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1. Introduction

The two modes of singing Overdrive and Edge, from the terminology of Complete Vocal Technique, have recently been investigated using audio perception, laryngostroboscopic imaging, acoustics, LTAS, and EGG, resulting in a call for more research into voice with similar methods of comparison¹. The current paper on Curbing provides an example of such an analysis of other types of sounds known as Curbing with a ‘reduced metallic’ characteristic as compared to the full metallic characteristic of Overdrive and Edge¹⁻⁵. This line of comparative inquiry follows recent research done into non-classical styles of singing, which historically have been rarer than studies of classical singing styles in spite of the more common use of non-classical styles⁶.

Other studies on non-classical styles argue that comparing non-classical singing – or rather Contemporary Commercial Music (CCM) – to classical styles makes little sense, as classical measures of vocal production are not viable and useful ways of assessing non-classical styles; hence CCM should be considered on its own merits^{7,8}. However, relatively little research has been done on the style of CCM⁷, which has been explained by Zangger Borch et al as an outcome of the styles viewed historically as ‘unhealthy’ or detrimental to vocal health⁹. Conversely, recent studies into voice production of e.g. ‘Belting’ or ‘full metallic singing’ argue for the health of such types of voice production, and point to the phonatory function being the crux of the issue^{1,6}. Studying CCM styles of singing echoes the notion that research into non-classical singing is at least as important as research into classical singing¹⁰, and that a terminology for classifying voice accordingly is called for. It has been argued that the first step in developing a method for teaching specific sounds is to understand ‘the premises and conditions of the desired sounds’¹.

The present study contributes to exploring CCM styles by investigating sounds known as ‘Curbing’ and compares findings on Curbing to previous findings in the area done on Overdrive and Edge to investigate such conditions and premises. The term ‘Curbing’ stems from the terminology of the Complete Vocal Technique (CVT)² method, which has been developed by author Cathrine Sadolin and investigated by Brixen et al.³⁻⁵ and McGlashan et al.^{1,11} as a genre and style-free approach. In the Complete Vocal Technique method ‘Curbing’ relates to the audio perception of sounds that have a reduced metallic *‘slightly plaintive or restrained sound’* compared to Overdrive which is a *‘direct sound with a more shout like character’* and Edge which has a *‘light and somewhat aggressive sound with a more scream like character’*⁴.

A recent study of two other CVT categorisations, namely ‘Overdrive’ and ‘Edge’, showed statistically significant differences between the two categories of sounds¹ and argued for a multidimensional approach to studying voice based on audio perception, laryngostroboscopic imaging, acoustics, Long-Term Average Spectrum, and Electrolaryngography. The findings on Overdrive and Edge indicated a dominant second harmonic, as well as a progressive constriction of the supraglottic structures leading to the definition of the two modes of singing as ‘metallic’. Particularly, the following intentional constrictions in the larynx were identified: ventricular folds covering visual parts of the vocal folds, anterior-posterior narrowing of the arytenoid-cuneiform complexes and petiole, an anteromedial rolling in of the cuneiforms, an acute angle between the aryepiglottic folds and the epiglottis, narrowing of the piriform sinuses and a heightened larynx position¹. These findings are similar to findings from previous studies of ‘belting’^{12,13} as well as the findings of Hanayama, Camargo, Tsuji, Rebelo Pinho¹⁴ on the metallic voice where pharyngeal wall narrowing, laryngeal rise, aryepiglottic, and lateral laryngeal constrictions were found.

Utilising an identical approach to the McGlashan et al. paper, the present study analyses and defines the mode of ‘Curbing’ and compares the findings on ‘Curbing’ to the previous findings on Overdrive and Edge to further test the proposed method and its validity for developing a voice classification system, as well as exploring the voice classification ‘Curbing’ itself. The purpose of the study is, therefore, to investigate the categorisations of voice offered by Complete Vocal

Technique by means of laryngostroboscopic imaging, acoustics, LTAS, EGG, and audio perception. Consequently, this study tests and evaluates the following hypothesis:

- H1: There is no visual difference between the laryngeal gestures of ‘Curbing’ compared to the previous findings on Overdrive and Edge
- H2: There is no significant difference in the LTAS profile of ‘Curbing’ compared to the previous findings on Overdrive and Edge
- H3: There is no significant difference in the multi-dimensional acoustic properties of ‘Curbing’ compared to the previous findings on Overdrive and Edge
- H4: There is no significant difference in the multi-dimensional EGG-derived measurements of ‘Curbing’ compared to the previous findings on Overdrive and Edge.

2. Methods

2.1 Participants

The study analysed data from 20 professional singers (10 males and 10 females), all with training in the categorisation Curbing. The median age of the singers was 34, ranging from 20-52. The singers’ singing experience ranged from 2-26 years, with a median of 13.5 years of singing experience. The participants’ CVT-related training ranged from 1-15 years, with a median of 4.6 years of CVT-specific training. Singers had various nationalities; 13 Danish singers, 4 Norwegian singers, 1 Icelandic singer, and 2 Dutch singers. The singers self-identified their various styles of singing, including: rhythmical (1 singer), pop (singers), rock (3 singers), classical (2 singers), jazz (1 singer), soul (2 singers,) experimental (1 singer), and gospel (1 singer). Data for the study was obtained from all 20 participants, however data from four participants was excluded from the study of EGG and laryngostroboscopic imaging as the participants either could not tolerate the examination (1) or the data quality was not adequate for interpretation/could not be obtained (3).

2.2 Instrumentation

The study was conducted in two stages. The first stage was concerned with obtaining the laryngostroboscopic images, which were recorded with a videonasoscopy camera system (ENFV2 videoscope and OTVS7 camera from Olympus/Keymed). A Laryngostrobe system (Laryngograph ® Ltd) captured the images while simultaneously acquiring the acoustic and EGG signals. A head-mounted omnidirectional microphone recorded the acoustic signal and two electrodes placed on both sides of the singers’ larynxes recorded the electrolaryngograph (EGG) signal. The Laryngograph microprocessor synchronised and processed the two signals.

The second stage of the study was concerned with obtaining an acoustic signal and an EGG signal with Speech Studio (vers. 3.56 Laryngograph® Ltd). A Sony ECM 989 microphone was used to record the audio signal, and it was kept at a constant 25cm from the singer. Audio and EGG was captured simultaneously. The Laryngograph microprocessor synchronised and processed the signals for analysis in the Speech studio software.

2.3 Vocal task

All participants were instructed to sustain¹⁵ an [I] on C4 for males (262Hz) and B4 for females (494Hz). The vowel was sustained for approximately 2-3 seconds.

2.4 Laryngeal Gestures

The study utilised a separation of the vocal tract according to McGlashan et al.’s division into 6 levels¹ as visible in illustration 1.1 and focused on levels 1-4. The 6 levels relate to the vocal fold level (1); the ventricular folds (2); the arytenoid cartilages/cuneiform, epiglottis, and aryepiglottic folds (3); piriform fossa and posterior pharyngeal wall of the hypopharynx (4), Soft palate, uvula,

oropharynx, and the back of the tongue (5), and, the oral and nasal cavities (6). Still Images from the laryngostroboscopic footages was chosen based on blind checks by one of the authors (CS) by listening for ‘Curbing’ sounds without viewing the imaging material or the electroglottograph signals. Having chosen a representative sound example for the mode of ‘Curbing’, the corresponding still image from the footage was used for further analysis based on visual clarity. The further analysis of laryngeal gestures was based on a detailed evaluation of the similarities and differences of Curbing as compared to the findings on Overdrive and Edge in a previous study¹. The analyses and comparisons were done by two of the authors (MAT and CS) until a consensus agreement was obtained on each gesture for each still image. The still images were examined for males and females respectively, and each identified laryngeal gesture was rated on a scale of degree ranging from 0 to 4; 0 (not at all), 1 (a little), 2 (more), 3 (a lot), or 4 (almost fully). In total 18 stills for curbing were examined and compared to the findings on 18 stills of Overdrive and 18 stills of Edge.

Illustration 1.1 – The 6 levels of the vocal tract
Reprinted from McGlashan et al. (2016): “Overdrive and Edge as refiners of ‘belting’”

2.5 EGG and Acoustic recordings

EGG was used as a non-invasive method for obtaining data of the vocal fold activity¹⁶, usable for distinguishing between the modes of singing¹. To obtain the EGG and acoustic signals the Laryngograph® and electroglottograph was used. A head-mounted, pressure sensitive, omnidirectional electret microphone with a +/- 2dB, 100Hz to 10kHz, noise level 26dB (SPLA), and a dynamic range of 88dB was used. The EGG consisted of two gold-plated electrodes placed on the surface of the skin over the thyroid cartilage of the participant. Both signals were acquired simultaneously by the Laryngograph® microprocessor, recorded by Speech Studio onto a laptop.

2.6 EGG and Acoustic Measures

The Electrolaryngograph (EGG) was used to obtain and enable analysis of the vocal fold activity during phonation, enabling the comparison of differences and similarities between the vocal modes tested. Based on the EGG derived measures a multi-dimensional voice profile (MDVP) was generated which included Qx, QxSD, Fx, FxSD, Jitter First, Jitter Second, Jitter Factor, and

Relative Average Perturbation. The EGG provided a resonance-free measure¹ which precluded data impact from vocal tract resonance (area function¹⁷), yielding a more accurate description of the laryngeal activity.

To further quantify acoustic differences between Curbing and Overdrive and Edge the study included measures of Shimmer +, Shimmer -, Shimmer dB, Harmonics-to-Noise Ratio, Normalised Noise Energy, Cepstral Peak Prominence, and mean Sound Level Pressure (SPL). These measures combined with the EGG made up a multi-dimensional voice profile^{1,18}. Statistical significance was tested using the paired student's t-test for males, females, and males and females combined.

2.7 Long-Term Average Spectrum

LTAS was used as a means for obtaining an 'objective voice classification'^{19,20} of the measured modes based on acoustic frequency responses, and included both Narrowband and Broadband analyses of the obtained sustained vowel. The acoustic signal was used in Speech Studio to generate the spectra, ranging from 0Hz to 8000Hz. Narrowband was used to analyse harmonic structures, whereas Broadband was used to analyse the formants. Both Broadband and Narrowband data was normalised for loudness for each sample²¹ to allow for better comparisons according to a correction factor, similarly to previous studies performed with LTAS significance testing¹. The correction factor was calculated on the differences in dB from Overdrive to Edge and Overdrive to Curbing at the fundamental frequency of the sample note (494Hz for females and 262 for males). The normalisation was done at the closest integral value (500Hz for females and 250Hz for males). The Curbing data was compared to the Overdrive and Edge data from a previous study¹ and test of significance was done by student's t-tests, for males, females, and male and females combined respectively between Curbing and the previous study findings.

3. Results

3.1 Laryngeal Gestures

The following observations of the laryngeal movements in levels 1-4 were made in the study:

Level	Laryngeal Gesture	Maximum potential score (4*18)	Total score for Overdrive	Total score for Edge	Total score for Curbing
2	<i>How much of the vocal folds are covered by the false folds?</i>	72	29	52	13
	<i>Vocal folds seen along their length</i>	72	33	15	54
	<i>False folds are active giving a rectangular appearance</i>	72	31	9	60
3	<i>Anterior posterior narrowing between arytenoid/cuneiform</i>	72	37	61	25

	<i>complex and petiole</i>				
	<i>Cuneiforms rolled in antero-medially</i>	72	37	65	19
	<i>Laryngeal inlet is triangular shaped</i>	72	34	62	15
	<i>Acute angle between the aryepiglottic folds and epiglottis</i>	72	43	64	30
4	<i>Narrowing of the piriform sinuses</i>	72	40	61	23
	<i>Higher Larynx</i>	72	38	66	51

Table 1.1 – Summary of Laryngeal Gestures and a quantified comparison of Curbing, Overdrive and Edge

For Curbing (see illustration 1.2 and 1.3) there seemed to be identifiable activity at levels 2-4. In level 2, the false folds were not predominantly covering the vocal folds, yielding free visual access to the vocal folds – visible along their length (54 score out of 72 possible), and the activity. Interestingly, the false folds were active in terms of giving a rectangular appearance (60 score of out 72 possible). On level 3 there was some anterior and posterior narrowing taking place between the arytenoid and cuneiform complexes and the petiole (25 score out of 72), but there seemed to be little rolling in of the cuneiforms antero-medially (19 score out of 72 possible) and little triangularly shaped appearance of the laryngeal inlet (15 score out of 72 possible). A somewhat acute angle between the aryepiglottic folds and the epiglottis was observed (30 score out of 72 possible). On level 4 there seemed to be very little narrowing of the piriform sinuses (23 score out of 72 possible), however, the larynx seemed to be elevated (51 score out of 72 possible for higher larynx). The combination of seeing the vocal folds at their entire length, a rectangular-shaped false folds and a higher larynx seem to be characteristic for the laryngeal setting of Curbing.

Illustration 1.2 and 1.3 – Examples of videonasoscopic images of Curbing showing the identified laryngeal gestures

3.2 Long-Term Average Spectrum

The LTAS analysis yielded some interesting findings for the mode Curbing, with significant differences visible from Overdrive and Edge on both Narrowband and Broadband measures. On Narrowband, it seems that there is a significant amount of energy in the area between 438-563Hz for females and between 219-375Hz for males. There seems to be less harmonic structure in the spectra from around 5100Hz for females and from around 3kHz for males. Generally, Curbing seems to have less energy in the spectrum than both Overdrive and Edge, which seems to be very prominent for males particularly, particularly before loudness correction, but also significantly after normalisation. This is particularly observable after the 2nd harmonic and onwards. The male Curbing samples seem to indicate relatively less energy throughout the entire spectra after 406Hz, whereas, the female Curbing samples seem to indicate relatively less energy from around 781Hz and throughout the rest of the spectra. Whereas Overdrive and Edge both seem to show a relative clear harmonic structure in the area from 5kHz and upwards for males and 8kHz for females, Curbing does not seem to have any clear harmonic structure after 5kHz for females and from around 3kHz for males. Both Overdrive and Edge seem to have a peak around the 2nd harmonic and a low fundamental, whereas Curbing seems to show a peak at around the fundamental and lower 2nd harmonic (see illustration 1.4 and 1.5 for males and females respectively).

Illustration 1.4 – Female Narrowband LTAS – Curbing compared to Overdrive and Edge

Illustration 1.5 – Male Narrowband LTAS – Curbing compared to Overdrive and Edge

Comparing the Curbing data to the findings on Overdrive and Edge there seems to be high statistically significant differences between Curbing and both Overdrive and Edge throughout the LTAS Narrowband spectra. In total 256 P-values were calculated based on the narrowband data, and the normalised Curbing samples differed on 251 of those compared to Overdrive and 242 compared to Edge with p values ranging from 0.05-0.00. Of these P-values, 217 differed with $P=0.00$ comparing Curbing to Overdrive, and 231 comparing Curbing to Edge. This is also the case for gender-specific comparisons, where female Curbing differs on 213 measures compared to Overdrive, and 237 compared to Edge, and male Curbing differs on 231 measures compared to Overdrive, and 244 compared to Edge (see summary of comparisons in table 1.2). The very few measures that were not statistically significantly different are commented on below for mean measures of Curbing, and for males and females respectively.

	<i>N</i>	<i>P = 0.00</i>	<i>P=0.05 or below</i>
<i>Female C/O</i>	256	96	213
<i>Female C/E</i>	256	124	237
<i>Male C/O</i>	256	113	231
<i>Male C/E</i>	256	137	244
<i>Male + Female C/O</i>	256	217	251
<i>Male + Female C/E</i>	256	231	242

Table 1.2 – Summary of P-values From Two-Tailed t Test on LTAS Narrowband for Curbing

Comparing mean and normalised measures of Curbing to mean and normalised measures of Overdrive and Edge, there seems to be little statistical difference in the area between 250-375Hz when comparing to Overdrive (P-values ranging from 0.12-1.00) for Overdrive and in the area between 250-469Hz when comparing to Edge (P values ranging from 0.06-0.95). In the area from 688 to 8000Hz all measures vary significantly between Curbing and Edge and Curbing and Overdrive, with P-values of 0.00 throughout the comparisons. All differences between Curbing and Overdrive and Edge are to be found in the 1st and 2nd harmonic structures on mean measures.

Comparing the female Curbing and female Overdrive samples specifically, there seems to be no statistically significant difference between the two in the area from 250-344Hz, from 406-719, and in the area from 2469-2594Hz and 2969Hz-3031Hz (P-values ranging from 0.06 to 0.63). Similarly, comparing the female Curbing and female Edge samples specifically, there seems to be no statistically significant difference between the two in the area from 250-375Hz (P-values ranging from 0.30 to 0.95) or in the area between 469-563Hz (P-values ranging from 0.10-0.15). Furthermore, the measures at 688Hz, 7719Hz, and 6719 show P-values approximating 0.10 indicating a weak statistically significant difference at these measures. The statistically significant findings on 213 out of 256 measures seems to be accounted for after the 2nd harmonic also for females.

Comparing the male Curbing and male Overdrive samples specifically shows similar results with no statistically significant difference from 31Hz-375Hz (P-values ranging 0.07-0.77), and weak statistically significant differences at 4594hz (P=0.08), 4625Hz (P=0.06), 4781-4906Hz (P-values ranging from 0.06-0.15), 5063 (P=0.06), and 6625-6656Hz (P= 0.10 and 0.13). Similarly, comparing the male Curbing and male Edge samples specifically, there seems to be little statistical difference in the area from 31Hz to 375Hz (P-values ranging from 0.06-0.67), with all spectra above varying with statistically significant differences (P=0.00).

Comparing Curbing on broadband measures seem to indicate an even further statistically significant difference between Curbing and Overdrive and Curbing and Edge. On the broadband LTAS 128 P-values were calculated, of which Curbing differed on 118 from Overdrive and 126 from Edge with P-values ranging from 0.05-0.00, of which Curbing differed from Overdrive on 118 measures with P=0.00 and from Edge on 126 measure with P=0.00. Curbing seems to have a significantly different first formant as compared to the coinciding first formant of Overdrive and Edge.

Illustration 1.6 – Female Broadband LTAS – Curbing compared to Overdrive and Edge

Illustration 1.7 – Male Broadband LTAS – Curbing compared to Overdrive and Edge

The statistically significant differences pointed out in the mean-summary in table 1.3 are also visible in gender-specific comparisons, where female Curbing differs on 115 measures ($P=0.00$) compared to Overdrive, and 125 ($P=0.00$) compared to Edge, and male Curbing differs on 47 ($P=0.00$) measures compared to Overdrive, and on 126 ($P=0.00$) compared to Edge. The few measures that were not statistically significantly different are commented on below for mean measures of Curbing, and for males and females respectively.

	N	P = 0.00	P=0.05 or below
Female C/O	128	115	115
Female C/E	128	125	125
Male C/O	128	47	47
Male C/E	128	126	126
C/O (mean)	128	118	118
C/E (mean)	128	126	126

Table 1.3 – Summary of P-values From Two-Tailed t Test on LTAS Broadband for Curbing

Comparing broadband findings on female Curbing to female Overdrive specifically, there seems to be no statistically significant differences in 13 of the 128 measures. There seems to be no or weak statistically significant differences between Curbing and Overdrive for females at 63Hz-188Hz (with P-values 0.55, 0.79, and 0.7) and from 2313-2813Hz (P-values ranging from 0.08-0.29).

Similarly, for female Curbing compared to female Edge, there are only three measures that differ, which are found at 63Hz ($P=0.11$), 563Hz ($P=0.35$), and 625Hz ($P=0.15$). Inspecting the

visual representation of the female Broadband (see figure 1.6), Curbing seems to follow a similar formant structure as Overdrive from around 3kHz, with a clearly reduced amount of energy across all spectra.

Comparing the male samples of Curbing to male samples of Overdrive yield the least amount of statistically significantly different measures, with only 47 measures differing between male Curbing and male Overdrive. The male samples seem to show high statistically significantly different values at 63-2188Hz ($P=0.00$) contrary to the female findings. However, there seems to be little or weak statistically significant differences from 2250-4125 (P-values ranging from 0.06-0.40), from 4250-5250Hz (P-values ranging from 0.06-0.35), and from 5500-7250 (P-values ranging from 0.06-0.24). Contrastingly, this does not apply to male Curbing compared to male Edge, where only 2 measures are not statistically significantly different. These are at 563Hz and 625 Hz with P-values of 0.50 and 0.15. Inspecting the visual representation of the male Broadband (see figure 1.7), male Curbing, similarly to the female sample, also seems to follow a formant structure similar to Overdrive, with reduced energy in all the spectra. However, both the female and male sample seems to indicate a large drop in energy in the higher frequencies from around 7500Hz, compared to both Overdrive and Edge.

	PAIRED MEASURE	MEAN	SD
GROUP 1	C No. Periods	1078,80	852,67
	OD No. Periods	859,84	595,51
	E No. Periods	738,74	519,79
GROUP 2	C Mean SPL (dB)	88,47	6,64
	OD Mean SPL (dB)	101,94	5,18
	E Mean SPL (dB)	99,02	3,74
GROUP 3	C Average Fx (Hz)	378,81	113,28
	OD Average Fx (Hz)	370,73	114,46
	E Average Fx (Hz)	391,89	124,76
GROUP 4	C SD Fx (Hz)	3,97	10,72
	OD SD Fx (Hz)	1,72	2,26
	E SD Fx (Hz)	4,71	8,94
GROUP 5	C Jitter First (%)	1,37	2,18
	OD Jitter First (%)	0,89	1,06
	E Jitter First (%)	4,95	16,30
GROUP 6	C Jitter Second (%)	1,12	2,55
	OD Jitter Second (%)	0,53	0,63
	E Jitter Second (%)	3,27	10,90
GROUP 7	C Jitter factor (%)	1,77	4,02
	OD Jitter Factor (%)	0,84	0,99
	E Jitter Factor (%)	5,01	16,45
GROUP 8	C RAP (%)	0,88	1,19
	OD RAP (%)	0,70	0,97
	E RAP (%)	3,32	10,75
GROUP 9	C Shimmer dB (dB)	0,68	0,30
	OD Shimmer dB (dB)	0,39	0,21

	E Shimmer dB (dB)	0,91	0,72
GROUP 10	C Shimmer + (%)	7,53	3,30
	OD Shimmer + (%)	4,24	2,22
	E Shimmer + (%)	10,17	7,99
GROUP 11	C Shimmer - (%)	-7,64	3,76
	OD Shimmer - (%)	-4,28	2,37
	E Shimmer - (%)	-9,35	4,32
GROUP 12	C Average Qx (%)	50,95	8,53
	OD Average Qx (%)	53,10	9,44
	E Average Qx (%)	53,09	12,50
GROUP 13	C SD Qx (%)	2,80	2,12
	OD SD Qx (%)	2,52	3,23
	E SD Qx (%)	5,22	7,10
GROUP 14	C Max Qx (%)	56,88	8,01
	OD Max Qx (%)	59,31	10,91
	E Max Qx (%)	62,53	11,51
GROUP 15	C Min Qx (%)	42,82	12,46
	OD Min Qx (%)	46,43	14,32
	E Min Qx (%)	42,24	22,96
GROUP 16	C NNE (dB)	-21,77	6,95
	OD NNE (dB)	-29,24	7,14
	E NNE (dB)	-19,70	7,40
GROUP 17	C HNR (dB)	19,18	3,74
	OD HNR (dB)	24,44	3,16
	E HNR (dB)	17,88	4,59
GROUP 18	C CPP	6,21	1,27
	OD CPP	7,75	1,25
	E CPP	7,27	1,68

Note: N = 16 for each pair; C = Curbing; OD = Overdrive; E = Edge; SPL = Sound Pressure Level; Average Fx = Average Fundamental Frequency derived from EGG; SD Fx = Standard Deviation of Fundamental Frequency derived from EGG; RAP = Relative Average Perturbation; Average Qx = Average Contact Quotient; SD Qx = Standard Deviation of Contact Quotient; NNE = Normalized Noise Energy; HNR = Harmonics to Noise Ratio; CPP = Cepstral Peak Prominence; SD = Standard Deviation

Table 1.4 - Paired Samples Measures Across EGG and Acoustics

3.3 EGG and Acoustic Measures

An overview of the means and standard deviations used for statistical evaluation of EGG and Acoustics can be seen in table 1.5 with the reported significances visible in table 1. Due to the relatively small sample size (n=16), P values less than 0.10 are partially highlighted, indicating findings that may be interesting regardless of the slightly weaker statistically significant differences.

Comparing Curbing to Overdrive there seems to be statistically significant differences in terms of numbers of periods (P=0.02), Max Qx (P=0.06), Average Qx (P=0.05), Shimmer+ (P=0.00), Shimmer- (P=0.00), Shimmer dB (P=0.00), NNE (P=0.00), CPP (P=0.00), HNR (P=0.00), and Mean SPL (P=0.00). This does vary slightly if comparing the female Curbing to the

female Overdrive, where the max Qx and NNE measures do not seem to have as high a statistical significant difference (P= 0.10 for both measures). Comparing the male Curbing to the male Overdrive, there similarly seems to be a lower statistically significant difference on the max Qx measure (P=0.05). In the mean comparison of Curbing and Overdrive, Curbing seems to differ with statistical significance on a total of 11 out of 21 measures.

Comparing Curbing to Edge there seems to be statistically significant differences in terms of number of periods explained by duration of the sung note, duration (P=0.02), Max Qx (P=0.01), CPP (P=0.00), and Mean SPL (P=0.00). This varies slightly when comparing gender-specific findings. Comparing female Curbing to female Edge there seems to be no differences from the mean comparison. However, comparing the male Curbing to the male Edge the no. periods, as well as the CPP does not vary with statistical significance (P=0.32 and 0.13 respectively). Out of the 21 measures, the Mean Curbing differs from the Mean Edge on a total of 5 out of 21 measures.

Comparing findings across the P-values, it seems that the main differences of Curbing compared to Overdrive and Edge can be found on measures of shimmer, NNE, CPP, HNR, and mean SPL, as well as some Qx measures, where P-values approximate 0.00.

	PAIR 1: FEMALE CURBING TO FEMALE OVERDRIVE	PAIR 2: FEMALE CURBING TO FEMALE EDGE	PAIR 3: MALE CURBING TO MALE OVERDRIVE	PAIR 4: MALE CURBING TO MALE EDGE	PAIR 5: MEAN CURBING TO MEAN OVERDRIVE	PAIR 6: MEAN CURBING TO MEAN EDGE
MEASURES						
NO. PERIODS	0,02	0,03	0,50	0,32	0,02	0,02
MEAN SPL	0,00	0,00	0,00	0,00	0,00	0,00
AVERAGE FX	0,17	0,87	0,31	0,35	0,12	0,33
SD FX	0,28	0,19	0,28	0,66	0,36	0,65
JITTER FIRST	0,53	0,84	0,38	0,33	0,28	0,31
JITTER SECOND	0,42	0,81	0,35	0,33	0,28	0,31
JITTER FACTOR	0,44	0,82	0,35	0,33	0,28	0,31
RAP	0,86	0,53	0,39	0,34	0,51	0,31
SHIMMER DB	0,04	0,35	0,00	0,37	0,00	0,23
SHIMMER+	0,02	0,35	0,00	0,37	0,00	0,23
SHIMMER-	0,03	0,62	0,00	0,41	0,00	0,31
AVERAGE QX	0,14	0,13	0,24	0,79	0,05	0,25
SD QX	0,82	0,37	0,24	0,26	0,69	0,17
MAX QX	0,10	0,05	0,38	0,08	0,06	0,01
MIN QX	0,50	0,62	0,58	0,41	0,37	0,73
NNE	0,10	0,50	0,01	0,71	0,00	0,42
HNR	0,00	0,72	0,00	0,21	0,00	0,49
CPP	0,00	0,00	0,00	0,13	0,00	0,00

Note: N = 16 for each pair; C = Curbing; OD = Overdrive; E = Edge; SPL = Sound Pressure Level; Average Fx = Average Fundamental Frequency derived from EGG; SD Fx = Standard Deviation of Fundamental Frequency derived from EGG; RAP = Relative Average Perturbation; Min Qx = Minimum Contact Quotient; Max Qx = Maximum Contact Quotient; Average Qx = Average Contact Quotient; SD Qx = Standard Deviation of Contact Quotient; NNE = Normalized Noise Energy; HNR = Harmonics to Noise Ratio; CPP = Cepstral Peak Prominence

Table 1.5 – Comparative p values from EGG and Acoustic Two-Tailed t Test (P=0.00, P<0.05-0.10) with a 95% confidence interval

4. Discussion

In a recent paper, the two modes Overdrive and Edge from the terminology of Complete Vocal Institute were investigated by McGlashan et al. utilising and correlating between audio perception, laryngostroboscopic imaging, Acoustics, LTAS, and EGG, calling for more research into voice with similar methods of comparison¹. The current paper on Curbing provides an example of a similar analysis of other types of sounds known as Curbing with a ‘reduced metallic’ characteristic as compared to the full metallic characteristics of Overdrive and Edge¹⁻⁵. The findings support the establishing of Curbing as its own mode of singing – a particular larynx and vocal tract position and the accompanying source and filter interaction²² resulting in consistent auditory perceptual properties. The findings support a rejection of all the proposed hypotheses. H1 can be rejected since Curbing does indeed feature a specific laryngeal gesture, different from Overdrive and Edge. H2 can be rejected as the LTAS reveal a large number of statistically different frequency response on both LTAS Narrowband and Broadband. H3 and H4 are rejected as Curbing differs with statistical significance on both EGG derived and acoustic measurements from Overdrive and Edge.

Comparing Curbing to Overdrive and Edge with normalised LTAS, the Broadband reflects that Curbing differs from Overdrive on 118 of 128 measures and from Edge on 126 of 128 measures with P-values of 0.00. Similarly, the Narrowband analysis indicate that Curbing differs from Overdrive on 251 of 256 measures and from Edge on 242 of 256 measures, of which 217 for Overdrive and 231 for Edge are observed with P=0.00. While the LTAS measurements proposed here do not necessarily translate directly into metallic-measures, it is indeed discernible that Curbing seems to have similar structures to Overdrive and Edge in some frequency ranges, but with less energy across all the frequencies observed. This could be related to the ‘metallic character’ also recognised by Hanayama et al.¹⁴ who concluded that metallic voice seems to have an increased 2nd formant. Similarly, Curbing was observed with a high 1st harmonic and low 2nd harmonic for both males and females, compared to the subsequent high 2nd harmonic and low fundamental of Overdrive and Edge. These findings correlate with what Brixen et al.⁴ found on a different cohort of singers, namely that on an FFT-based Narrowband analysis of Curbing, Overdrive, and Edge, Curbing seems to have a high first formant, and a low second formant, compared to Overdrive and Edge where a low first formant, and high second formant was noted. The findings in this study, correlated with the Brixen et al. findings, challenge the current conception of metallic voice as relating solely to a high 2nd harmonic, and pose that metallic voice might be a combination of harmonic structures, which is the case with Curbing, Overdrive, and Edge.

Conversely, metallic voice has been related to aryepiglottic constriction²³, which seems to correlate well with the findings on Curbing as well as previous findings on Overdrive and Edge. Curbing scored 30 out of 72 possible on this laryngeal gesture, translating to a medium amount of aryepiglottic constriction, compared to the higher Overdrive score of 43 and Edge score of 64. Moreover, Curbing seems to have a particular laryngeal gesture in a combination of the vocal folds seen along their length (54 out of 72) and the false folds being active giving a rectangular appearance (60 out of 72). These two features seem characteristic for Curbing compared to Overdrive scoring 33 and 31, and Edge scoring 15 and 9 on the same measures.

While Curbing displays distinctive laryngeal gestures that seem to be prominent for the mode in particular (the rectangular appearance of the false folds and the visibility of the vocal folds along their length) it seems that some of the prominent and distinctive features of Overdrive and Edge are not observable as equally prominent in Curbing. Both Overdrive and Edge are observed with the cuneiforms rolling in antero-medially and the laryngeal inlet appearing triangularly-shaped (with

Overdrive recorded as 37 and 34 on the two measures, and Edge scoring 65 and 62 respectively). Curbing in comparison only scores 19 on the cuneiforms rolling in antero-medially, and scoring as low as 15 on the laryngeal inlet providing a triangularly shaped inlet. This is also the case for the activity of the false folds in covering the visibility of the vocal folds, where Overdrive scores 29, Edge 52, and Curbing only 13. This would suggest that while there are similar features between Curbing and Overdrive and Edge, Curbing is indeed visually recognisable and displays its own set of distinctive laryngeal gestures.

This argument is in line with the proposition by McGlashan et al.¹ that Overdrive and Edge can be understood as differing on the merits of a progressive constriction of the supraglottic laryngeal structures, with a continuous narrowing of the laryngeal inlet moving from Overdrive to Edge. Situating Curbing on this progression, it would seem that Curbing would be only medium-progressively narrowed, compared to the increasing narrowing moving to Overdrive and finally Edge.

Similarly, these findings resemble previous findings on ‘belting’^{12,14,23,24}, such as the study by Lawrence who concludes that ‘belting’ has a constricted pharynx accompanied with closed ventricular spaces²⁵, arguing for a more constricted setting needed to obtain sounds such as belting. It can be argued that Curbing shares some characteristics with Overdrive and Edge, and subsequently Belting, in terms of laryngeal gestures, however, it differs significantly on EGG and acoustic measures such as shimmer+, Shimmer-, and Shimmer dB compared to Overdrive and Edge particularly. Moreover, investigating the EGG and acoustics comparison further, Curbing has a significantly different mean SPL than Overdrive and Edge. So, whereas Overdrive and Edge, along with varying forms of belting, have been reported with high dB SPL^{13,26,27}, Curbing is observed with a somewhat relatively lower dB SPL and overall spectral energy, which is also visible in the LTAS spectra, even after normalisation. Correspondingly, Curbing is observed with drops in spectral readings around 3kHz on both Narrowband and Broadband, also known as the singer’s formant²⁸, which has previously been discussed as a strategy for loudness and subsequent heightened dB SPL.

Conclusively, the presented findings corroborate previous suggestions that a multidimensional assessment of voice using audio perception, laryngostroboscopic imaging, EGG, acoustics, and LTAS is indeed relevant and yields interesting measures for comparisons of different types of voice productions, which enabled the categorisation of voice based on metallic characteristics.

5. Conclusion

Based on the current study, restrained sounds with a reduced metallic character can be categorised in terms of Curbing, differing conceptually from Overdrive and Edge with statistically significant differences across all proposed measures of audio perception, laryngostroboscopic imaging, Acoustics, LTAS, and EGG. Further research into the metallic character is suggested to investigate the conditions under which ‘metallic’ sounds can be produced, which muscles are involved in producing the Curbing mode, and how to best conceptualise and measure this strategy of voice production. Moreover, further studies comparing the findings from this study to other conceptualisations of voice should be undertaken to test how other restrained as well as non-restrained sounds with or without a reduced-metallic character can be conceptualised. Finally, it is proposed to study the boundary conditions and variation in muscle activity between the various conceptualisations Curbing, Overdrive and Edge to further the understanding of these singing strategies.

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