rain" – entire spectrum – pointing gesture.

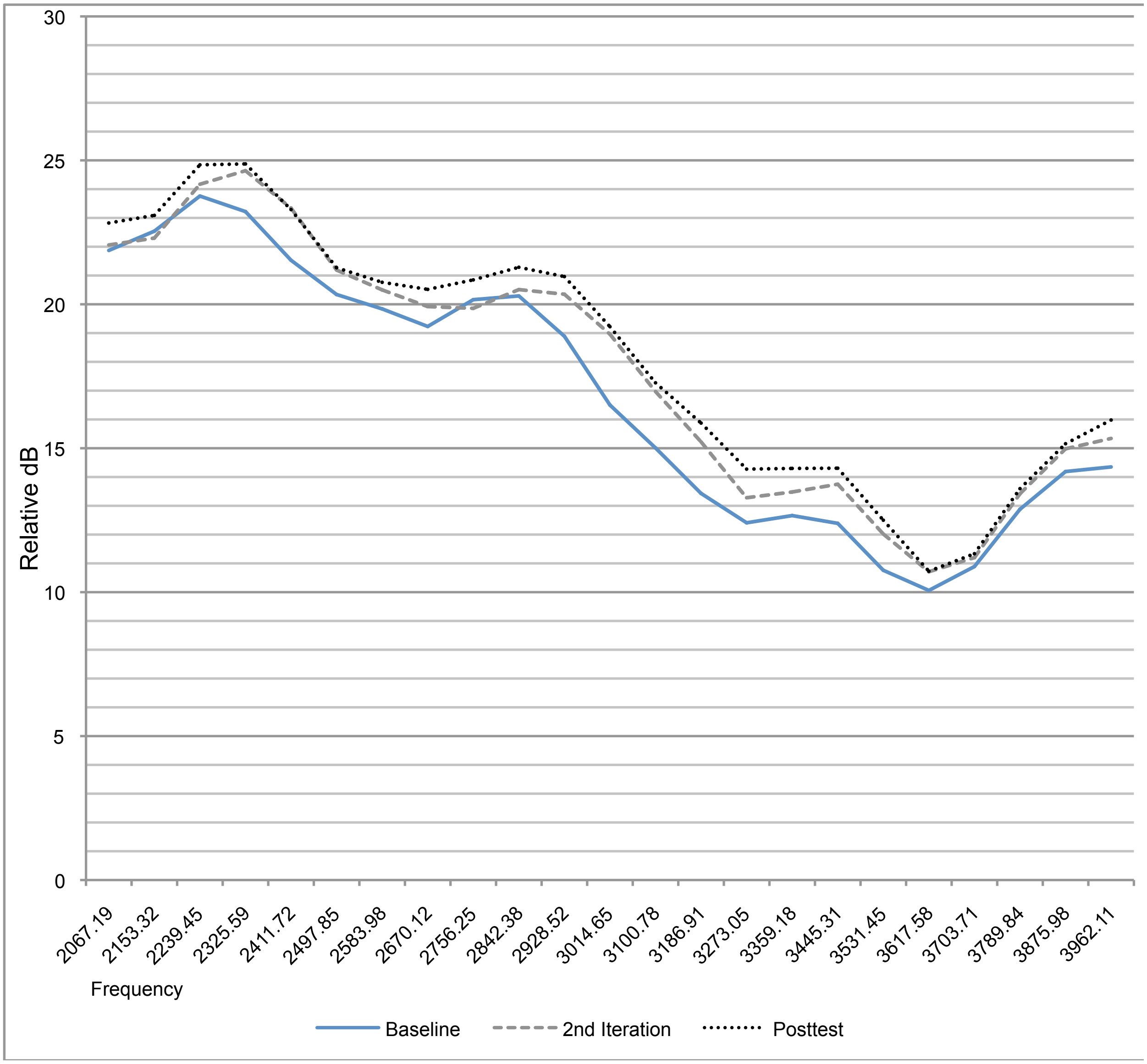

Figure I20. 2nd gestural iteration of "Singin' in the Rain" – singer's formant region – pointing gesture.

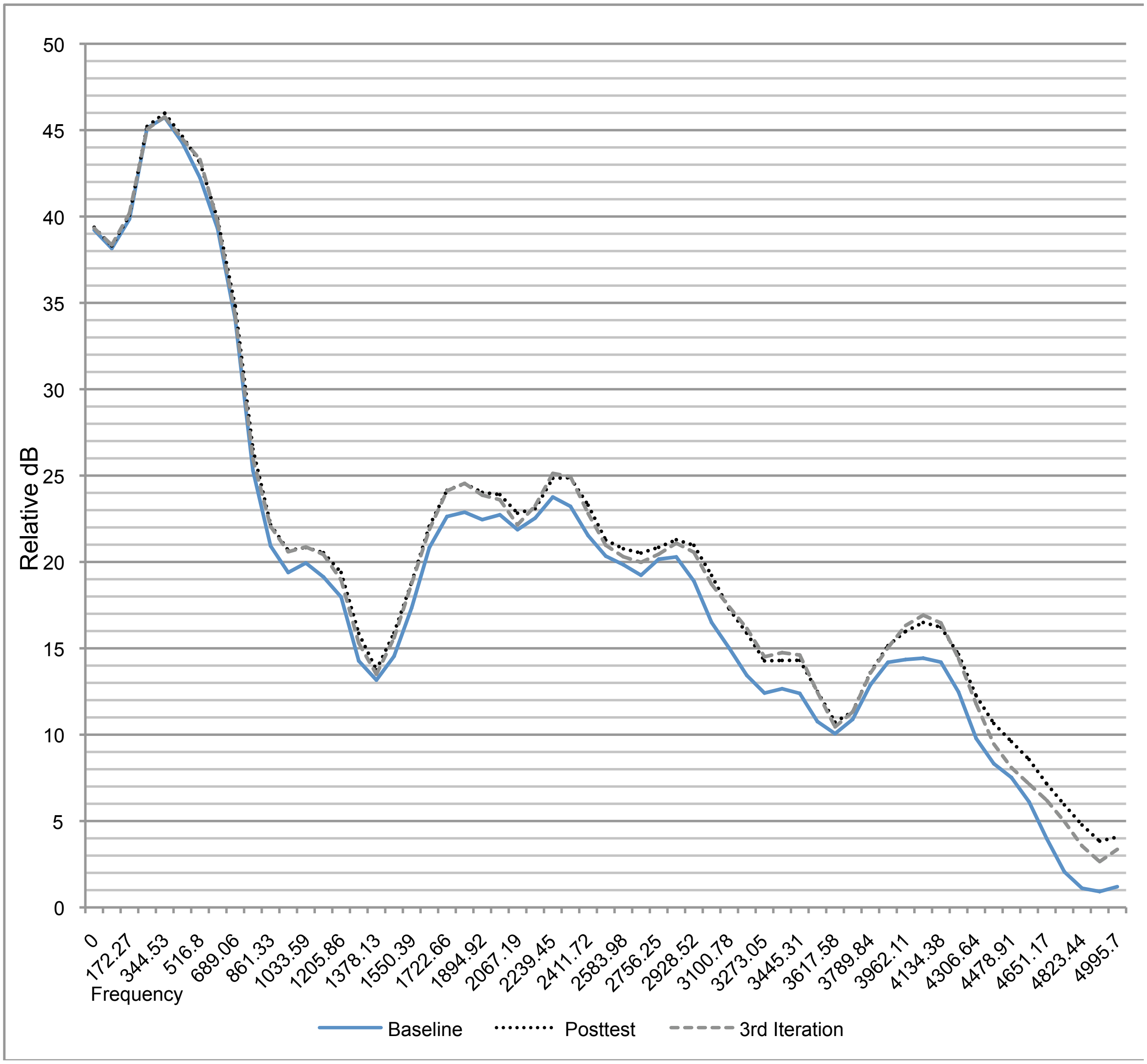

Figure I21. 3rd gestural iteration of "Singin' in the Rain" – entire spectrum – pointing gesture.

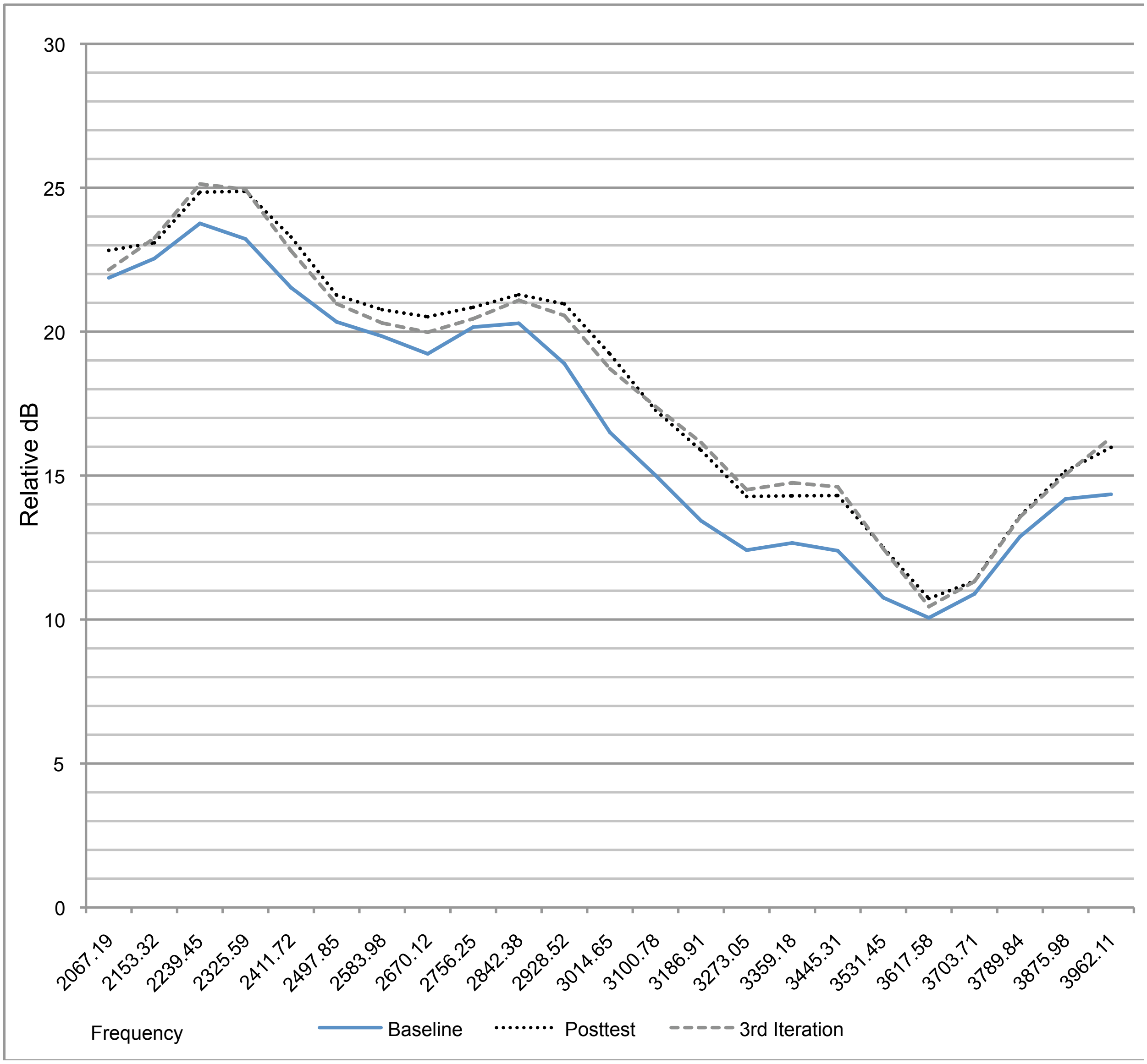

Figure I22. 3rd gestural iteration of “Singin’ in the Rain” – singer’s formant region – pointing gesture.

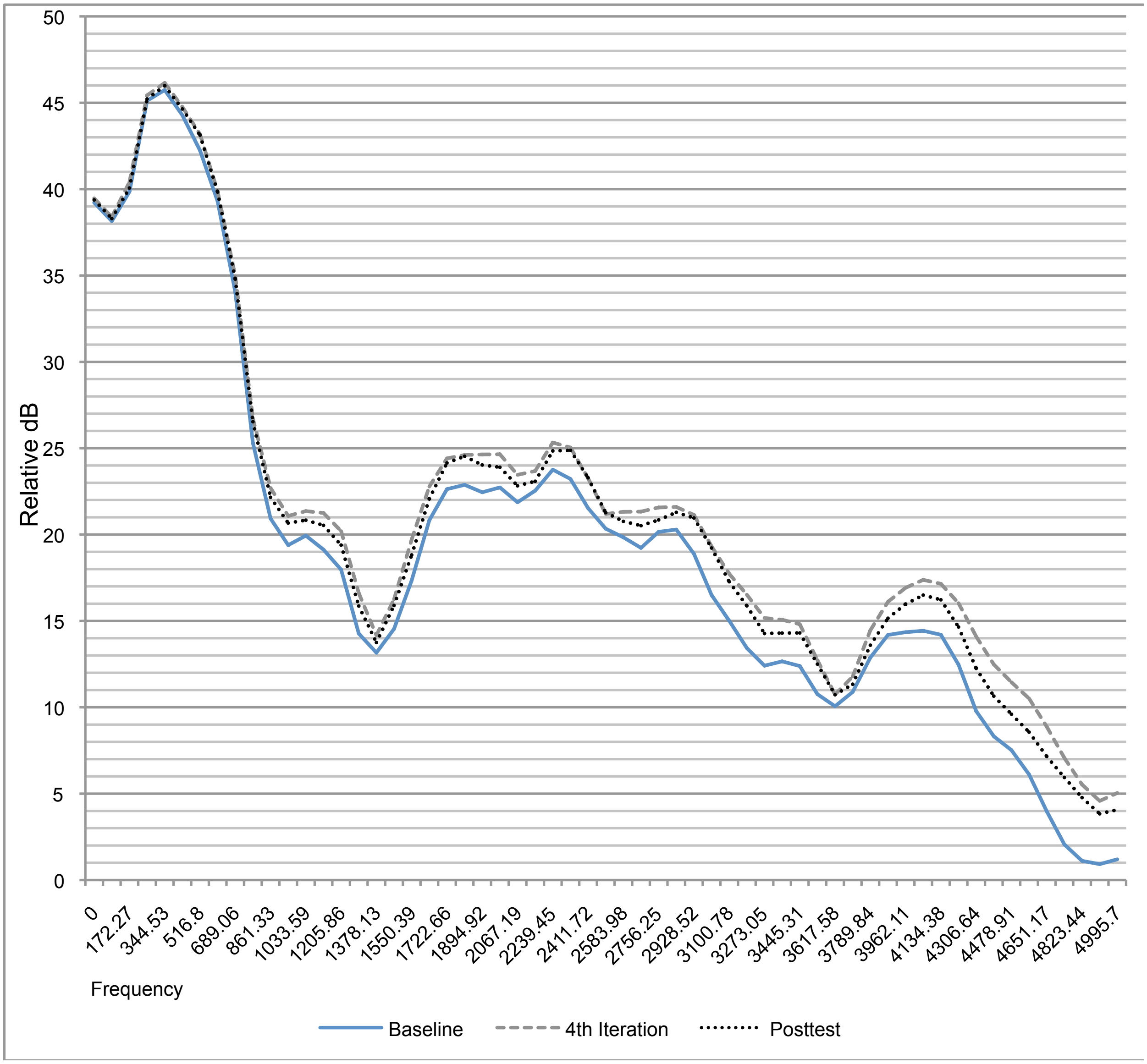

Figure I23. 4th gestural iteration of “Singin’ in the Rain” – entire spectrum – pointing gesture.

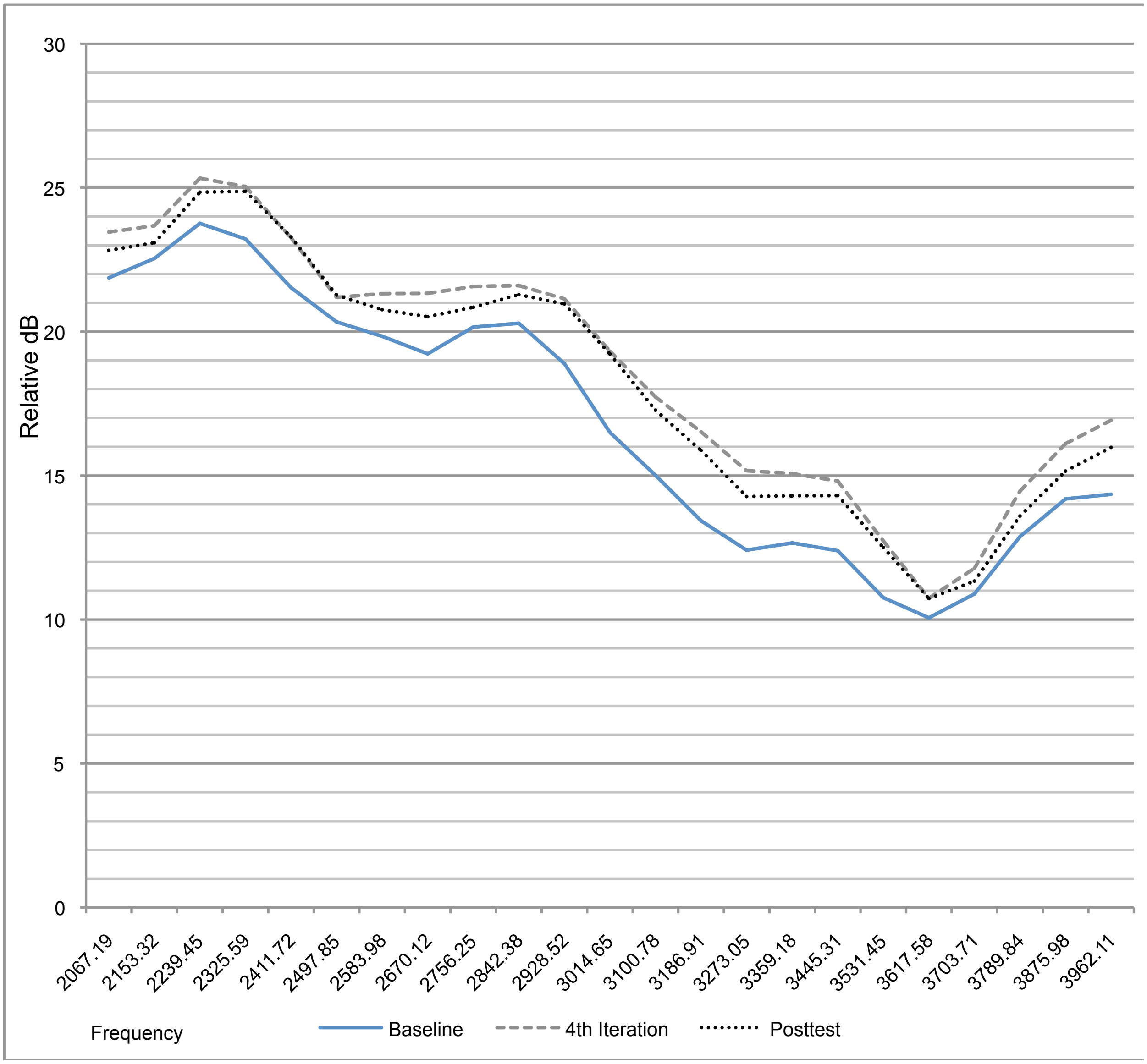

Figure I24. 4th gestural iteration of "Singin' in the Rain" – singer's formant region – pointing gesture.

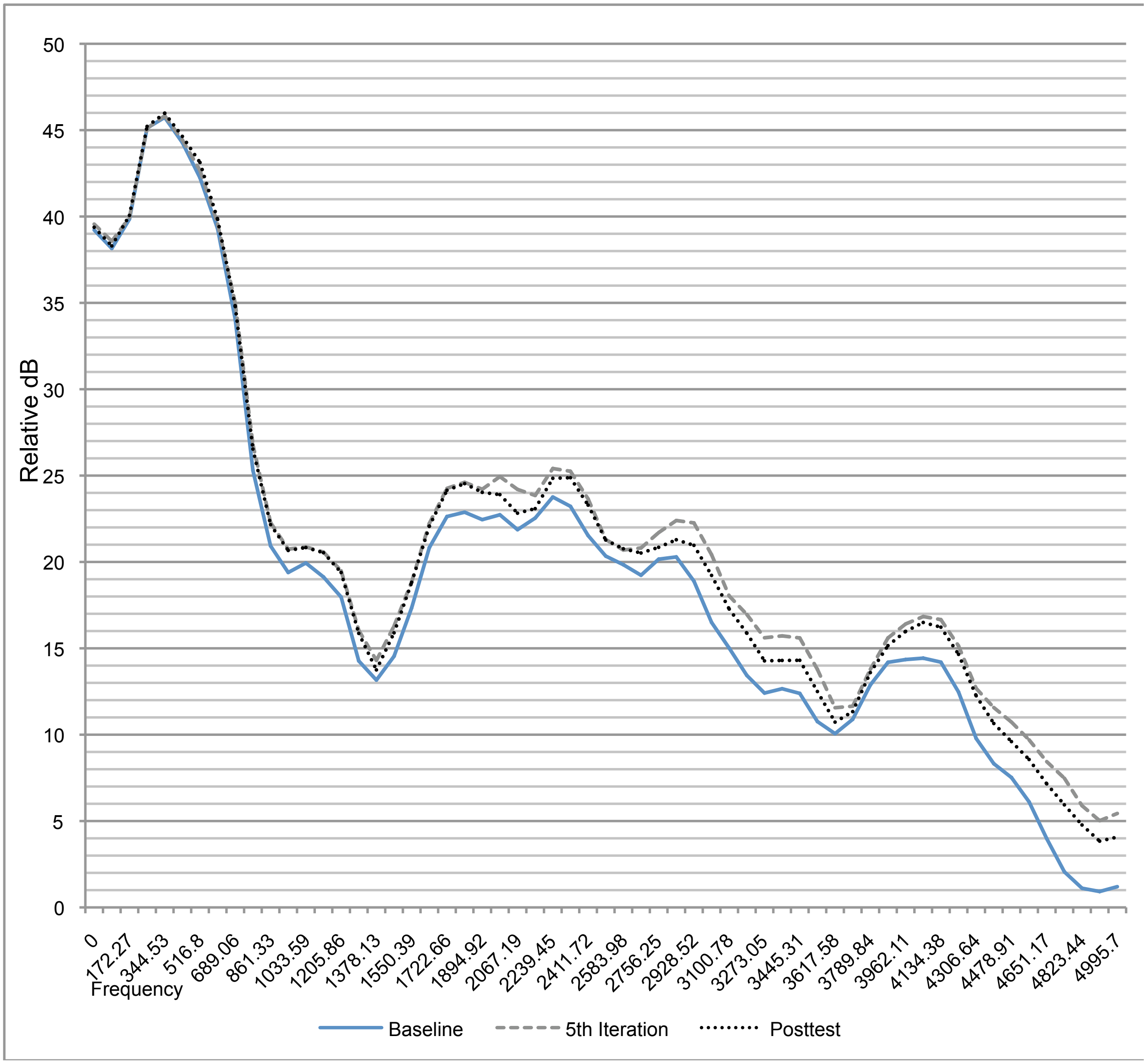

Figure I25. 5th gestural iteration of “Singin’ in the Rain” – entire spectrum – pointing gesture.

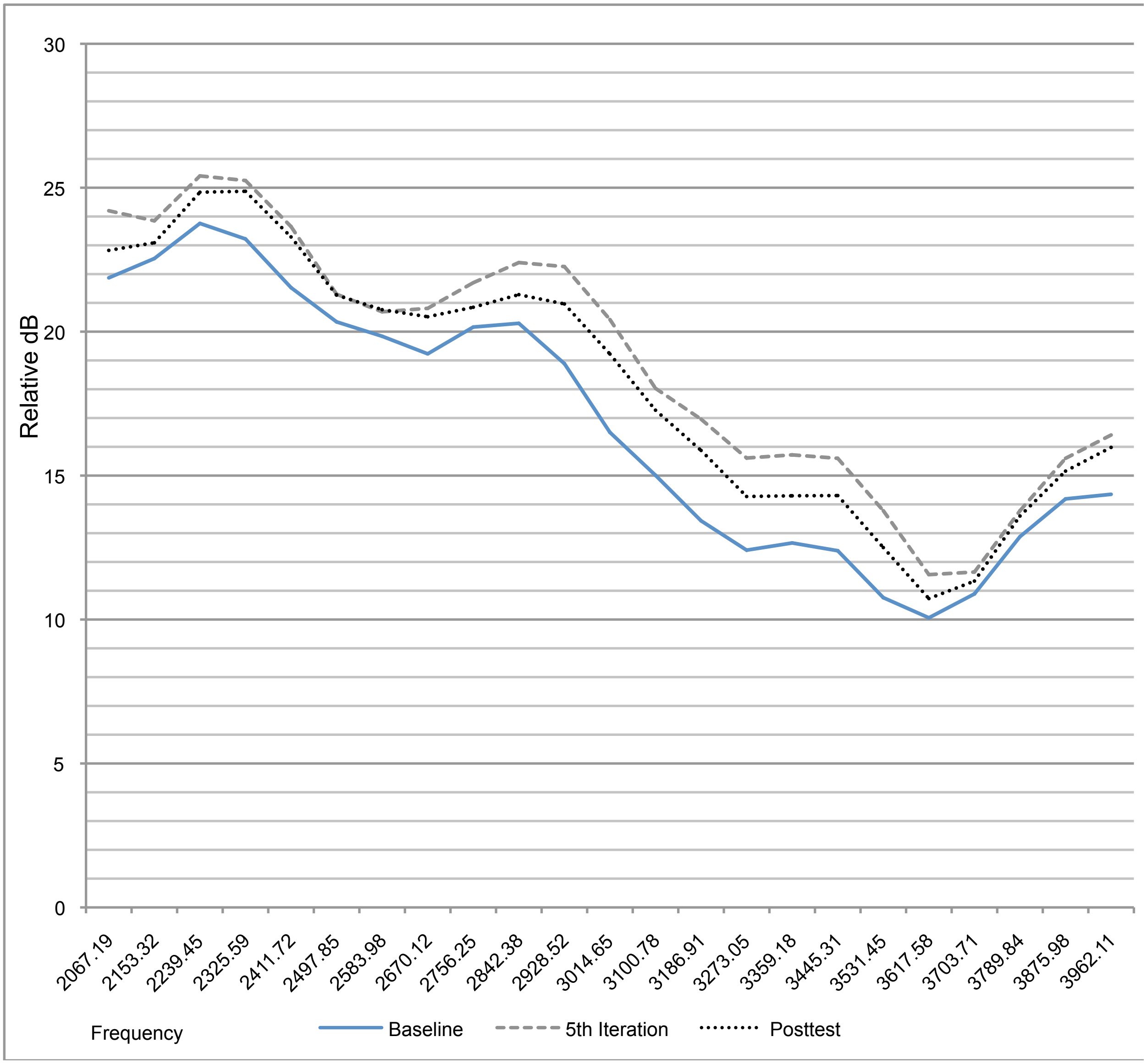

Figure I26. 5th gestural iteration of "Singin' in the Rain" – singer's formant region – pointing gesture.

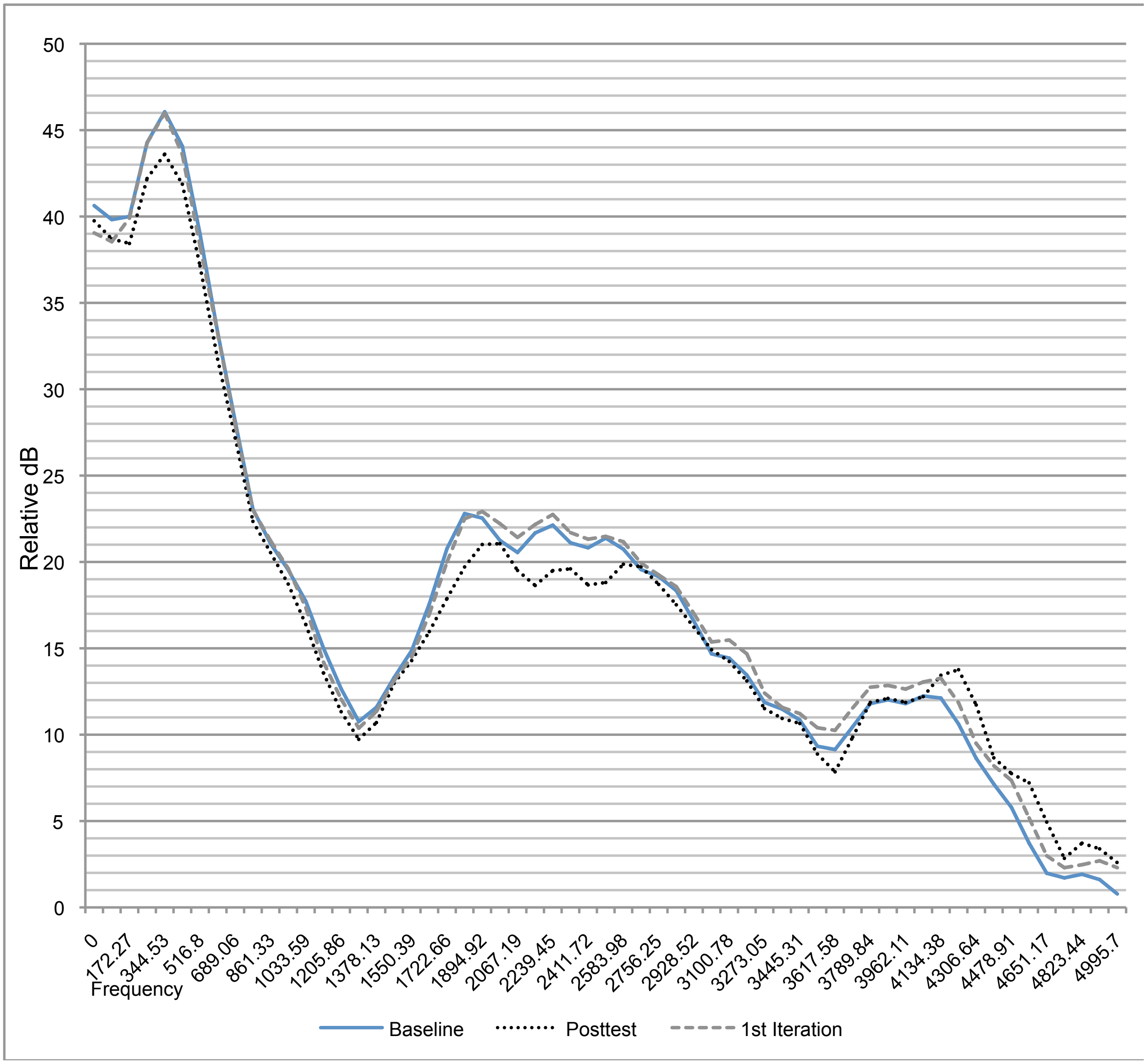

Figure I27. 1st iteration of "Hawaiian Rainbows" – entire spectrum – arched hand gesture.

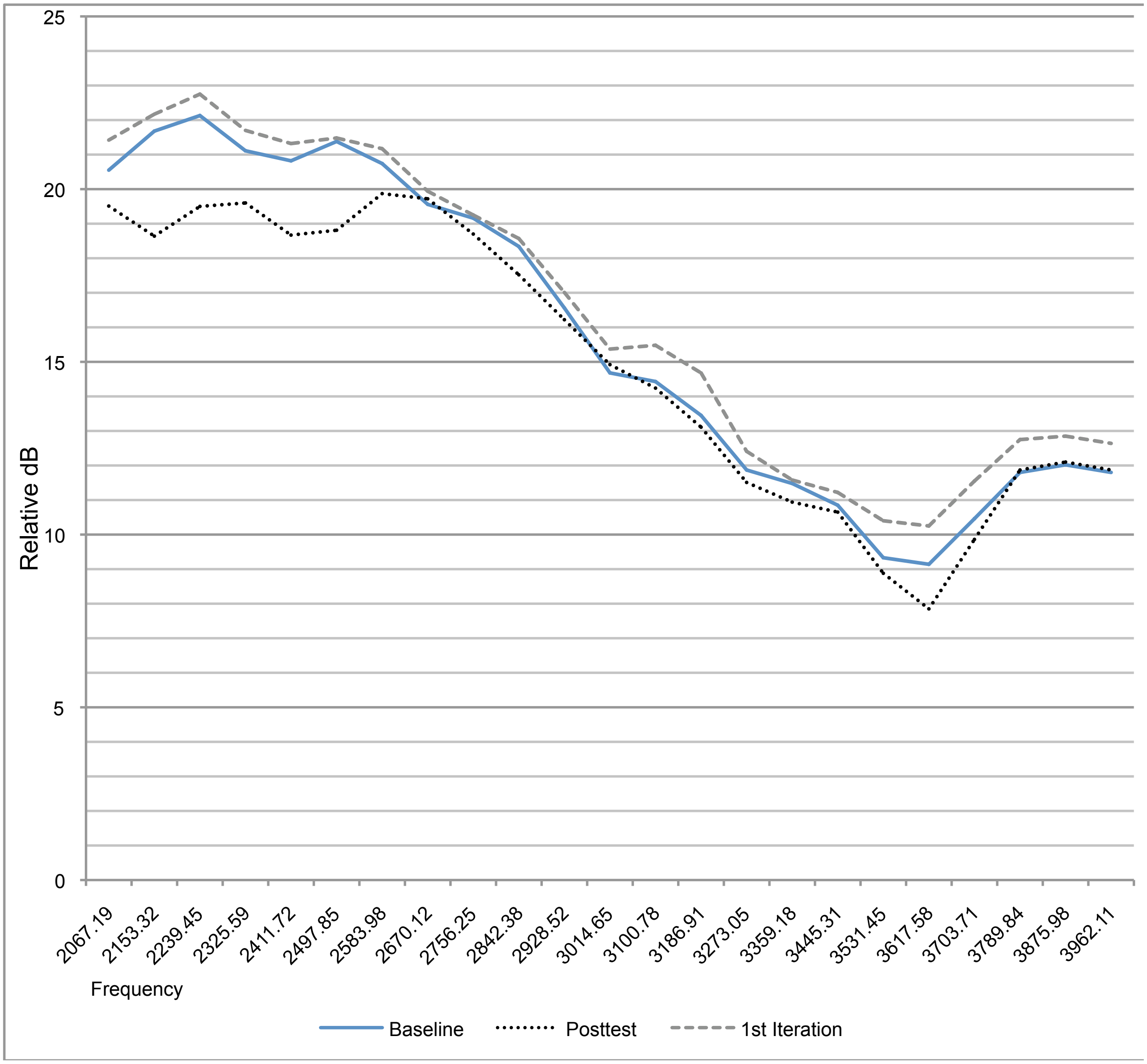

Figure I28. 1st iteration of "Hawaiian Rainbows" – singer's formant region – arched hand gesture.

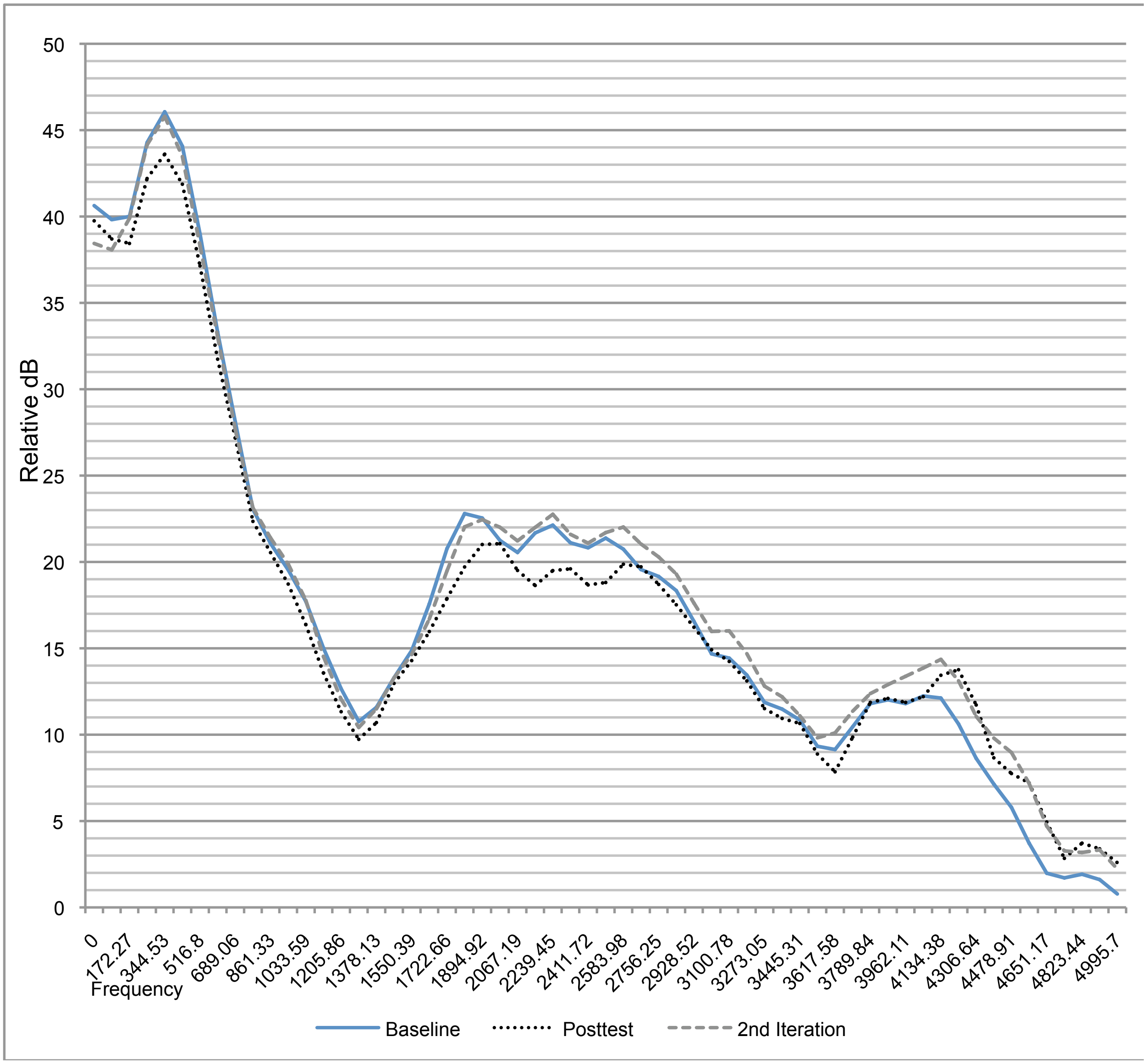

Figure I29. 2nd iteration of "Hawaiian Rainbows" – entire spectrum – arched hand gesture.

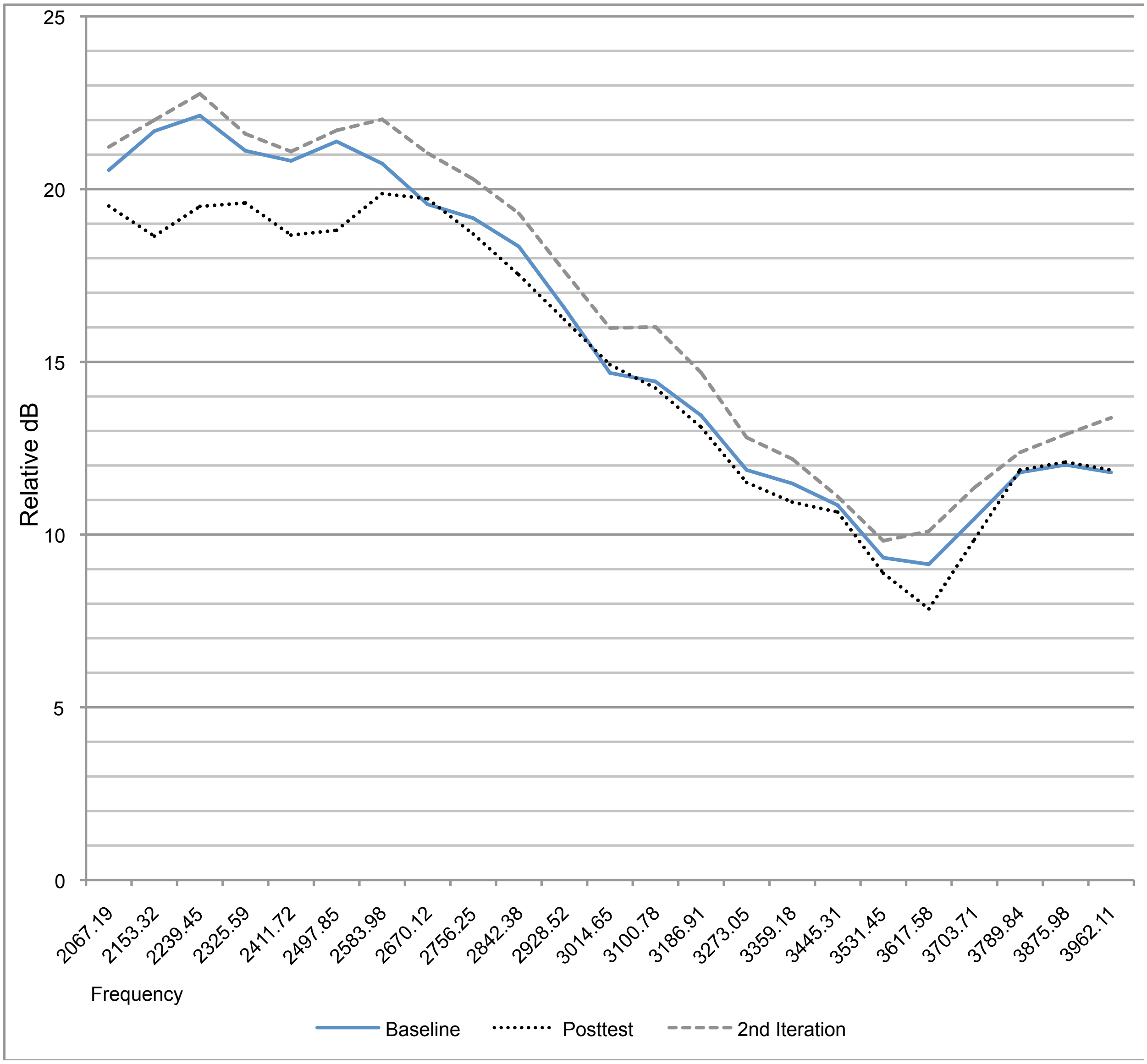

Figure I30. 2nd iteration of "Hawaiian Rainbows" – arched hand gesture.

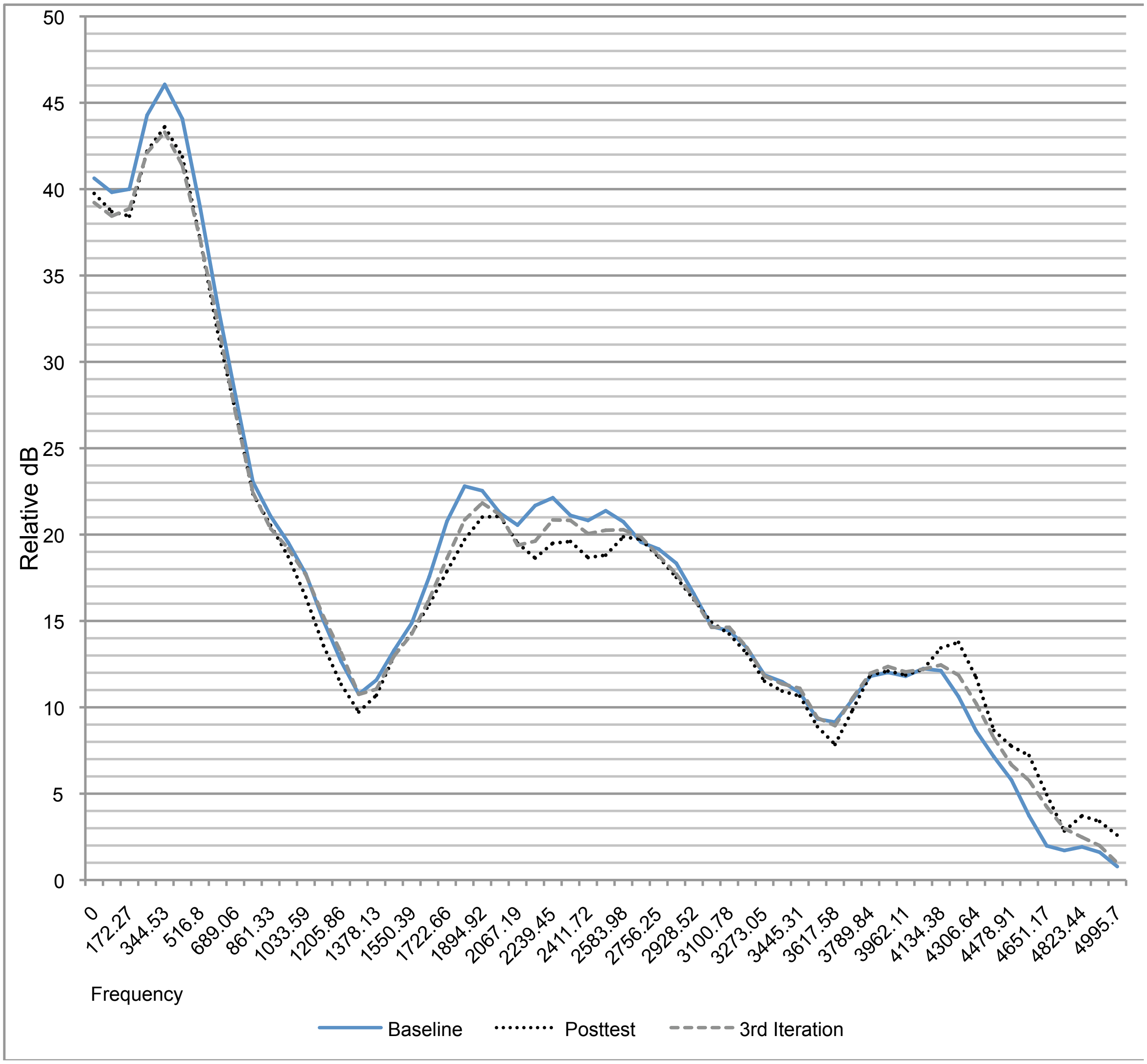

Figure I31. 3rd iteration of "Hawaiian Rainbows" – arched hand gesture.

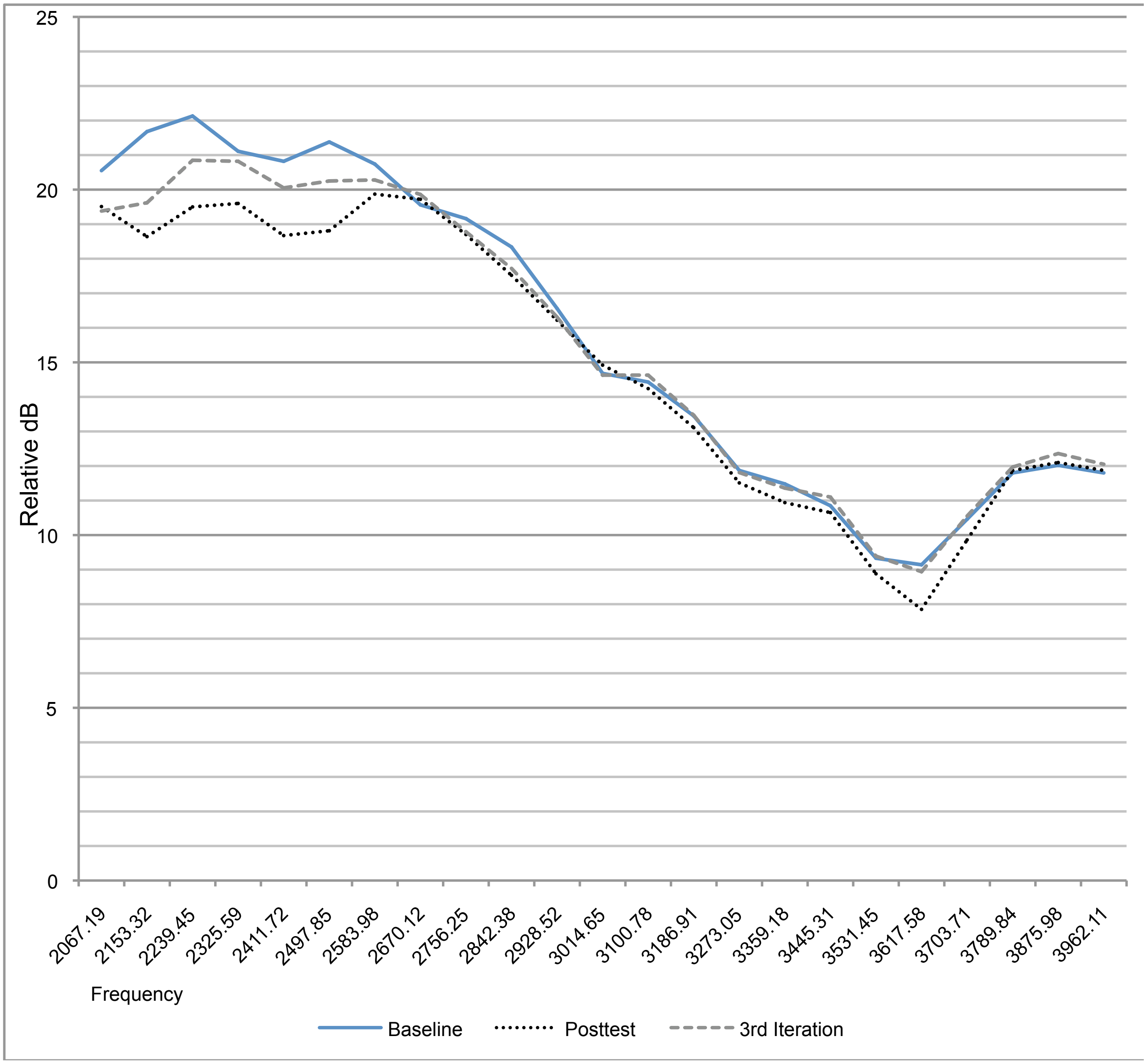

Figure I32. 3rd iteration of "Hawaiian Rainbows" – arched hand gesture.

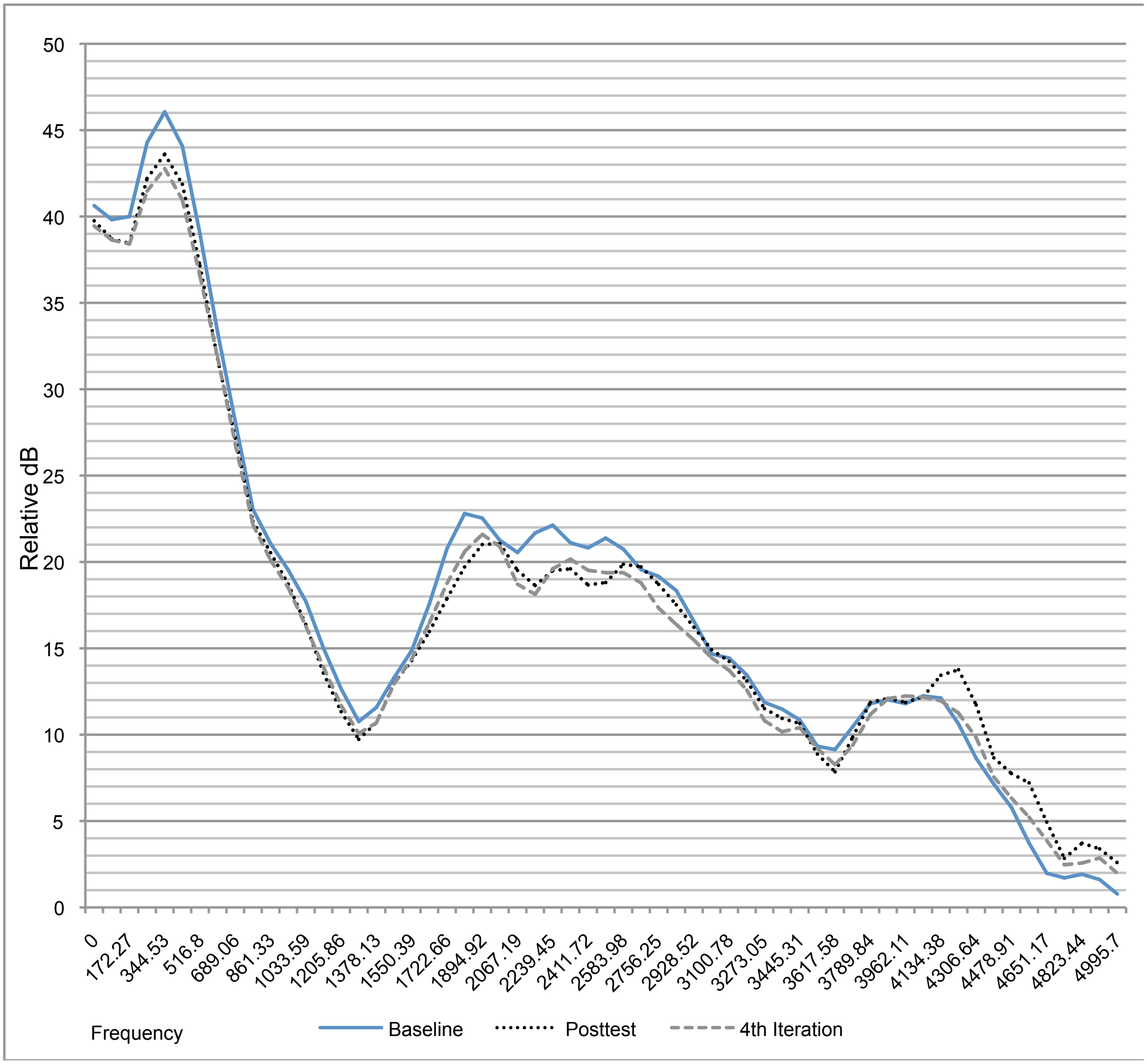

Figure I33. 4th iteration of "Hawaiian Rainbows" – entire spectrum – arched hand gesture.

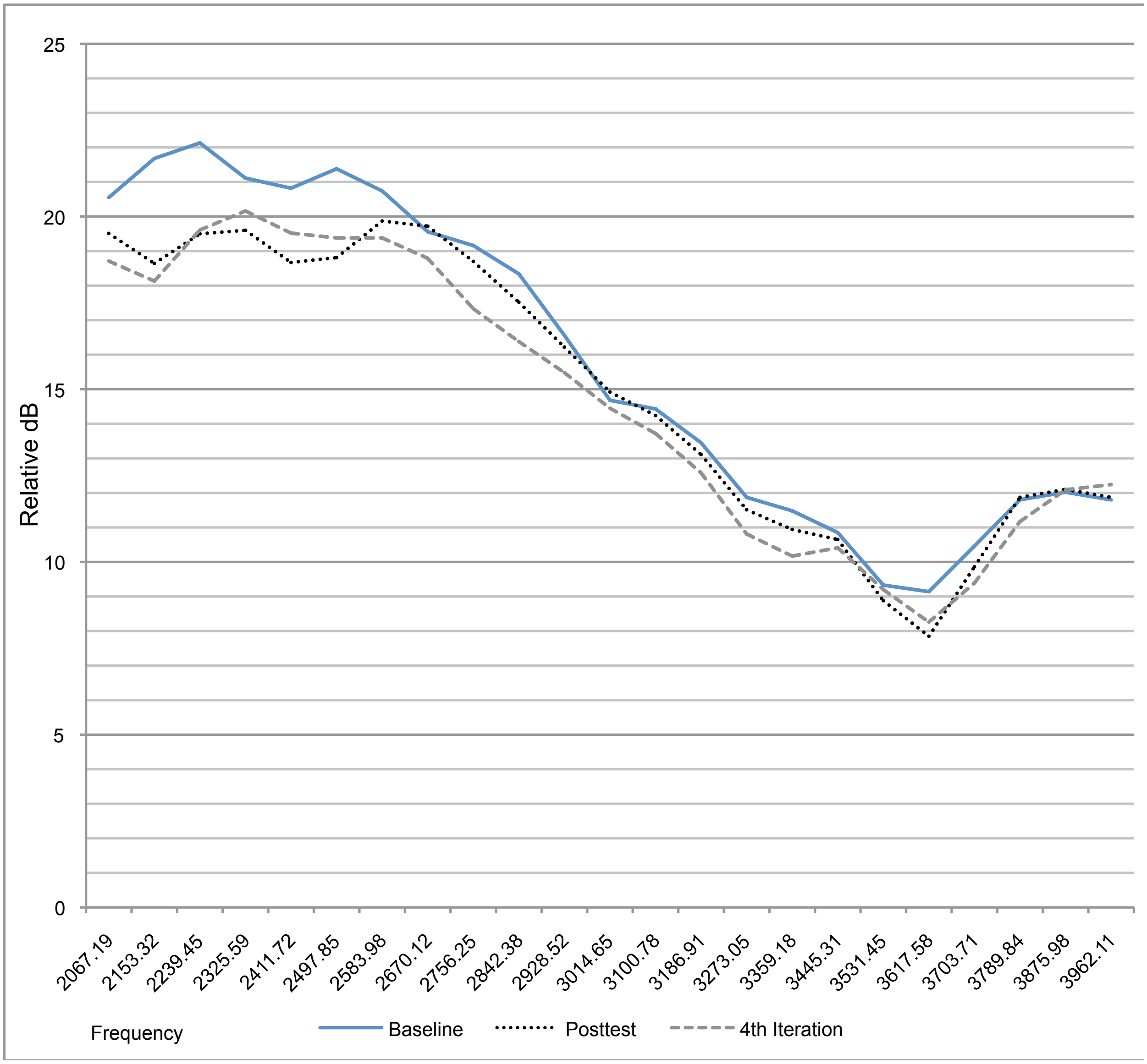

Figure I34. 4th iteration of "Hawaiian Rainbows" – singer's formant region – arched hand gesture.

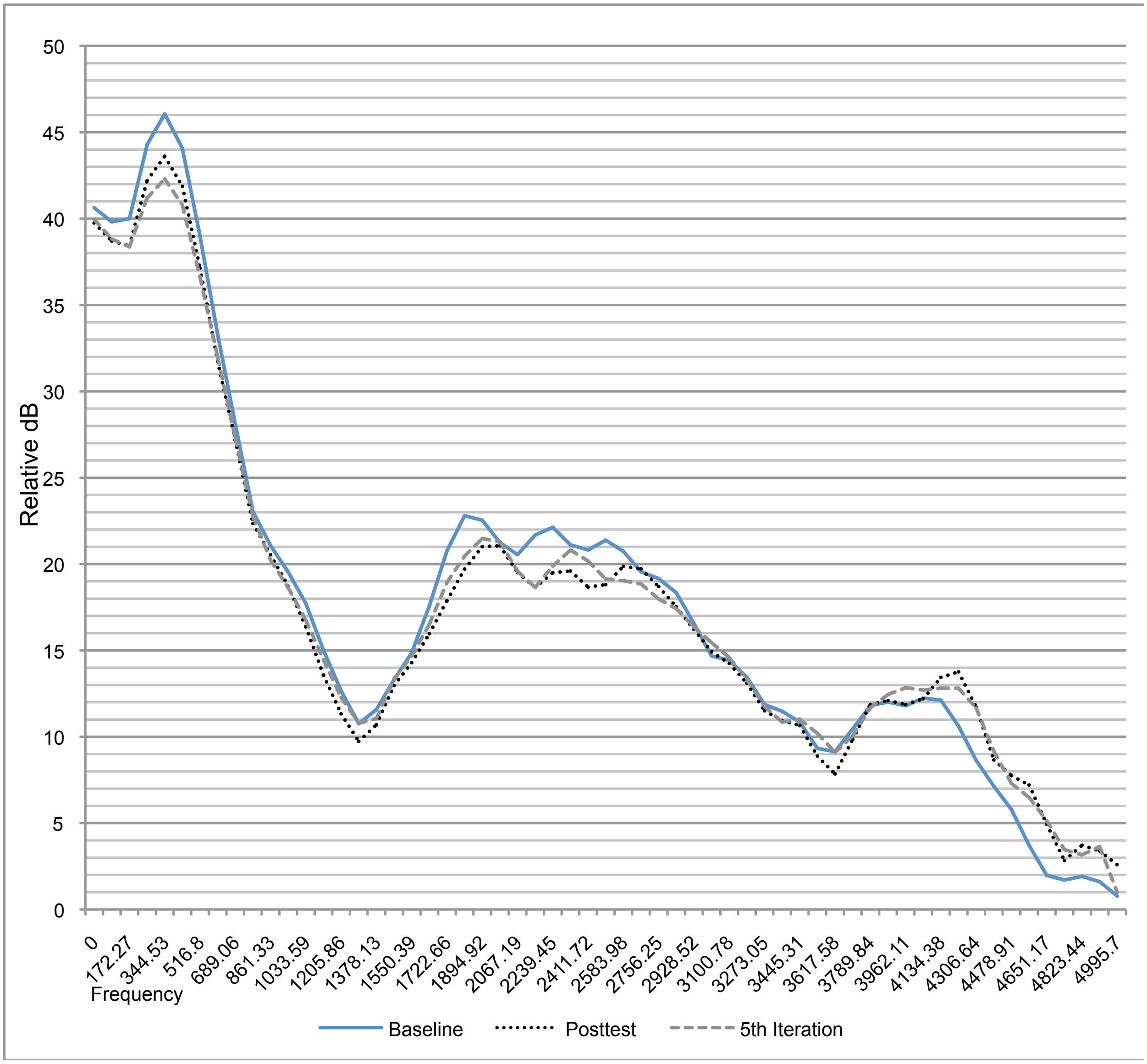

Figure I35. 5th iteration of "Hawaiian Rainbows" – entire spectrum – arched hand gesture.

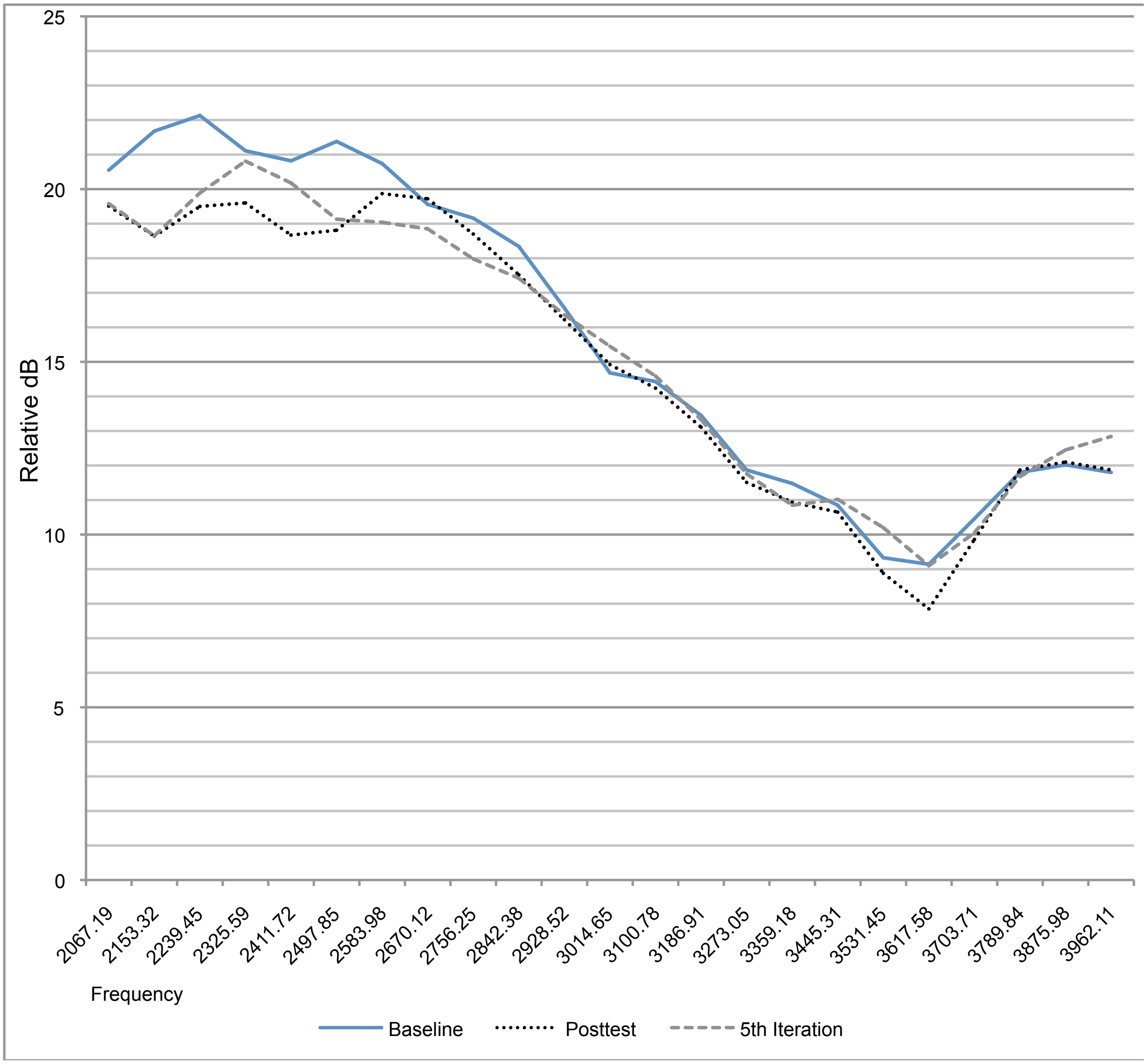

Figure I36. 5th iteration of "Hawaiian Rainbows" – singer's formant region – arched hand gesture.