Overall and posterior glottal adduction in singing

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Introduction

It is known that glottal adduction can be adjusted both posteriorly by posterior cricoarytnoid, lateral cricoarytenoid and interarytenoid (PCA/LCA/IA) muscles, as well as in overall by the thyroarytenoid (TA) muscles. An independent control of the posterior glottal adduction and TA activity is useful for achieving better flexibility in controlling the singing voice quality. However, there is a lack of singing exercises to train singers in achieving this control. The goal of this study was to design and test such singing exercises.

	Low TA activity	High TA activity
Low arytenoids adduction	'naïve falsetto'	'light chest'
High arytenoids adduction	'quality falsetto'	'heavy chest'

Table 1: Suggested model for producing four extreme phonation types.

Methods

The phonatory exercises were designed to target four extreme phonation types: a) 'naïve falsetto' (breathy), b) 'quality falsetto', c) 'light chest' (breathy) and d) 'heavy chest' (Tab. 1). 6 female and 6 male singers and non-singers were asked to imitate an instructor (subject CH, whose ability to produce the 4 distinct phonation types has been documented in an earlier study). The phonations had to have a pitch that was within the range of the chest/falsetto register transition (C#4 to F4). In order to maintain the desired registration (chest or falsetto), the target notes were reached by singing a descending (for falsetto) or ascending (for chest) scale of five notes. The subjects were asked not to 'blend or mix the registers'. The phonation was monitored by videostroboscopy, videokymography (VKG), electroglottography (EGG) and audio recording.

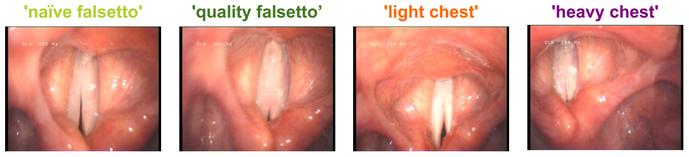

Fig. 1: Typical laryngeal configurations for all attempted phonation types (female subject MM), as revealed by laryngeal videostroboscopy. The images were taken at the moment of maximal vocal fold closure.

Results

For a majority of the subjects, the results confirmed distinct laryngeal configurations (Fig. 1) and vocal fold vibration characteristics (Fig.2) for the four phonation types. All subjects had a less adducted posterior glottis in the two breathy phonation types than in the non-breathy phonations (Fig. 1, Tab. 2). In some cases, the arytenoid processes were clearly vibrating during the breathy phonations (Tab.3). The closed quotient rose when changing from the light to heavy chest and from the naïve to quality falsetto (Fig. 3). All subjects had mucosal waves and sharp lateral peaks in VKG when phonating in "heavy chest" voice. In 9 subjects, mucosal waves of some degree were found in all phonation types, i.e., even in both the falsetto phonations (example in Fig.2).

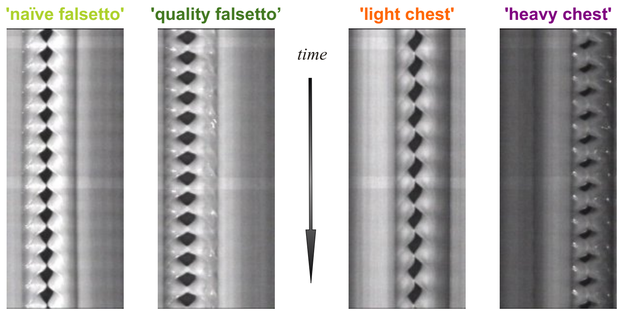

Fig. 2: Typical VGK images for all attempted phonation types (female subject HM). Note that the 'resonant falsetto' phonation had a longer closed phase than 'light chest'. (All the VKG images were recorded at the place of max. vibration amplitude of the vocal folds; total time displayed: 40 ms)

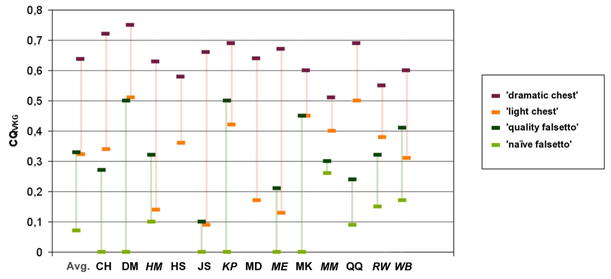

Fig. 3: Videokymographic closed quotients (CQ_{VKG}) for all subjects and all attempted phonation types. The female subjects are indicated with italic initials. (The falsetto phonations of subjects HS and MD are omitted, because criteria for inclusion in analysis were not met.)

Discussion / Conclusions

The findings of this study suggest that the designed phonatory exercises can be used to produce 4 extreme types of singing voice. The designed phonatory exercises aid in training singers to gain an independent control of the voice register and glottal adduction, thus making the voice more flexible. The data also showed that the closed quotient can in some subjects achieve larger values in "quality falsetto" than in "light chest" phonations (Fig.3, subjects HM, JS, KP, ME, WB), implying that the closed quotient is not a sole indicator of the voice register in singing.

	'naïve falsetto'	'quality falsetto'	'light chest'	'heavy chest'
CH	PGC(m)	full glottal closure	PGC(m)	full glottal closure
DM	PGC(m)	PGC(c); slight anterior gap;	PGC(m)	full glottal closure
HM	PGC(m)	full glottal closure	PGC(c)	full glottal closure
HS	no vocal fold contact at all	full glottal closure	PGC(m)	full glottal closure
JS	no vocal fold contact at all	full glottal closure	PGC(m)	full glottal closure
KP	PGC(m)	full glottal closure	PGC(m)	full glottal closure
MD	cartillarenous glottis closed; mid-membranous glottal chink	arytaenoid processes pressed together; slight anterior glottal gap	PGC(c)	full glottal closure
ME	PGC(m)	PGC(c)	PGC(m)	full glottal closure
MK	PGC(m)	full glottal closure	PGC(m)	full glottal closure
MM	PGC(m)	PGC(c)	PGC(m)	full glottal closure
QQ	PGC(c)	full glottal closure	PGC(c)	full glottal closure
RW	PGC(m)	PGC(c)	PGC(c)	full glottal closure
WB	PGC(m)	full glottal closure	N/A	full glottal closure

Table 2: Observed types of glottal closure: PGC(c) refers to a posterior glottal chink in the cartilaginous glottis; PGC(m) labels a posterior glottal chink that reaches into the membranous portion of the vocal folds. Note the increase of adduction from "naïve falsetto" to "quality falsetto" and from "light chest" to "heavy chest."

	CH	DM	HM	HS	JS	KP	MD	ME	MK	MM	QQ	RW	WB
'naïve falsetto'	YES	no	YES	no	YES	N/A	no	no	YES	YES	YES	YES	no
'quality falsetto'	no	no	no	no	no	no	no	no	no	YES	no	YES	no
'light chest'	YES	YES	YES	YES	YES	YES	YES	no	YES	YES	YES	YES	N/A
'heavy chest'	no	no	no	no	no	no	no	no	YES	no	no	YES	N/A

Table 3: Presence of vibration of the vocal processes of the arytaenoid cartillages. In some cases, no assessment could be made, since the posterior glottis was not visible.

Reference

Herbst, Christian, and Švec, Jan: Investigation of four distinct glottal configurations in a classically trained male singer. Proceedings of the 3rd International Conference on the Physiology and Acoustics of Singing (PAS3). 2006, York, England.

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