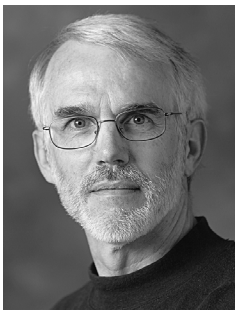
Scott McCoy, Associate Editor

The Pedagogic Use of Absolute Spectral Tone Color Theory

Kenneth Bozeman



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In 2015 Ian Howell of the New England Conservatory introduced into the voice pedagogy community the concept and term *absolute spectral tone color* (ASTC) from the field of psychoacoustics. The basic premise of ASTC is that, just as humans perceive light frequencies as colors, humans perceive sound frequencies both as degrees of brightness or darkness and simultaneously as vowel-like tone colors. Low frequencies (below C_5) seem dark and /u/-like, while high frequencies (above C_7) seem bright and /i/-like. Frequencies in between display intermediate degrees of brightness and vowel quality (Figure 1).

From this theory we understand that all sound is perceived by humans as comprised of various combinations and mixtures of spectral tone colors, and that a narrow stratum of sound from any source will share the same tone color to human perception. Vocal tone is therefore a blend of the tone colors of the harmonics being featured by its resonances (formants). The first two formants contribute qualities such as degrees of warmth, depth, brightness, and vowel identity. The singer's formant cluster (SFC) contributes a ringing quality. I have previously observed that as singers traverse their ranges and harmonic sets rise through formants, vowel and timbral qualities emanating from the same vocal tract shape grow increasingly closer. That is, vowels migrate or passively modify without vocal tract shape change. ASTC adds a very helpful degree of specificity to our understanding of how this perceptual phenomenon occurs.

SOME IMPLICATIONS OF ABSOLUTE SPECTRAL TONE COLOR

If one considers the typical range/tessitura of vocal tract resonances in the light of ASTC, these implications follow:

- The lowest resonance (F_1) of the vocal tract is almost always in contact with or within the treble clef. This is the spectral tone color range of /u/ and /o/ with occasional excursions of high treble voices into /ɔ/. This circumstance clarifies the mechanism by which the first formant (F_1) is contributing depth, warmth, and roundness to the tonal construct. It also means that the vowels /u/ and /o/ are actually defined by the tone color contribution of F_1.
- The second resonance of the vocal tract (F_2) typically begins just above the treble clef (at about G_5) and extends to about C_7, which is in the spectral

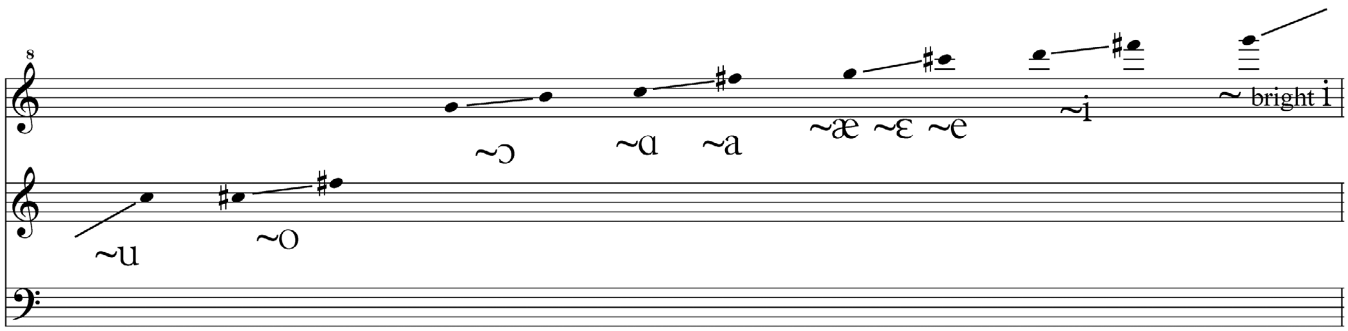

Figure 1. **Absolute Spectral Tone Colors (adapted with permission from Ian Howell, "Parsing the Spectral Envelope: Toward a General Theory of Vocal Tone Color" [DMA Thesis, New England Conservatory of Music, 2016]).**

tone color territory of /ɔ ɑ a æ ɛ e i/. This circumstance clarifies how the second formant contributes specifically to the identities of that set of vowels. Being higher in frequency also means that F_2 contributes some degree of clarity, projection, or brightness.

- The third resonance area of the vocal tract is the so-called singer's formant cluster (F_{sfc}), a gathering together of formants three through five, usually within the top octave of the keyboard (C_7-C_8). This is the tone color territory of /i/ to very bright /i/. Thus the "ringing" or brilliant quality of a tone is essentially a bright /i/ tone color component, regardless of the composite vowel.

The overall tone quality percept is then a blend of the spectral tone colors of harmonics being featured by at least these three vocal tract resonances. For most tones, these three contributions can be summarized as:

- F_1 : warmth, roundness, depth, and for /u/ or /o/, vowel identity.
- F_2 : clarity, degree of brightness, and for /ɔ ɑ a æ ɛ e i/ vowel identity.
- F_{sfc} : ring, projection, forwardness/brightness percept.

THE SINGER'S PERCEPTION

The question remains as to how the singer perceives or may be trained to perceive these individual components. Howell and I propose that singers can learn to attend to the various components in useful ways. The lowest resonance, though tuned by overall tube length, degree of pharyngeal space, and degree of mouth/jaw opening, is primarily sensed in the pharynx and can be termed a kind of "under vowel." The second resonance, though primarily tuned by changes in tongue shape, is perceived to be located in the mouth and along the "ceiling" of the vocal tract, can be termed a kind of "over vowel." The singer's formant cluster is tuned by the epilarynx and various microadjustments along the vocal tract, and is also perceived/felt to be higher, often in the area of the nasopharynx and in the bony structures of the front quarter of the skull (the so-called mask area). As singers learn to attend to and gain skill in adjusting the vocal tract to change the quality and percentage of over and under vowel contributions, their ability to achieve acoustic efficiency improves significantly.

IDENTIFYING AND EXPLORING OVER VOWEL AND UNDER VOWEL TONE COLORS AND FREQUENCIES

It is useful to explore the effects of vocal tract resonances (formants) on these tone color components. To do this, a frequency rich sound source must be introduced into the resonator. This has been done in various ways to explore formant tuning; for example, vocal fry is recommended by Donald Miller and used by a number of teachers and researchers for this purpose. It is best for revealing lower formants, and with practice can be done at close to typical phonation vocal tract postures.

This author proposes the use of an open-throated whisper to generate a wider band of frequencies for revealing or "playing" the formant contributions of the vocal tract. However, in instinctive whispering, the pharynx is typically narrowed and the larynx raised to highlight the higher frequencies of the orally sensed second resonance or over vowel, where, as we now understand from ASTC, most vowels are defined. For this reason, it is difficult to produce a strong, true /u/ or /o/ in typical whispering, since they are defined by the pharyngeally sensed lower first resonance. Those vowels are either significantly modified in whispering to be defined by the higher over vowel resonance, or are significantly quieter. In open-throated whispering, the student attempts to whisper (introduce an /h/more deeply and with closer approximation resistance at the glottis) through an idealized vocal tract shape with a neutral or slightly lower larynx. The goal is to achieve a *chiaroscuro* whisper with both low and high frequency components—a sort of "Darth Vadar"–like sound.

Certain affects, such as inner amusement or pathos, can help motivate the lower, more open laryngopharynx without recruiting tongue depression. With practice the student may be able to notice the vowel color and the frequency of both over and under vowels. For example, in the author's voice, the sequence /i e ɛ ɑ ɔ o u/ if well tuned, results in the over vowel "tune:" B_6 A_6 G_6 D_6 B_5 A_5 G_5. This is so reliable that, though lacking "perfect pitch," I can locate the pitch class "A" from the tone color frequency of my /e/ vowel. It is also possible to predict with reasonable accuracy the pitch excursions of high frequencies from coloraturas or sirens via their tone colors. The under vowel pitch and tone color can be brought out more by whispering with a deepening affect, such as warm-hearted pathos. Vowels with widely separated resonances can then be heard as a duet between the "pitches" of the first and second resonances. Spectral tone colors of vowels with more closely associated first and second resonances tend to blur together perceptually.

EXAMPLES OF PEDAGOGIC USE OF THE CHIAROSCURO WHISPER

Active Modification of /i/

The /i/ vowel most frequently needs active vowel modification: for nontreble males wanting to stay in robust, "virile" timbre, the first resonance should be raised to stay above the sung pitch, since matching the sung pitch with the first resonance would result in whoop timbre, a quality more appropriate for sweet quiet tones or for countertenor timbre. Treble voices will need to modify for pitches above the first resonance in order to maintain fullness of whoop timbre. Since the identity of the/i/ comes from the tone color of a very high pitched second resonance, an /i/ can be sung with intelligibility quite high. However, to raise the first resonance, the mouth must be opened. How can the student explore the best way to do this? Once the "pitch" of the second resonance is clearly identified—by means of its /i/-like quality—that pitch and tone color can be maintained (by means of the height of the tongue dorsum and the exposure of the front of the mouth) while experimenting with degrees of openness of the mouth to raise F_1. As long as the second resonance "pitch" and tone color persist, the percept of the result will be an /i/ no matter how exaggeratedly the mouth is opened in front of that tuning. The student can experiment with keeping the larynx neutral by increasing the percept of pharyngeal verticality, keeping the under vowel sensation reasonably low, the and the over vowel tuned to /i/ while increasing the degree of mouth opening. The student is usually surprised at how far the mouth can be opened—if the pitch/tone color of the over vowel is maintained—and still result in a balanced /i/.

Establishing a Settled, Open Throat

A second strategy is very good for training a settled, floating larynx with pitch ascent. It is impossible to make a true, pure, close /u/ or /o/using the *chiaroscuro* whisper unless the larynx is appropriately low and the throat appropriately open. The percept of the vowel location needs to have a significantly deep, but free laryngopharyngeal component. It is, however, very possible to depress the tongue and overhollow the mouth in the attempt, resulting in a dulled whisper. If the student is instructed to make a completely pure /u/ or close /o/ that is deep enough to be pure but simultaneously as bright or sparkling as possible, preferably through the use of an affect like strong amusement or mischief, a more relaxed, fronted tongue results and an ideal *chiaroscuro* tuning of the vocal tract can be found. These opposite directives (pure /u/ *and* high ring) are both compatible and mutually limiting. In this author's experience, it is not possible to get both without tuning the vocal tract well. Fortunately, those directives are fairly straightforward to monitor and achieve. Both of these whisper explorations increase kinesthetic awareness of how the first and second resonances of the vocal tract are tuned and increase skill and independence in

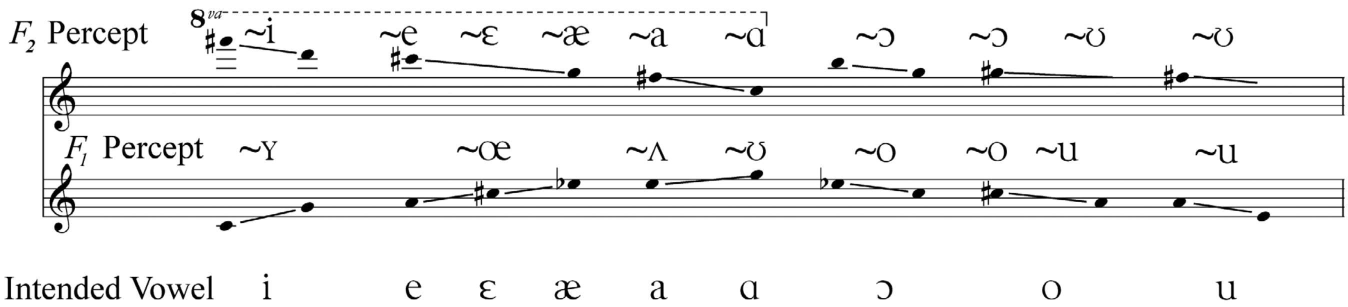

Figure 2. **Perception of the Tone Color Contributions of Vowel Formants (from Kenneth Bozeman, *Kinesthetic Voice Pedagogy: Motivating Acoustic Efficiency* [Gahanna, OH: Inside View Press, 2017]).**

their tuning. This becomes very useful in a variety of circumstances.

Perception of the Tone Color of Over Vowels and Under Vowels

The under vowel, living almost always within the treble clef, if heard in isolation, contributes an /u/ or /o/–like (occasionally /ɔ/) quality to the composite tonal percept. In context, however, most students will not perceive its isolated form when it is part of a front vowel construct. There seems to be a perceptual blending that results in a mixed under vowel percept; that is, the under vowels of front vowels take on some of the over vowel quality in addition to their rounded warmth. However, the under vowel percepts of the back vowels are closer to, or identical to their actual tone colors.

The chart in Figure 2 suggests likely over and under vowel percepts. The intended vowels are indicated below the lower clef. The perceived over vowels are indicated above and/or on the higher treble clef, and the perceived under vowels are indicated between the clefs. Notice that the over vowel (F_2) percept is the same as the intended vowel for most vowels: for all front, mid, and back vowels through /ɔ/, since the over vowel frequencies *are* the tone qualities of those vowels, but not for /o/ or /u/. Notice also that the under vowel (F_1) percept is the same as the actual under vowel tone color and intended vowel for /o/ and /u/. However, the suggested under vowel percept for the front to mid vowels /i e ɛ æ ɑ/ is mixed. (Howell has suggested that some treble voice singers at high enough fundamental frequencies are eventually able to hear the true under vowel tone colors of some front vowels—such as an /u/ under an /i/.)

SPECTRAL TONE COLOR, ACOUSTIC REGISTRATION, AND VOWEL MODIFICATION

These mixtures of resonance(formant)/harmonic contributions to tone color offer possible explanations for historical strategies of active vowel modification. The term vowel modification in voice pedagogy writings has usually meant what I term "active vowel modification"—changes of vowel timbre effected by changes in vocal tract shaping. I have proposed the terms "passive vowel modification" or "vowel migration" for vowel changes that occur through the same vocal tract shape but at different sung pitches. Prior vowel modification strategies recommended reshaping the vocal tract in the direction of the speech level vowel shape of the perceived under vowel. For example, singers were encouraged to modify an /i/ to the shape of an /y/, or an /ɛ/ to the shape of an /œ/, reducing or compromising intelligibility for the sake of fuller resonance. When the degree of independence in the role of the pharynx in tuning those under vowel percepts is understood, this degree of active modification becomes reduced or unnecessary. Rather, ensuring and maintaining a settled, open, or neutral laryngopharynx will contribute enough of that mixed quality to the composite result to avoid the need for heavy active modification and the unnecessary reduction in high frequency components that accompanies lip rounding. Furthermore, facial appearance can stay closer to the typical speech articulation and look of the intended vowel.

Several factors are at play here that cause timbral change and vowel migration:

- As the sung pitch is raised, the entire harmonic set rises and is more spread apart relative to available vocal tract resonances.
- If the vocal tract shape is maintained during pitch ascent, harmonics inevitably pass through formants, growing and then diminishing in intensity as they reach and surpass formant peaks.
- The vowel and overall timbre "closes" to some degree whenever a harmonic passes through the first resonance (formant), the primary acoustic shift from open timbre (*voce aperta*) to close timbre (*voce chiusa*) occurs when the second harmonic surpasses the first resonance, and maximal vowel migration occurs when the first harmonic (the fundamental frequency or the sung pitch itself) reaches the first resonance, arriving in whoop timbre.
- Furthermore, as harmonics rise with ascending pitch, their individual tone color contributions migrate as well according to the innate spectral tone colors of their rising frequencies, and the intensity of their contributions varies depending upon their locations relative to vocal tract resonance peaks.
- Vowel migration and modification is inevitable. For example, pitches above C_5 are too high to have any actual /u/ tone color present. Therefore, a true /u/ cannot exist above C_5—only an /o/-like /u/ is possible up to about F_5, and an /ɔ/-like /u/ above the treble clef. A true /o/ does not exist above the treble clef. That said, it is impressive that well produced high treble voices in textual context can often persuade us of the identity and "purity" of those vowels at pitches that cannot contain any of their actual speech level tone color.

CONCLUSION

Absolute spectral tone color theory, in combination with the effects of acoustic registration phenomena (open, close, and whoop timbres) offer the possibility of great specificity of understanding of tone and vowel quality and strategy in training the singing voice. Understanding these effects can provide a factual basis for creative kinesthetic strategies. A number of pedagogic implications are already apparent. More remain to be realized.

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Kenneth Bozeman, tenor, holds performance degrees from Baylor University and the University of Arizona. He subsequently studied at the State Conservatory of Music in Munich, Germany on a fellowship from Rotary International. He is chair of the voice department at the Lawrence University Conservatory of Music in Appleton, Wisconsin, where he teaches voice, voice science, and pedagogy. He has received both of Lawrence University's Teaching Awards (Young Teacher Award, 1980; Excellence in Teaching Award, 1996) and an endowed chair in 1999. His former students have participated as apprentices at Sante Fe, Tanglewood, Seattle Opera, Houston Grand Opera, Central City Opera, and Utah Opera, and have sung with Houston Grand Opera, Boston Lyric Opera, Opera Colorado, Wolf Trap Opera, Seattle Opera, Sante Fe Opera, and Deutsche Oper of Berlin.

Mr. Bozeman has a strong interest in the application of voice science to singing and received the 1994 Van L. Lawrence Fellowship Award from the Voice Foundation for "excellence in teaching and active interest in voice science and pedagogy." He has been a member of the Editorial Board of the *Journal of Singing* for a number of years, serving as chair since 2000.

Mr. Bozeman was an active performer of recitals and of oratorio, including singing the tenor roles in the *St. Matthew* and *St. John Passions*, the *Christmas Oratorio*, the *B Minor Mass*, the *Magnificat*, and various cantatas of Bach, Handel's *Messiah*, Haydn's *Creation*, Mendelssohn's *Elijah*, and Vaughn Williams's *Hodie*. He has performed with the Milwaukee Symphony, the Wisconsin Chamber Orchestra, the Green Lake Music Festival, the Purgatory Music Festival of Colorado, the Louisville Bach Society, the Historical Keyboard Society of Wisconsin, and on Wisconsin Public Radio's "Live from the Elvehjem."