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A Pair of Advanced Exercises as a Register Treadmill

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Research on the biomedical origin of modal-falsetto registration has focused on adduction of the lower portion of the vocal folds.[1] This lower adduction is controlled by the thyroarytenoid muscle, but acoustic pressures in the vocal tract can influence it.[2] Register transitions can be smooth or abrupt, intentional or unintentional, or in some cases apparently nonexistent. With highly registered voices, teachers spend much studio time to find a register balance, or equalization, in critical pitch ranges. The effect of vocal tract acoustic pressures on registers is most pronounced when a source harmonic with relatively high energy passes through a formant. Of particular interest is a first, second, or third harmonic passage through one of the lower two formants (F_1 or F_2). The harmonic energy can be altered in this passage, and some instability (a pitch jump or register "break") may be triggered due to sudden changes in acoustic pressures.[3]

A pair of exercises (call them the Titze register treadmill) is designed to expose problems in register management. I do not recommend them as a practice exercise until the voice is very warmed up with semioccluded vocal tract exercises (lip trills, straw phonation, tongue trills, humming, etc.). As a diagnostic tool, however, they can be used anytime. When they are mastered without instabilities, a mixed registration is evident. In musical form, the exercises are five-note scales (up and down) with a vowel change on each note (Figure 1). The two exercises differ only in their vowel sequence, one being the low-vowel sequence /a-ɔ-o-ʊ-u/ and the other the high-vowel sequence /æ-ɛ-e-I-i/. The starting note and the ending note (a fifth higher) depends on the voice classification. The male *secondo passaggio* or the female *primo passaggio* should be somewhere in the middle of the five-note pitch range for a given classification. The range shown in Figure 1 would be appropriate for a tenor or a mezzo soprano. For basses the starting pitch can be around A_3 and for sopranos around F_4.

The acoustic (spectrographic) caricatures of these exercises are shown in Figure 2. Three of the dominant harmonics (F_0, $2F_0$, and $3F_0$) are drawn with solid lines and the lowest two formants (F_1 and F_2) are shown with dashed lines. The vowel sequence is shown on the horizontal axis. The important feature of the exercises is that, by design, there are multiple vowel-pitch combinations where formant and harmonics cross each other. In Figure 2a, the low vowel sequence, the first formant (F_1) crosses $2F_0$ and then F_0, provided the starting vowel /a/ is very bright (as in the Boston dialect).

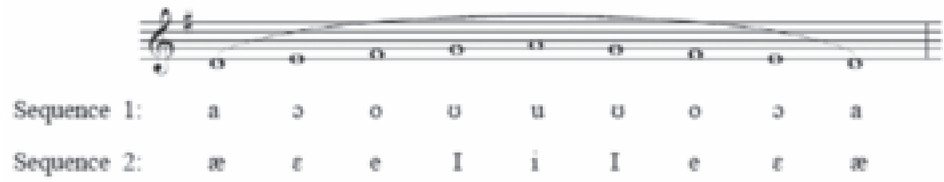

Figure 1. **Two sequences of vowel transitions on an upward-downward scale.**

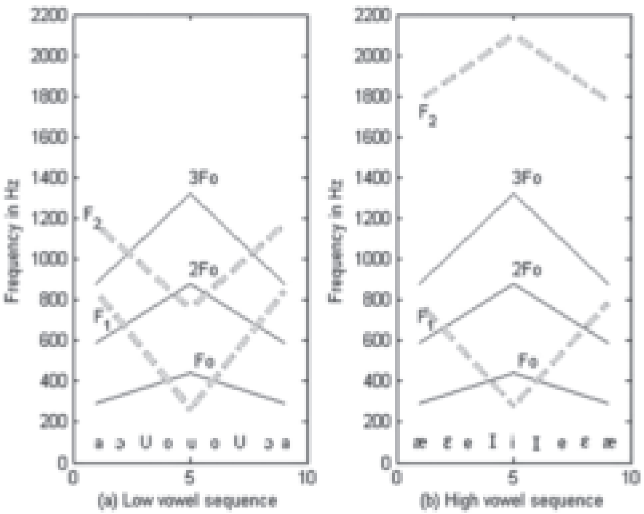

Figure 2. **Spectrographic representation of harmonic and formant crossings in vowel sequences on a 5-note scale.**

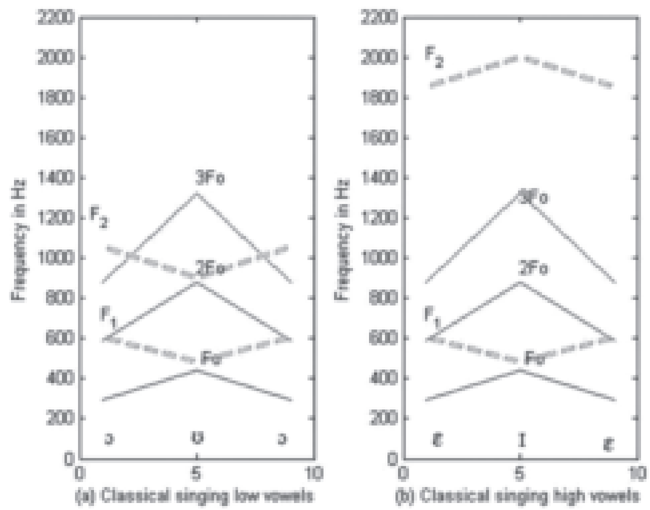

Figure 3. **Spectrographic representation of centralized vowels to avoid formant-harmonic crossings**

The second formant F_2 passes through harmonics $3F_0$ and then $2F_0$, provided the /u/ is speech-like and not modified for singing. All of these crossings reappear in the opposite direction on the downward scale. In Figure 2b, the high vowel sequence, the crossings for F_1 are similar to those in Figure 2a, but F_2 does not cross any harmonics. Hence, the two exercises can be used to isolate F_1 transitions alone from combined F_1 and F_2 transitions.

As a diagnostic tool, the objective in the exercises is to reveal abrupt register changes, pitch jumps, or instabilities in phonation. As a practice tool, the objective is to avoid instabilities and discontinuities. This is usually accomplished by maintaining a mixed registration. Note that the crossings occur near the vowels /ɔ/ and /o/ in the low vowel sequence (Figure 2a) and near the vowels /ɛ/ and /I/ in the high vowel sequence (Figure 2b). Most singing teachers know that central vowels are often used for register equalization. The classical approach of reducing the ten vowels to something like four, /ɔ/, /ʊ/, /ɛ/, and /I/, eliminates the formant-harmonic crossings altogether (Figure 3). F_1 then stays between F_0 and $2F_0$ for both vowel sequences, and F_2 stays between $2F_0$ and $3F_0$ in the low vowel sequence. Thus, register breaks triggered by formant-harmonic crossings are avoided. Since the harmonic and formant frequencies can remain close to each other at these centralized vowels, one could make an argument for formant-harmonic tuning, but the utility of such tuning would be mainly for sustained "money" notes. When articulation or note changes are rapid, a balance of loudness and timbre across sequences is usually more important and feasible.

Note also that the most unequalized registration occurs when the end-point vowels /a/ and /u/ for low vowels or the end-point vowels /æ/ and /i/ for high vowels are toggled back and forth. The exercises then basically become a yodeling exercise. In the low vowel yodel, the first formant F_1 jumps from above $2F_0$ to below F_0 in Figure 2, while the second formant F_2 jumps from above $3F_0$ to below $2F_0$. This gives rise to the sudden timbre change in yodeling. For the high vowel yodel, only the F_1 jump is relevant.

In summary, the two exercises I have called a "register treadmill" can bring out the best and the worst in registration. The treadmill can be used as a diagnostic tool as well as a training tool. But it should be restated that, because of its inherent difficulty, vocal training with this treadmill should follow a thorough warm-up that first emphasizes mixed registration over a much wider pitch range (several octaves). Also, it is not wise to belabor the exercise, especially if the vowels are executed as true speech vowels. Their intensity will not be equal, even if register is equalized. Equalization of intensity requires either a microphone or vowel modification as described. Modifying the ten vowels toward /ɔ/, /ʊ/, /ɛ/, and /I/ eliminates or minimizes the formant-harmonic crossing altogether. F_1 stays between F_0 and $2F_0$ for both vowel sequences, and F_2 stays between $2F_0$ and $3F_0$ in the low vowel sequence. Thus register breaks triggered by formant-harmonic crossings are avoided. The cost is that a full set of speech vowels can no longer be a first priority for communication of the verbal message.

NOTES

1. Isao T. Tokuda, Marco Zemke, Malte Kob, and Hanspeter Herzel, "Biomechanical Modeling of Register Transitions and the Role of Vocal Tract Resonators," *Journal of the Acoustical Society of America* 127, no. 3 (March 2010): 1528–1536.
2. Ingo R. Titze, Tobias Riede, and Peter Popolo, "Nonlinear Source-Filter Coupling in Phonation: Vocal Exercises," *Journal of the Acoustical Society of America* 123, no. 4 (April 2008): 1902–1915.
3. Ibid.