A Hypothesis About Whistle Voice

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Young adult females sometimes stumble upon a very high pitched piccolo-like sound they can produce in their larynx. It is known as whistle voice, or whistle register. When first experienced by a singer, it often startles her as much as a listener. It seems to be produced with ease at pitches starting from G_6 (about 1570 Hz) to G_7 (3140 Hz). Some authors have claimed that whistle voice can start below 1000 Hz, especially in untrained females,[1] but trained lyric and coloratura sopranos usually sing notes well above 1000 Hz in nonwhistle phonations.

The hypothesis here is that whistle voice makes use of a source-vocal tract interaction based on acoustic inertance below the third formant. Acoustic inertance of the vocal tract helps to set the vocal folds into vibration.[2] For a female vocal tract (see eleven vowel shapes in Figure 1a), the third formant occurs above 3000 Hz and vocal tract inertance is found for most vowel shapes if frequencies are in the 1500—3000 Hz range. This range is on the upskirt of the third formant F_3 (see Figure 1b, where formants F_1, F_2, and F_3 are labeled for the vowel /o/). Formants (the resonances of the vocal tract) are where the inertance curves make an upward turn followed by a sharp drop. When the inertance is high (above the zero line), source frequencies are reinforced. In particular, the fundamental frequency F_0 gets a boost. Note that for the /o/ vowel shape, the inertance curve is above zero for pitches slightly below and above C_7. But the higher harmonics ($2F_0$, $3F_0$, $4F_0$ . . .) are not systematically reinforced. They face variable inertances from the vocal tract. Note that the harmonics $2F_0$, $3F_0$, and $4F_0$ lie in the midst of a cluster of formants above F_3. Similar situations occur for most of the other vowel shapes. Thus, the frequency range below and above C_7 (1500—3000 Hz) is particularly advantageous and consistent for the fundamental F_0, but quite irregular for higher harmonics.

Two examples of spectrograms of whistle voice of recorded artists are shown in Figures 2 and 3. Figure 2 is from Georgia Brown, a Brazilian recording artist.[3] She produces a long sustained whistle note at F_0 = 2400 Hz (about D_7) without vibrato, followed by a lower note with vibrato at 1860 Hz (about B-flat$_6$). For both notes, the fundamental F_0 is very strong, apparently reinforced by vocal tract inertance. The second harmonic $2F_0$ is also strong, but no higher harmonics are evident in the first note. In the second note, the third harmonic has some energy. The exact vowel shape used by the performer is not known, but it would appear from Figure 1b that vowel shapes like /ɑ/ and /i/ would have both F_0 and $2F_0$ reinforcement, whereas a shape like /ɔ/ could also have $3F_0$ reinforcement.

The second example (Figure 3) is a spectrogram of Mariah Carey, an American female pop singer.[4] In the recording, she produces a series of vo-

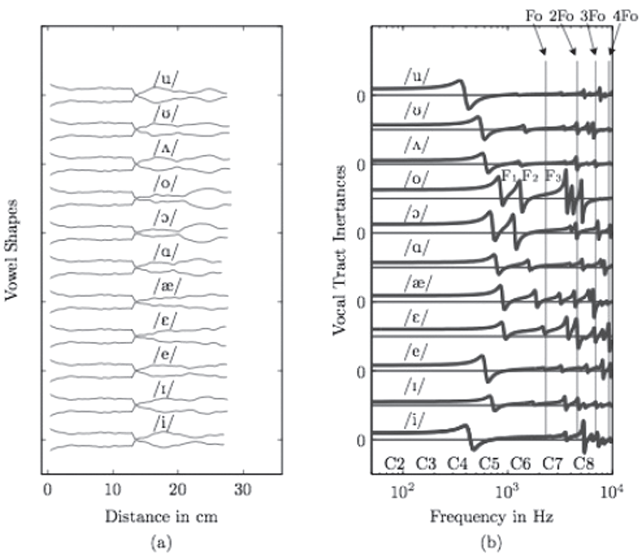

Figure 1. **(a) Female vocal tract shapes for 11 vowels, showing a constant tracheal shape from 0—13 cm and a variable pharynx-mouth shape from 13—27 cm;* (b) corresponding vocal tract inertance as it changes over a logarithmic frequency range from 10^2 = 100 Hz to 10^4 = 10,000 Hz. Some reference pitches (C_2 to C_8) are labeled on the horizontal axis. Formants (vocal tract resonances) occur where the curves have sharp up and down changes, as noted on the /o/ vowel curve. For a pitch near C_7, the four harmonics of the source (F_0, $2F_0$, $3F_0$, and $4F_0$) are shown by vertical lines.**

***B. H. Story, "Synergistic Modes of Vocal Tract Articulation for American English Vowels," *Journal of the Acoustical Society of America* 118, no. 6 (December 2005): 3834–3859.**

cal glides to a maximum fundamental frequency of 2400 Hz (about D_7, where F_0 is labeled). Some energy is seen in both $2F_0$ and $3F_0$, but the energy is mostly in F_0 at all pitches.

The examples shown here support the hypothesis that whistle voice may be a production in which the fundamental frequency F_0 is strongly reinforced by vocal tract interaction below F_3. Supraglottal inertance is known to support vocal fold oscillation by lowering the phonation threshold pressure. The frequency range of about 1500 Hz to 3000 Hz lies in an inertance region (the upskirt of the third formant) in females. Occasionally, whistle voice reaches the 4000—5000 Hz region. This would be in the vicinity of C_8 for F_0. It is not clear from Figure 1 which vowel shape or formant structure would support such a high fundamental frequency.

Higher harmonics are not systematically reinforced for whistle voice, but may for some pitches find favor-

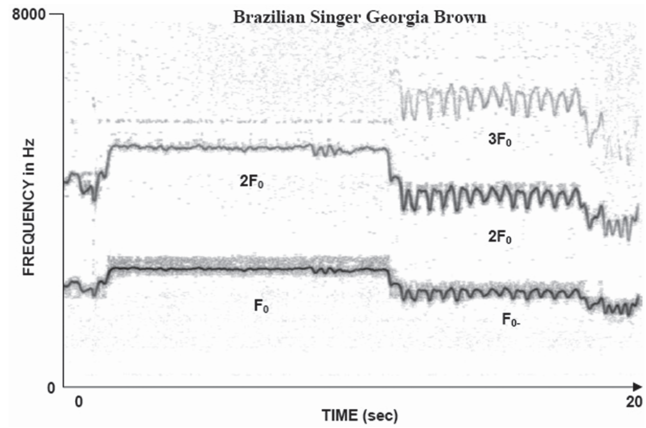

Figure 2. **Spectrogram of whistle voice as recorded by Georgia Brown for her website, and posted in October, 2005. The fundamental F_0 is strong at both pitches (D_7, about 2400 Hz; and G_6, about 1568 Hz), but the second harmonic $2F_0$ and the third harmonic $3F_0$ are variable in**

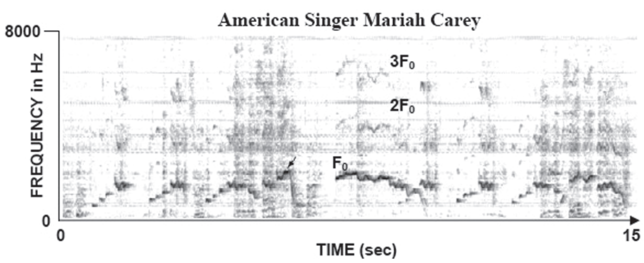

Figure 3. **Spectrogram of whistle voice pitch glides as recorded by Mariah Carey and posted on the Internet August, 2006. The fundamental frequency F_0 ranges from 1000 Hz to 2400 Hz. Little reinforcement of harmonics $2F_0$ and $3F_0$ is seen. The apparent noise in the spectrogram comes from the sounds of the instrumental accompaniment.**

able inertance offered by formants 4–6. Much future work is needed to sort out the interactions between source harmonics and the vocal tract.

NOTES

1. D. G. Miller and H. K. Schutte, "Physical Definition of the 'Flageolet Register,'" *Journal of Voice* 7, no. 3 (September 1993): 206–212.
2. I. R. Titze, *Principles of Voice Production* (Denver, CO: National Center for Voice and Speech,2000), Chapter 4.
3. Recording of Georgia Brown: sound clip from:www.dutchdivas.net/nighC.html (link to http://escravosdegeo.sites.uol.com.br/index1.htm), last accessed 11/27/07.
4. Recording of Mariah Carey: www.youtube.com/watch?v=EUUE4ePt8Xc, last accessed 11/30/07.

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