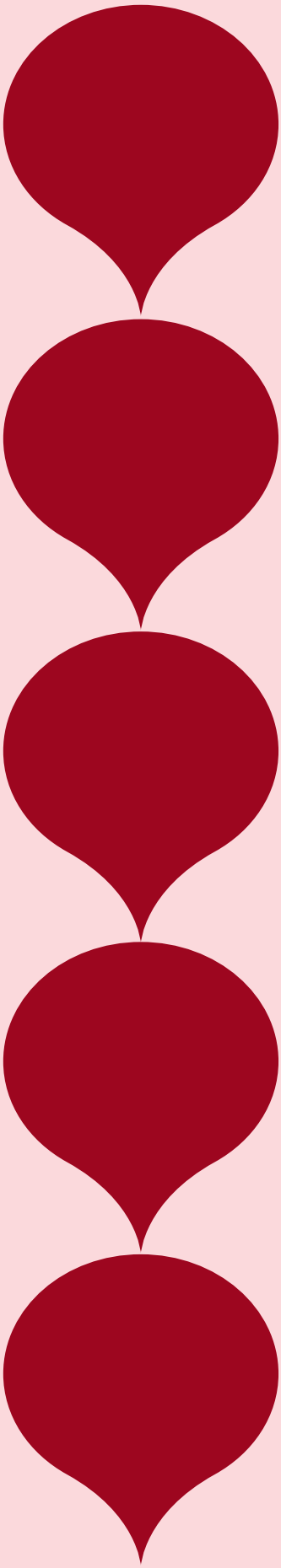
Nothing can dim the light
that shines from within.

—Maya Angelou



Our own voice is likely the first sound we hear when we enter the world. Long before language develops, it is our essential tool for expression. A voice teacher of mine rightly designated the larynx our "emotional barometer." Imagine how it feels when we laugh, are about to cry, or take a deep breath after a long day. Our voice illuminates what is inside our mind. The potential colors of a voice or group of voices carries this expressive impact into singing and the choral realm. When I sing with other people, I feel the resonance of their voices with mine and savor the way a group of voices creates a sense of electricity in the room. This vocal resonance seems to beget a resonance beyond sound—a spiritual one. I believe this is why I, and many others, love to sing in a choir.

Imagine if we could see the overtones swirling over us like light as we sing, and what it sounds like when we maximize our vocal potential to create a powerful sound that shines. The more we know and understand the inner workings of the voice, the more potential we have to make those sonic and spiritual connections. As choral conductors, we often serve as the initial voice teacher for many of our singers, whether in church, school, or community settings. Conductors and choruses of every level can benefit from an increased understanding of the principles of vocal pedagogy and resonance in a group setting. The scope of this article is limited to sound building, but I recommend that suggestions found here be married with textual and musical expressive pursuits, which also play an important role in encouraging our singers and ourselves to continually fall in love with the sound of a group of voices.

Pedagogy of Choral Sound and Spirit

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In the midst of the Coronavirus pandemic, many choral music educators are searching for solutions to engage their ensembles. The teaching tips and technology platforms in this article present opportunities to pair visual learning with vocal development with both in-person and online applications. I am using the software Vocevista Video in some images featured throughout, with my own voice. This software is available to download online for both PC and Mac users. More information can be found at www.vocevista.com. The sound generating these images was captured with a built-in computer microphone. An external microphone will improve the depth of sonic information you can capture and provide the best possible results, but a variety of microphones will produce clear enough results for teaching and explanation/comparative purposes.

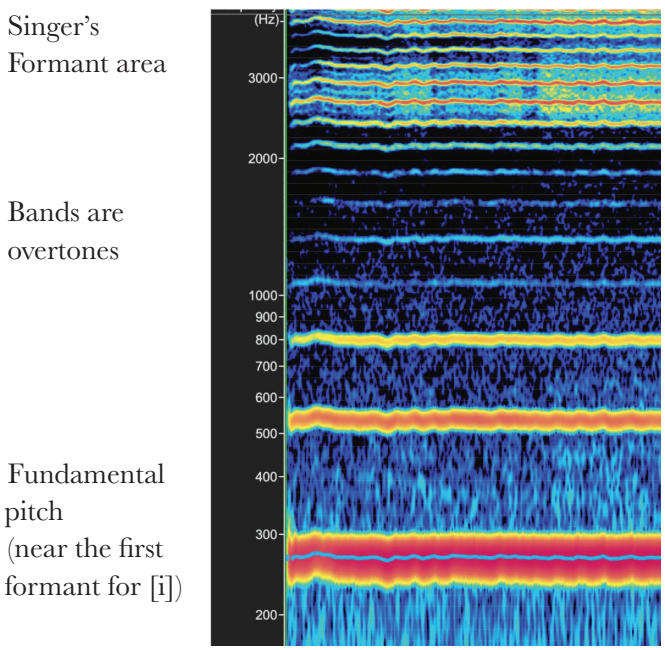
Formants and Vowels: It Takes Two

All vocal sound comprises a fundamental pitch plus its overtones. While the overtone series of intervals is invariable regardless of gender or age, the emphasis of specific overtones in the series is highly variable. Our ability to perceive vowel and timbre arises from varying acoustical emphases among the fundamental pitch and its overtones. Another way to consider this is to understand that when you produce a sound that is breathy, shiny, loud, or soft, it always has a fundamental plus overtones, but there are variations of volume from one overtone (or group of overtones) to the next, and this affects our perception of vowel and timbre.

See Figure 1. On the left side of the image (spectrogram), the vertical numbers represent Hz, the cycles per second that represent pitch, or frequency. Those numbers are more spread out at the bottom and get closer toward the top near 3000 Hz (the area of the singer's formant), but that is simply so we can see all of the information on the screen; in reality, those numbers would be equally spaced, but the default setting of the software is designed to see the whole picture in one screen. You can see a strong red line near 260Hz, then another line at 520Hz, a softer color at 780Hz, etc. The first line is the fundamental pitch, and the other lines are overtones; the brightness and color of the lines represents the volume of those overtones. Red is the loudest, and it fades to blue. The reason the first line is so strong and then the overtones fade until around 3000 Hz is largely due to this being the image of an [i] vowel. As a reminder, the lines (overtones) appear thinner and closer together near the 3000Hz mark, but that is just due to the software and imaging, not due to volume; volume is represented by color rather than the size of the line.

Two formants must be present for us to perceive a vowel. A formant is not an overtone but an area of potential acoustic energy created by the shape of the vocal tract. Trained singers learn to align the fundamental or its overtones with formants to achieve clarity of vowel and maximize resonance. Resonance, according to the Merriam-Webster Collegiate Dictionary for our purposes here, states that it is *the intensification and enriching of a musical tone by supplementary vibration.* A sound becomes

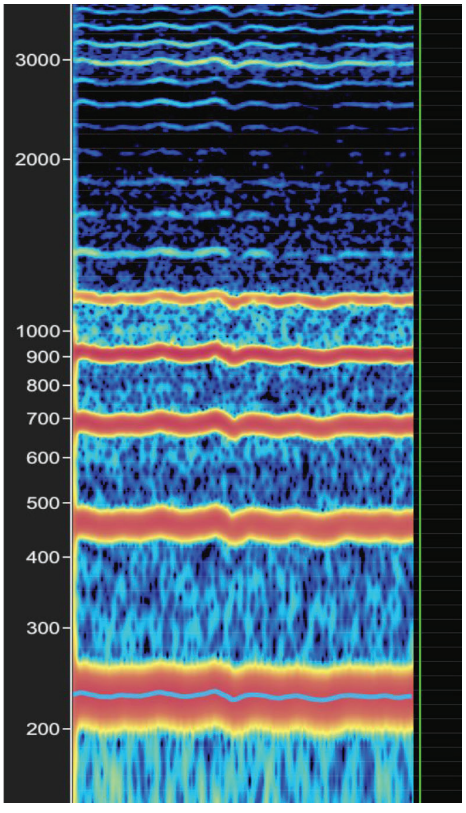
Figure 1. [i] sung on Vocevista Video



The scale on the vertical axis is frequency (pitch, in Hz) and the horizontal axis represents the passage of time.

more intense and colorful when it vibrates something beyond its original sound source. Scott McCoy, author of *Your Voice: An Inside View,* describes the resonance phenomenon with an example of a child on a swing. When the person pushing synchronizes their action with the swinging child, the system becomes efficient and the required energy input can be very small. The same is true in a system with vocal resonance. "Small vibrations (the gentle pushing of the helper) induce large vibrations (the swinging child)."[1] This concept is further explained in the book in reference to how the vocal tract interacts with the column of air generated by our breath and the vibrating vocal folds to create resonance, the resulting sound of which is further aided by vowel modification, or formant tuning. There are many crucial events happening at the level of the larynx in relation to formant tuning, but our main focus will be on the impact of resonance for this article.

Figure 2. [a] sung on VoceVista Video



When the vocal tract is shaped to produce an [i] vowel, the first formant (F1) naturally occurs around 300Hz (D4), and the second formant (F2) around 2800Hz. If the fundamental pitch and one or more of its overtones align with those two formants, we will perceive the vowel [i] and the resonance will be boosted. Thus, [i] is naturally resonant for many because the location of F1 (~D4) often falls near the fundamental pitch in choral singing for several of the voice parts (or is near the first overtone for basses), but more importantly, F2 falls near the singer's formant, which will be explained below. As we ascend in pitch, increasing our mouth opening allows the first formant (F1) to rise; this is why, as we sing an [i] vowel, we must begin to modify toward [a] as we ascend to keep F1 within range of the fundamental pitch or one of the first few overtones.

In contrast to [i], F1 for [a] is around 820Hz (G5), so it is difficult to align the fundamental to the F1 unless singing a pitch near G5. To have the vowel perceived as [a] while singing in the staff, we must align one of the overtones with F1 if the fundamental is far below it, as it often is in choral repertoire. Without our resonator (vocal tract), volume naturally decreases from the fundamental pitch through the overtone series. This is why some singers find [a] difficult to resonate in the midrange of the voice. Please see Figure 2 for an image of [a]. You will notice that the third overtone (fourth band) is the brightest in red color, because it is closest to F1 for this vowel (near 820Hz) and is therefore boosted.

Another way to think of formants is to take an object, such as a tube, and place one end to your lips. If you sing through it sliding the pitch of your voice up and down, you will likely find a pitch that makes the sound coming through the tube suddenly seem louder, and you may feel the tube vibrate. This is because you have introduced a pitch into the tube that matches its formant frequency, so the tube seems to resonate (but it is actually the column of air that makes this happen). A full discussion of how resonance in a closed-open tube works (i.e., the vocal tract) is beyond the scope of this article, but there are several great books on these topics, which are included in a list of suggestions for further reading at the end.

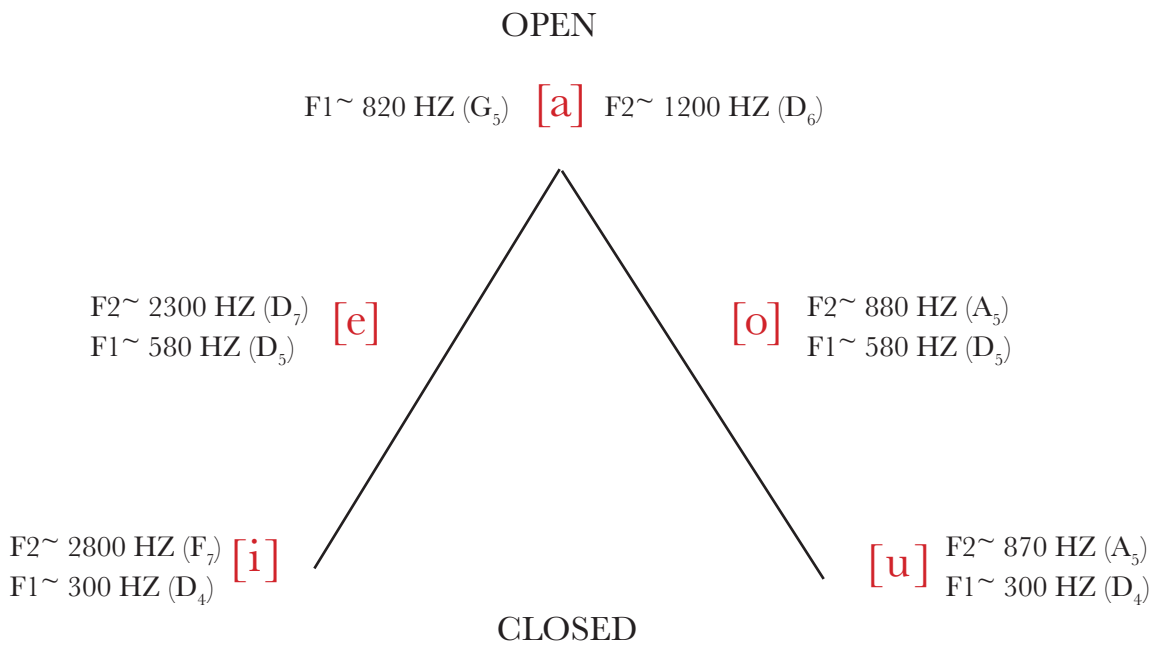
Singers' Formant and Resonance

To review, formants move depending on the shape of the vocal tract, so if you change the vowel, you change where the formant sits. Trained singers make miniscule adjustments of the vocal tract to better align the fundamental or its overtones to formants. This process, called formant tuning, allows maximum resonance on a fixed pitch by modifying toward a vowel whose formants are closer to the fundamental or overtones of the pitch one is singing. In a treble voice, when lower in range, this might entail modifying toward a more closed vowel with a lower first formant ([i] or [u]), or, when singing higher, modifying toward a more open vowel with a higher first formant ([a]). See Table 1 for a vowel chart that shows the approximate pitches for the formants for the five principle vowels.

While many of us make vowel adjustments instinctively with our ears, having these numbers to reference aids our understanding, and can inform our choices when seeking for sound solutions for spread or out of tune singing, for example. Whether or not you want to share the numbers with the singers is certainly up to the individual. In my own teaching, I have had more durable success using the vowel chart (without numbers) to quickly clarify and make adjustments that can be re-employed through remembered sensation.

As mentioned earlier, there are formants beyond the first two. The phenomenon called the "Singer's Formant" occurs near 3000Hz and can be heard in a trained singing voice. Some discrepancy still exists as to how exactly this phenomenon is produced, but it may be a result of the clustering together of formants three through five (F3-F5). The presence of this formant area creates the very intense "ring" that allows a singer to be heard over an orchestra because most orchestral formants peak at lower pitch levels. When treble voices are singing in their lower range, they may also have need to tap into this formant, but when they are singing at a higher fundamental frequency, it becomes unnecessary and at some point impossible to produce. The higher the fundamental, the more efficient the resonator becomes, and the louder the volume of the voice, thus reducing the need of the singer's formant for sopranos singing in the upper range. The singer's formant tends to occur

Table 1. Vowel Chart with Formant Frequencies



with a comfortably low laryngeal position and firm glottal closure.

Choral Resonance and Group Sound

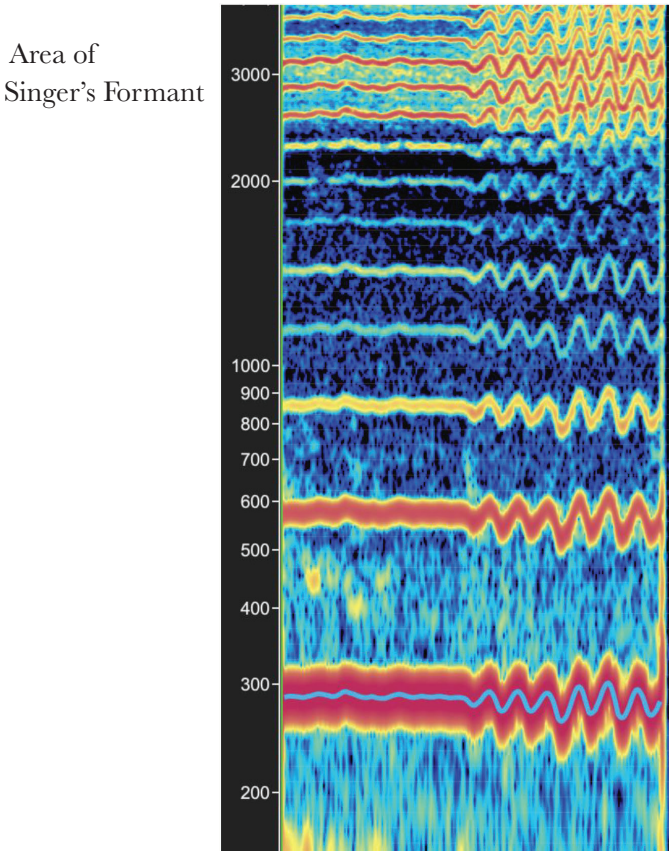
> *There is no reason to have a Stradivarius sound like a cigar-box violin so that both will sound the same. Instead of removing the resonance from the voices that have it, one should try to establish the formant in all voices of the choir in which it is lacking.*[2]
>
> —*Berton Coffin*

The fundamental pitch plus overtones creates the "vocal picture." When choristers create similar vocal pictures while singing, they may hear and feel a sense of resonating into one another, creating a collective "choral resonance." This can increase comfort for individuals to sing within an ensemble and enhances somatic sensations. This is not a matter of singing precisely the same vowel, but instead relies on each individual singer's use of formant tuning to produce their best alignment of formants and overtones. This informs our "vocal picture" and creates a "unity in the sound." This unity can be far more effective than one made by reducing the color in the most resonant voices to that of the least, but of course, choral repertoire requires a great variety of color choices, so there is no one "best" color; the goal is to encourage each singer's best sound and to place it into the sleeve of the whole.

Pitch and vibrato must be addressed, because if we are not singing exactly the same pitch or the vibrato rates are widely different, the result can create a sound that, while it may produce a similar vocal picture, will not sound cohesive or in tune. Clarity of pitch and individual resonance are essential to choral resonance; strong overtone presence aids the tuning of octaves, fifths, and other chord tones. Vibrato is separate and apart from resonance; it is possible to access the singer's formant both with and without vibrato. The human voice is never entirely without vibrato, but the amplitude of pitch oscillation can vary widely based on vocal production. "Healthy vocal production perceived as straight tone is still, to some degree, vibrating. Even when vibrato is minimized in straight tone, the carrying power and ring of the voice associated with the singer's formant can still be present."[3] The RIAS Kammerchor, a German choir, received the following comments in a review: "There are dynamic extremes, too: extraordinary chords hit with a force that seemed doubly overwhelming Thursday because of the palpably dead-on accuracy of the tuning. The volume was almost physically intimidating. It seemed impossible that so much sound could come out of such a small group of people and yet not sound in the least like shouting."[4]

See Figure 3. You will notice that while the overtones become easier to see as they become wider/wavy lines vs. more straight lines, the actual color intensity of the lines is the same, which is the indication of the volume of the resonance. In thinking of intonation, if vibrato rates among singers in a group are similar, then lining

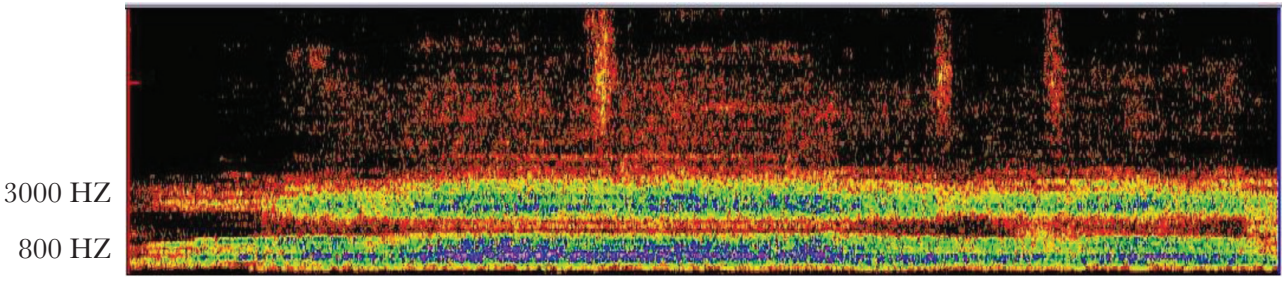
Figure 3. Singer's Formant with and without vibrato on [i]



up overtones is easier. When vibrato rates differ greatly from one singer to the next, the vocal picture does not have an opportunity to find an alignment because it is a moving target; the overtones move up and down in lock-step ratios with the fundamental pitch. This does not imply that vibrato is bad or good, simply that the choices of the director or ensemble members should be clarified regarding the approach to vibrato. Most important in this discussion is the health or efficiency of the vocal technique itself. While there are a wide variety of vocal color choices possible in choral singing, sound that is supported by breath and body with efficient vocal fold closure and tonal clarity is a step in the right direction.

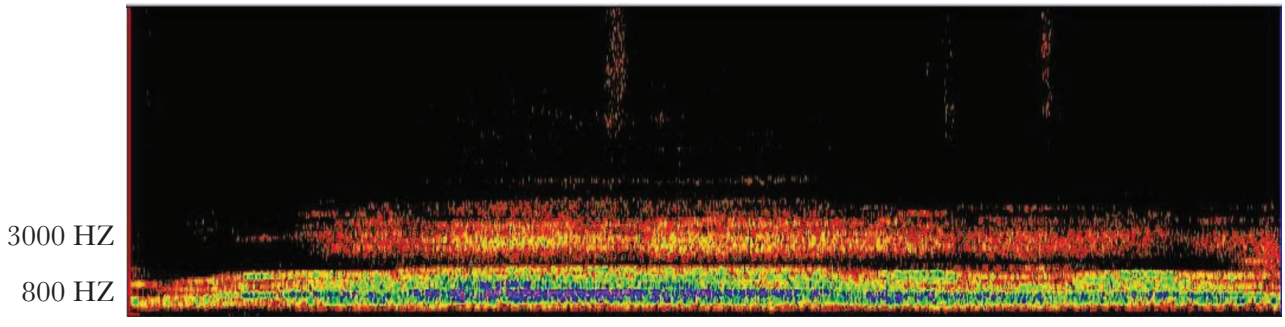
It is possible to use Vocevista Video with choirs. However, keep in mind that if you are working with repertoire, it will likely yield better results to work with a single section when trying to teach formant tuning, since adding fundamental pitches means adding overtones, and this adds much more visual information to the screen. You can run choral recordings through Vocevista Video as well, and while it is not possible to see individual overtones very easily, you can see clusters of information, especially in the comparative presence of the area of the singer's formant. For example, below is an image of two choirs singing the exact same passage from Rachmaninoff's *Vespers.* Notice that you can see general clustering near the fundamental pitches and nearby overtones, and then again around 3000 Hz. There is a considerable difference in the area of the singer's formant from one choir to the next. This result can be affected by several things, however, including the types and proximity of recording microphones, and other acoustic factors in the space that cannot be ignored. However, the resulting recording, and the resulting sonic product, are what we can compare. See Figure 4 below.

Figure 4. Spectrogram of two choirs



Choir 1, above, shows considerably more acoustic presence near the range of the singer's formant than Choir 2, show below.

Note this is a different software program, and the color blue represents the greatest volume.



Choral Pedagogy and Tips

Warm-ups should set up success, not struggle. Incorporating descending vocalises based on [i] and [u], starting within the staff (suggested five-notes, beginning in C-major [c3/c4]), optimize singer success at the outset of rehearsal. Generally, [i] has a first formant close to the fundamental pitch when in the staff and a second formant near the Singer's Formant, making it valuable for training formant tuning and creating easy resonance when singing in the mid-voice. [u] shares a first formant similar to [i], and can also facilitate the engagement of head register. When we perceive that our ensemble needs more space in their sound, we often go to an [a] vowel. This may seem like an obvious solution, but [a] can create fatigue, especially in the mid-voice if one is not aware of how formants work. As stated earlier, the first formant for [a] is near g5, and does not always yield successful results at the outset of a vocal warm-up especially in mid to lower ranges. It is helpful to start where singers can succeed and find efficient collective resonance before exploring the more extreme parts of the range.

Another aspect of resonance is the use of chest register, or belting. A discussion of register exceeds the scope of this article, but it is important to understand how registers work, as the use of vowel modification alone will not solve all vocal faults. In styles that require more chest or belt in the sound, formant tuning is still relevant, but the crucial part is to sing with one's own most efficient and healthy vocal picture. In a belt, the picture will look different than with mixed or head voice, and you may hear a strong prominence of the first overtone in the sound (an octave).

As trained singers are aware, all singing styles and sounds that are successful tend to be rooted in excellent breath support. The topic of breath support is enormous and foundational for singing. For more resources on breath support and technique, please see the end of the article. For beginning vowels in teaching formant tuning, here are some suggestions:

1. Start in the mid-range of the ensemble, with no more than five-note, top-down exercises.
2. Choose repertoire that introduces a helpful vowel stream. Singing in English for American choirs can be difficult due to the great variety of pronunciation tendencies and habits formed through speech. Latin can provide a more helpful stream; consider texts such as Kyrie, Miserere, Os Justi, and others. The mixed vowel [y] found in German and French can also be a wonderful way to aid formant tuning, since it is a combination of [i] with [u], two vowels who share the same first formant range.
3. Working with unison and two-part repertoire can be a wonderful teaching tool. Pieces like Italian art songs are a must for training sound as well as artistry, and all of the other elements that come into play in choral performance.
4. If you have an SATB choir, repertoire that is written with fifths and octaves in the tenor and bass parts can be very useful for formant tuning and building choral intonation, since this follows the pattern of the overtone series.
5. I have found that solfège is a wonderful tool not only for literacy but for sound building if you help the choir unify the vowels. I generally teach solfège pronunciation exactly as written as if it were IPA, so the vowels are closed. Recall that the word *closed* in reference to a vowel is just an indication that the front of the mouth (lips or tongue) is creating a closed space, but there is space in the back of the throat. Notice, also, that roots and fifths share the same vowels [do] and [so], and leading tones in the scale use [i].
6. After solfège, we often work with neutral vowels, either [i] or [u] (modifying for ascending passages, especially for sopranos) to establish successful formant tuning in the choir. We play games where we number off every other singer, and the first group sings on the neutral vowel while the second group sing the text; this way, we always relate it back to the successful vowel stream we need. It is crucial to adjust the vowels as you go according to the range, tessitura, and registration shifts in each passage.

7. Here are suggestions for specific vowel usage:

[i] as in week
- builds resonance due to the location of first and second formants
- clarifies intonation
- creates freedom in the sound when supported by breath
- maintains placement in the mid to low voice

[u] as in boot
- engages head register
- creates clarity in the sound by aligning the first formant to the fundamental, and actually has a lower second formant, so we often perceive more of the fundamental pitch, helpful for tuning
- can aid in relaxation of the larynx (think "sigh on [u]")

[y] as in the German word grün
- can aid in bringing the positives of both of the above vowels together

[o] as in Minnesota
- a closed [o] is not a sound we find in most American English pronunciation, but we do find in other languages
- modify toward this vowel if [a] feels breathy or stuck, as this brings the first formant down from [a], which may help align the formant to the fundamental or one of the first overtones

[e] as in chaos
- a closed [e] is also not a sound we find in most American English pronunciation, but we do in other languages
- modify toward this vowel if [ɛ] feels spread or out of tune
- building sound on [e] before moving to [ɛ] can be helpful, especially when singing in Latin

[a] as in father
- helpful for treble voices as they ascend in pitch toward the top and above the staff
- can be useful if working to build chest register in descending passages

Figure 5 shows suggested warm-ups for building resonance in choral sound. The first, 5a, which employs [miŋ] (or ming), borrows from a few principles. First, the idea that vocal play can be very helpful for singers to explore their vocal production and sound possibilities. This may feel more like a noise than a sung sound, and this can be helpful for breaking through potential tension habits that inhibit vocal growth. The key is ensuring the sound is supported by the breath and engaged in the body. While in general conductors might prefer to avoid nasality in the sound, coupling vowels with nasal consonants can be a helpful step in finding resonance. This is because when we produce a nasal sound, we light up the

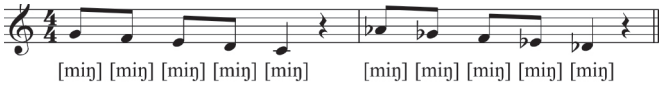


Figure 5a. Vocal play, finding ring

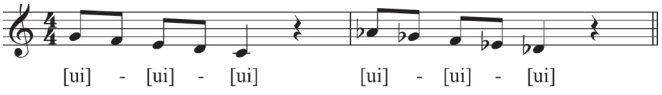


Figure 5b.

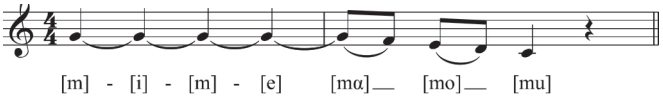


Figure 5c. Hum into vowel around the chart

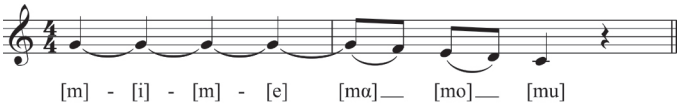


Figure 5d. Intonation exercise

Start with intervals natural to the overtone series: fifths and octaves.

part of the vocal picture (spectrum) related to the singer's formant. Remembered sensation is one of the best tools for voice teaching since we cannot physically manipulate the larynx with our hands, so finding a sound that begins in the right "spot" and then moves to the desired sound can be a helpful tool.

Conclusions

Singers who learn to resonate together tap into the beauty and power of their ensemble's sound, its collective resonance. This encourages individual vocal development, addresses the technical demands of most choral repertoire, and helps us to feel sonically and spiritually connected to one another. When the ensemble members begin to find the ring in their own voices, they will find it much easier to unify the tone as they learn to sing into the resonance of those around them. The choir can sing with more ease and less fatigue, and the collective blend will become aurally apparent because the sound is vibrant and rich, its whole greater than the sum of its parts. Teaching this concept in the choral rehearsal requires time and study on the part of the choral conductor, but the results are compelling. When increased resonance broadens the color palate, a choir can approach choral music of almost any era and style, with greater confidence that their performance will reach the soul of the listener. CJ

NOTES

[1] Scott McCoy, *Your Voice: An Inside View* (Princeton: Inside View Press, 2004), 28.

[2] Stephen C. Bolster, "The Fixed Formant Theory and Its Implications for Choral Blend and Choral Diction," *Choral Journal* 23, no. 6 (1983): 31.

[3] Sten Ternström, *Acoustical Aspects of Choir Singing* (Stockholm: Royal Institute of Technology, 1989), 12.

[4] Michelle Dulak Thompson, "Polished and Powerful Debut," review of the Rias Kammerchor, *San Francisco Classical Voice,* 16 November 2006, visited June 15, 2008. http://www.sfcv.org/arts_revs/rias_11_21_06.php

Further Reading

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