Intonation Drift in *A Capella* Soprano, Alto, Tenor, Bass Quartet Singing With Key Modulation

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Summary: Objectives/Hypothesis: When a soprano, alto, tenor, bass (SATB) quartet sings unaccompanied, or *a capella*, the members of the group will tend to make use of non-equal-tempered intonation to govern their tuning. If the music they are performing visits different keys and they do maintain non-equal-tempered tuning, then the pitch center will have to shift from its starting point, which is a necessary consequence of the physics behind the use of a non-equal-tempered tuning system. The implication of this shift for tuning in *a capella* singing is that it is not possible both to maintain accurate non-equal-tempered tuning and to stay in pitch throughout music that modulates in key. Methods: To test this notion, a set of four-part exercises were written by the author that visit several different key chords in sequential progression. In each case, the starting and finishing chords were either identical or exactly an octave apart. Mean fundamental frequency values for each note were measured using four electrolaryngographs (one per singer), and the f0 data were normalized and plotted with respect to equal-tempered tuning to enable any overall tuning shift to be observed. Results: The results indicate that singers do (1) tend to non-equal-tempered tuning and (b) do consequentially shift their intonation with modulation. Conclusions: These data indicate that pitch drift is potentially a necessary part of staying in-tune. Further work is required to identify items in the choral repertoire for which this effect is likely and then to inform the choral conducting and singing communities appropriately.

Key Words: Intonation—Singing—Choral singing—Tuning—In-tune singing—Electrolaryngography—Electroglottography—Vocal quartet.

INTRODUCTION

Experienced choral singers have the potential to command very fine degrees of control over their output pitches. This control is achieved primarily through the ability to make small subtle adjustments to the fundamental frequency (f0) of vibration of their vocal folds, but there are also secondary effects to be managed in terms of sustaining accurate intonation, including, for example, the subtle pitch changes associated with variations in both timbre, mainly manifested through vowel color, and loudness.[1] Choral singing demands

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a keen awareness by individual singers both of their sung pitches and those of other singers in the group in the context of the musical role (typically melodic in the upper voice and harmonic for the other voices) that their contribution is making. This ability demands not only musicianship, but also finely honed listening skills coupled with a fine degree of control over voice pitch through manipulation of the f0 of vocal fold vibration in the context of the timbre of the output sound and the overall loudness.

A capella (unaccompanied) choral singing provides additional challenges for the singers. Singers have the freedom to set their target pitch for each note in the context of their part within the music, but there is, though, a dichotomy between the tuning system that experienced choirs adopt to produce the most pleasing, or *consonant*, blended result and remaining in-tune. In many situations, this dichotomy is potentially unresolvable. It is often completely unrecognized by choral conductors, singing teachers, composers, recording engineers, and choral singers, and it forms the subject matter of this article.

Lindley's article on "just intonation"[2] provides a historical summary of pitch drift and just intonation, in which he cites Zarlino in 1558, Beneditti in the 1650s, and Rameau in 1737. When singers take care with their listening, they will tend away from non-equal-tempered tuning toward just tuning.[3–6] When singing a note of a major or minor triad, singers will tend to tune their note in relation to the tonic such that if they are singing the fifth, it is tuned with its f0 in the ratio 3:2 to the tonic, and if they are singing, the third it is tuned with its f0 in the ratio 5:4 (major third) or 6:5 (minor third) to the tonic.

These ratios arise from the musical intervals between the components of the natural harmonic series, the first eight of which are shown in Figure 1 related to the note C3, and such purely tuned major triads have been said to "represent complete harmony and therefore symbolized the Trinity."[5] A note sung by a singer will contain many harmonics (their relative amplitudes will depend essentially on the formant frequencies and voice quality employed). When two singers sing together, each harmonic of the note produced by one singer will have a nearest neighbor in the set of harmonics produced by the other singer. If the f0 values are tuned in just intonation to be in integer ratios (eg, 3:2 for a perfect fifth), then a maximum number of these neighboring harmonics will be exactly in tune, such as the third harmonic of the lower note and the second harmonic of the upper note (Figure 1). Harmonics that are exactly in-tune contribute toward the perceived consonance of the chord. When the frequencies of neighboring harmonics lie between 5% and 50% of a critical band, they contribute toward the perceived dissonance of the chord; maximum dissonance occurs when the frequency difference is a quarter of a critical bandwidth.[7]

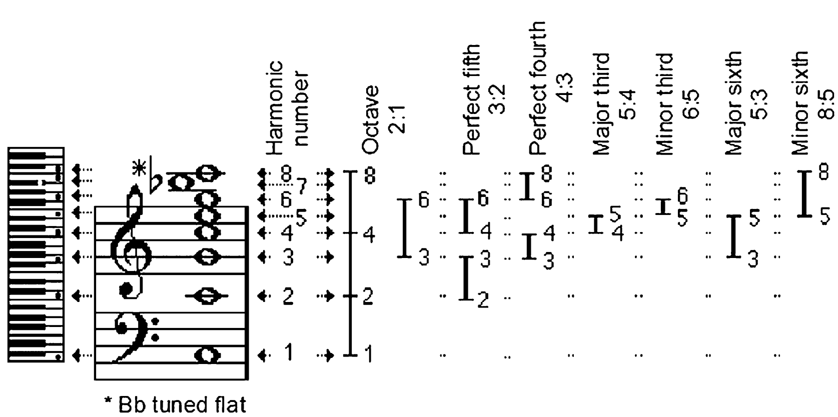

FIGURE 1. Frequency ratios and common musical intervals between the first eight harmonics of the natural harmonic series of C3 against a musical stave and keyboard. (Adapted from Howard and Angus[1].)