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Voice source and acoustic measures of girls singing "classical" and "contemporary commercial" styles

Chris Barlow[1], Jeannette LoVetri[2], and David Howard[3]

[1] School of Computing and Communications, Southampton Solent University, UK
[2] Brooklyn Youth Chorus Academy, USA
[3] Department of Electronics, The University of York, UK

The understanding of the singing voice of children and adolescents is still in its infancy, and there is a lack of a general developmental model of the young voice, in particular with relation to young singers. Available research has largely also been on "classically" trained voices, and contemporary commercial music (CCM) including pop/rock and musical theatre has largely been ignored. This study examined laryngographic and acoustic analysis of 10 young female singers, aged 14-17, training using a system which includes both classical and CCM techniques, particularly musical theatre (MT). Singers were found to have generally higher vocal fold closed quotient (CQ) at most pitches when singing in an MT style than in a classical style. The spectral slope was also found to be generally shallower for MT singing than classical, particularly over F0-F5.

Keywords: singer; musical theatre; acoustic; closed quotient; adolescent

The use of quantifiable voice measurements has been introduced in a number of singing studios with adult voices to provide biofeedback on the voice during coaching (Howard *et al.* 2003) and can provide both a pedagogic tool and a monitor of vocal health. Biofeedback tools based on Laryngographic analysis of F0 have been previously used with success in teaching children to pitch accurately (Welch *et al.* 1989). Analysis of vocal fold closed quotient (CQ), spectrographic analysis, and vocal tract modeling (Howard *et al.* 2003) have also been used to assess vocal production in adult singers and provide computer-based feedback.

A number of studies have examined quantifiable aspects of young singers' voices from a variety of perspectives, using laryngography (e.g. Pedersen 1997, Barlow and Howard 2002) and voice range profile (VRP; e.g. McAllister *et al.* 2000). However, despite this, quantifiable voice analysis of young singers to inform use of biofeedback tools is still limited in scope and quantity. There is a particular lack of research on voice production in contemporary commercial music (CCM; including musical theatre), despite the fact that young people are still the most likely demographic group to undertake training in singing (Barlow 2003), and particularly CCM. The theatre arts organization Stagecoach alone has over 39,000 students training in acting, dancing, and singing (Cole 2007).

The Brooklyn Youth Chorus Academy© is a uniquely positioned organization, working with a large number of international names from both the CCM and classical music worlds. The chorus regularly performs alongside artists as disparate as Elton John and the New York Philharmonic Orchestra. As such, the singers need to be able to adapt their vocal style according to the musical genre being performed.

Cross-Choral Training® (C-CT) is BYCA's program for developing vocal and musicianship skills in a choral setting. C-CT enables the singers to perform intentionally in a variety of coordinated adjustments and vowel sound qualities so the chorus can easily respond to the musical and expressive demands of diverse repertoire, including both CCM and classical styles of performance, and can sing any style of music appropriately.

This pilot study examines measurable parameters of ten BYCA students and aims to ascertain if quantifiable differences occur in voice production by the same student singing in both classical and musical theatre styles.

METHOD

Participants

Ten female students from the Brooklyn Youth Chorus Academy© took part in the study. Students were aged 14-17 years and were all designated as "trained" singers under the criteria used by the authors in previous studies (Barlow and Howard 2005, 2006). All students had a minimum of three years training under the C-CT system. All students spoke American English.

Materials

Subjects were recorded speaking and singing using a headset mounted electret reference microphone to record the speech signal (Sp) and a

Laryngograph®, which was used to record the laryngographic signal (Lx). The Lx signal was viewed on an oscilloscope during the recording to maintain correct electrode positioning. Recordings were made using the Laryngograph Microprocessor directly onto a Toshiba Libretto micro-laptop with 1Gb RAM and a Pentium Mobile processor running at 1.2 GHz. Sampling rate was 24 kHz, with 16 bit resolution.

Procedure

Subjects were recorded using a standard protocol: (a) reading aloud a passage of spoken text approximately 90 s in duration to determine mean spoken F0; (b) singing a verse of "happy birthday" in a classical style (termed "head" in C-CT terminology) in the key of C Major and then repeating it in a musical theatre style (termed "mix" in C-CT terminology). Five notes from the song were extracted for detailed laryngographic and acoustic analysis, including mean F0, long term average spectra, and mean CQ for each note.

The notes studied were taken from words on the root, third, fifth, seventh, and octave of the scale. Two notes were on the vowel "æ" (e.g. happy), one on the vowel "ɝ" (e.g. birth), and two on the vowel "u" (e.g. to, you). The musical phrase is shown in Figure 1.

SpectraLab© was used to generate Long term average spectra (LTAS) using a Hanning window with an FFT size of 2048 samples. This was used to derive the intensity of harmonics up to F5 (referenced to F0) for each note. Laryngographic data was used to calculate mean CQ values for each note.

RESULTS

LTAS analysis was used to calculate the mean intensity of each harmonic relative to F0 for each note. A higher mean intensity for the mix (CCM) voice was demonstrated in all harmonics up to F5 for all notes, particularly in harmonics F3-F5. For many notes sung in mix, the harmonics F1-F3 are stronger than the fundamental, and the overall spectral slope is relatively shallow over the first 5 harmonics. The classical (head) voice shows much weaker harmonics particularly above F2, and a much steeper spectral slope.

Figure 1. Happy birthday—syllables selected for analysis circled.

Table 1. Mean intensity of harmonic series.

			Mean intensity (dB)					
Voice	*Note/vowel*	*Freq (Hz)*	*F0*	*F1*	*F2*	*F3*	*F4*	*F5*
Head	C4/æ	262	0	-3.10	-0.45	-2.49	-7.08	-17.95
Mix	C4/æ	262	0	-1.05	5.66	7.62	-3.76	8.84
Head	C5/ɝ	523	0	-2.10	-7.99	-19.55	-22.91	-27.86
Mix	C5/ɝ	523	0	-1.38	-6.77	-12.90	-11.13	-17.97
Head	Bb4/æ	466	0	3.70	-0.55	-10.81	-23.98	-29.65
Mix	Bb4/æ	466	0	6.91	0.35	-2.37	-16.57	-12.08
Head	G4/u	392	0	-12.71	-21.21	-24.14	-29.86	-30.03
Mix	G4/u	392	0	-11.03	-22.88	-13.50	-19.59	-18.44
Head	E4/u	329	0	-16.05	-20.33	-21.70	-26.91	-43.72
Mix	E4/u	330	0	-11.58	-24.61	-23.42	-11.09	-12.84

Table 2. Mean larynx closed quotient (and standard deviation) for each note.

Voice		C4/æ	E4/u	G4/u	Bb4/æ	C5/ɝ
Head	Mean CQ% (SD)	26.2 (6.2)	25.6 (6.2)	24.6 (5.9)	28.3 (4.8)	28.2 (5.9)
Mix	Mean CQ% (SD)	31.1 (2.9)	31.1 (5.4)	29.4 (4.4)	33.6 (3.6)	27.8 (4.8)

Mean CQ was calculated for each note across the group for both singing styles (Table 2). Figure 2 shows mean CQ and standard deviation for 4 of the 5 notes analyzed is higher in 'mix', with the mean for C5 being nearly identical. Analyzed as individuals across all notes, 76% of mean CQs were higher in 'mix' voice than in 'head'. A one tailed student's T-test of the means demonstrated a significant difference between the two data sets ($p=0.018$).

DISCUSSION

The results clearly show consistent differentiation in both vocal function and acoustic output between the two different singing styles. The long term average spectra show a distinct increase in intensity of harmonics up to F5 for the CCM voice compared to the classical style of singing. This indicates potential differences in both voice source and resonance strategies for the performer between the two different singing styles.

Scherer (2005) demonstrated that pressed phonation increases the strength of harmonics and decreases the spectral slope of the glottal

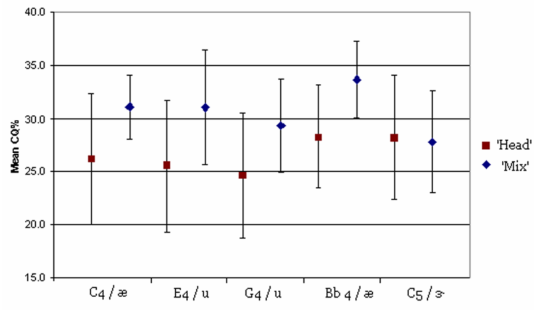

Figure 2. Mean CQ and standard deviation for each note/vowel sound.

waveform. Adult "belt" voices have been previously demonstrated to use significantly more pressed phonation than classical "bel canto" voices (Evans and Howard 1993), as demonstrated by raised CQ values.

The CQ data appears to support this finding, demonstrating raised CQ for mix singing compared with classical, suggesting stronger harmonics in the glottal waveform. The difference in CQ is relatively small, though significant between the two styles.

Scherer (2005) indicates that the glottal waveform of pressed phonation will have a negative slope, so these results suggest use of vocal tract resonances in CCM singing to further enhance harmonics up to F5, giving the characteristically "bright" sound to the voice of the young MT singer compared to the "rounded" tone of a classically trained singer.

Previous studies by the authors on classically trained choristers in the UK (Barlow and Howard 2005) demonstrated links between CQ and pitch. The pattern of mean CQ against pitch is almost exactly replicated here, suggesting that the classical singing style used by the BYCA is the same as that used by other conventionally classical youth choirs. Although vocal development over adolescence has been indicated to decrease sung CQ among classically trained girls (Barlow and Howard 2006), there is no apparent link shown by this data set between mean sung CQ and mean spoken F0.

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Address for correspondence

Chris Barlow, School of Computing and Communications, Southampton Solent University, East Park Terrace, Southampton, Hampshire SO14 0RD, UK; *Email:* christopher.barlow@solent.ac.uk

References

Barlow C. A. (2003). *Electrolaryngographically Derived Voice Source Changes of Child and Adolescent Subjects Undergoing Singing Training* Unpublished doctoral thesis, University of York.

Barlow C. and Howard D. M. (2002). Voice source changes in child and adolescent subjects undergoing singing training. *Logopedics Phoniatrics Vocology, 27*, 66-73.

Barlow C. and Howard D. M. (2005) Évaluation Électrolaryngographique des effects des cours de chant et du sexe sur la source vocale des chanteurs and chanteuses prépubères. *Medecine des Arts*, *52*, pp. 12-19.

Barlow C. and Howard D. M. (2006) Measured characteristics of development in adolescent singers. *Proceedings of the 4th Sound and Music Computing Conference SMC07*. (pp 101-107) Athens, Greece: University of Athens

Cole G. (2007) *Stagecoach Theatre Arts Plc: Annual Report and Accounts*. London: Stagecoach Plc.

Evans M. and Howard D. M. (1993). Larynx closed quotient in female belt and opera qualities: A case study. *Voice, 2*, pp. 7-14.

Howard D. M. (1995). Variation of electrolaryngographically derived closed quotient for trained and untrained adult female singers. *Journal of Voice*, *9*, pp. 163-172.

Howard D. M., Welch G. F., Brereton J., and Himonides E. (2003). Towards a novel real-time visual display for singing training. *Proceedings of the 3rd International Workshop on Models and Analysis of Vocal Emissions for Biomedical Applications MAVEBA-3* (pp. 179-182). Florence, Italy: University of Florence.

McAllister A., Sederholm E., and Sundberg J. (2000). Perceptual and acoustic analysis of vocal registers in 10 year old children. *Logopedics Phoniatrics Vocology, 25*, pp. 63-71.

Scherer R. C. (2005). Laryngeal function during phonation. In R. T. Sataloff (ed.), *Voice Science* (pp. 167-184). San Diego, California, USA: Plural Press.

Welch G. F., Howard D. M., and Rush C. (1989) Real-time visual feedback in the development of vocal pitch accuracy in singing. *Psychology of Music*, *17*, pp. 146-157.