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Please cite the final published version:

McGlashan, J., Aaen Thuesen, M., & Sadolin, C. (2017). Overdrive and Edge as Refiners of “Belting”? An Empirical Study Qualifying and Categorizing “Belting” Based on Audio Perception, Laryngostroboscopic Imaging, Acoustics, LTAS, and EGG. *The Journal of Voice*, 31(3), 385.e11-385.e22.
<https://doi.org/10.1016/j.jvoice.2016.09.006>

Publication metadata

Title:	Overdrive and Edge as Refiners of “Belting”? An Empirical Study Qualifying and Categorizing “Belting” Based on Audio Perception, Laryngostroboscopic Imaging, Acoustics, LTAS, and EGG
Author(s):	McGlashan, J., Aaen Thuesen, M., & Sadolin, C.
Journal:	<i>The Journal of Voice</i>
DOI/Link:	10.1016/j.jvoice.2016.09.006
Document version:	Accepted manuscript (post-print)

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Overdrive and Edge as refiners of ‘belting’?

An empirical study qualifying and categorising ‘belting’ based on audio perception, laryngostroboscopic imaging, Acoustics, LTAS, and EGG.

Julian McGlashan^{*}, Mathias Aaen Thuesen^a, and Cathrine Sadolin^b

^{*} *Department of Otorhinolaryngology, Queen's Medical Centre Campus, Nottingham University Hospitals, Nottingham NG7 2UH, UK*

^a *Department of Business Communication, Aarhus University, mat@bcom.au.dk, Jens Chr. Skous vej 4, 8000 Aarhus C, Denmark*

^b *Complete Vocal Institute, info@shout.dk, Kultorvet, Hausergade 3, 5th Floor, 1128 Copenhagen K, Denmark*

Summary: This study explores the categorisations Overdrive and Edge from the method Complete Vocal Technique as refiners of the often ill-defined concept of ‘Belting’ by means of audio perception, laryngostroboscopic imaging, acoustics, Long-Term Average Spectrum (LTAS), and Electroglottography (EGG).

Methods: 20 singers, 10 males and 10 females was recorded singing sustained vowels in two separate stages; the first stage recorded laryngostroboscopic using laryngostrobe (Laryngograph ®), whereas the second stage recorded the EGG and acoustic signals into Speech Studio (Laryngograph ®). The signals were then analysed based on audio perception, laryngostroboscopic imaging, acoustics, LTAS, and EGG.

Results: ‘Belting’ can according to the findings of this study be categorised into two modes of singing that vary significantly in measures of LTAS, EGG and acoustics, with visibly different laryngeal gestures. Broadband and Narrowband LTAS shows a statistical difference, particularly after the ninth harmonic, with a coinciding first formant. Physiologically, Edge seems to have a more constricted setting than that of Overdrive, where the ventricular folds seem to cover more of the vocal folds, the aryepiglottic folds show a sharper edge in Edge, and the cuneiforms are rolled in antero-medially. The EGG reflects a similar statistical difference on measures Shimmer+, Shimmer-, and Shimmer dB, as well as Jitter, HNR, and NNE ($p > 0.05$).

Conclusion: The two categories of singing ‘Overdrive’ and ‘Edge’ seem to vary with statistical significance across the suggested five measures, leading to the conclusion that sounds previously known as ‘Belting’ can, according to the findings of this study, be categorised into two modes of singing that vary significantly in measures of LTAS, EGG and acoustics, with visibly different laryngeal gestures and audio perceptive features.

Keywords: Complete Vocal Technique, Overdrive, Edge, Belting, Audio Perception, Laryngostroboscopic imaging, Acoustics, Long-Term Average Spectrum, Electroglottograph

Part of the findings from this study are to be presented at the XXIV Pacific Voice Conference October 2016 in Warsaw.

^{*} Department of Otorhinolaryngology, Queen's Medical Centre Campus, Nottingham University Hospitals, Nottingham NG7 2UH, UK, Julian.McGlashan@nottingham.ac.uk

1. Introduction

The term belting was once associated with ‘unhealthy use of the vocal mechanism’¹. This no longer seems to be the case. Concurringly, recent research into non-classical styles of singing has been receiving more attention¹⁻⁶ with an increased focus on differentiating these styles of singing from the current established understanding of classical singing. While the classical style of singing has been studied extensively, LeBorgne et al. conclude that there is not an adequately established consensus on the perceptual parameters of the ‘belt’ voice. This leads authors to conclude that there may be ‘several ways to produce healthy mix/belt singing’⁷. This lack of consensus indicates a growing discrepancy between current research into the singing voice and the practices of singers around the world’s stages. The discrepancy, may in part, be ascribed to what Miles and Hollien⁶ highlights as a lack of a clear definition of the term, which is in stark contrast to ‘belting’ being taught and used repeatedly across various styles. The lack of a clear definition of the term^{1,6} results in disparate findings on various aspects of ‘belting’, contributing to what LeBorgne et al.¹ call a semantic confusion.

Consequently, the use of the term ‘belt’ or ‘belting’ across genres and styles may in fact relate to very different sounds and physiological vocal tract settings. An example of said discrepancy is for instance the finding that ‘belting’ plays no part in classical singing and that belting is different from chest voice³⁶. Contrastingly, Schutte and Miller (1993) describe belting as *"taking the 'chest' register (source) to higher, sometimes much higher pitches than is generally advised in 'classical' singing" - a manner of loud singing which is characterised by consistent use of 'chest' register (> 50% closed phase of glottis) in a range where larynx elevation is necessary to match the first formant with the second harmonic on open (high F1) vowels, that is approximately G4-D5 in female voices"* (p. 147). Similarly, Estill also studied the use of belting in the operatic quality of voice⁸. These contradictive points serve to illustrate that the term ‘belting’ can be considered conceptually burdened due to its inconsistent use, which can confusion between singers, singing teachers, health professionals, and research. Nonetheless, while the semantic confusion and lack of a clear definition in and of itself warrants further study of ‘belting’, some progress towards defining ‘belt’ and ‘belting’ has been made.

‘Belting’ has generally been described as a voice quality close to a speech-like, yell-like, shouting, or ‘natural’ form of voice production used in singing, which has often been associated with contemporary commercial music genres⁹. Sub-styles of ‘belt’ have been proposed, such as heavy, brassy, ringy, nasal, speech-like, soft, quasi-belt, or low belt⁹. The sounds of ‘Belting’ have been investigated from vocal fold vibration patterns, closed quotient and speed quotient^{1,2,5,10,13,25}, subglottal pressure estimation^{10,8}, laryngeal gestures and height^{3,19}, resonance characteristics¹¹, and acoustic properties including characterising the frequency content through FFT-based spectral analysis^{12,8}. Additionally, it has been suggested that ‘belting’ as compared to other styles of singing does not result in difference in respiratory strategies^{2,9}. Similarly, it has been suggested that ‘belting’, compared to classical singing, is associated with a high laryngeal position, closed ventricular spaces, a tilted epiglottis, and a constricted pharynx with a high tongue position¹³. Acoustically enhancement of higher resonant frequencies^{1,8} in ‘belting’ has been reported, but it has been difficult to differentiate belting from classical singing based on formant frequencies⁹.

Methodologically, Estill⁸ in her work on voice quality looked at vocal fold contact phase based on EGG, as a way to measure the activity in the larynx. This is a practice that has been used repeatedly for the measurement of characterisation of the laryngeal mechanisms¹⁴⁻¹⁹. Previous studies have shown that the belt style of singing is produced with a ‘firmer glottal adduction’^{2,10}, which substantiates the use of EGG as a part-measure of ‘belting’. Other researchers have looked at the laryngeal gestures in the search for an understanding of Belting. Lawrence was the first to investigate the laryngological settings, defining belting by its high laryngeal position, closed ventricular spaces, constricted pharynx and tilted epiglottis combined with a high tongue position¹³. This was corroborated by Estill^{8,20} and her findings on aryepiglottic constriction.

Many of the studies reported here are single-subject studies, with perceptual evaluation of audio as a means of determining sounds as ‘belting’. That is, the audio perception of sound has, and is still, relied upon as a method for classifying the voice²¹. However, audio perception alone may prove difficult to validate for research purposes, as audio perception is determined by the hearer, and so perception may vary from different listeners as it is subjective in nature and therefore hard to quantify. This is also reflected in practitioners’ difficulty in accurately assessing whether or not a voice belongs to one particular voice category or another²² based solely on audio perception. This may in part be due to the fact that no consensus exists in the classification of voice²², a statement the authors of this paper find holds particularly true for ‘belting’.

Nevertheless, there has long been a need for a unified scientific definition and description of ‘belting’^{6,23}, particularly to overcome what Popeil²³ calls the multiplicity of belting. Since many sounds may be ascribed to what constitutes ‘belting’, further studies into these sounds may aid in clearing up and avoiding any inconsistency in the use of the term between singers, singing teachers, health professionals and researchers^{1,6}, echoing Robert Edwin’s statement that ‘it is imperative that we acknowledge the physiological and stylistic differences between classical and nonclassical singing and adjust our pedagogy accordingly’. However, since the term ‘belting’ has solidified in various ways across genres and styles, a unified definition of what constitutes ‘belting’ and a consistent use of the term may not be possible. Therefore, the need for a clear distinction of what belting is, and how it can be accurately measured as a voice strategy, regardless of genre-use, remains an area of interest for research^{2,9,24,25}. This need for a scientific definition was initially pointed out by Hollien and Miles⁶, and many researchers have since echoed that belting remains an issue of clarity^{1,26,27}.

As far as the authors of this paper are aware, no comprehensive evaluation and correlation of belting in relation to audio perception, laryngostroboscopic imaging, acoustics combined with LTAS, and EGG measures has been presented. Previous studies have looked at aspects of these measures, but no coherent argument evaluating belting as a classification-of-voice tool has been presented. It seems fair to assume that correlating data from these four established data sources may aid in the exploration of the sounds commonly conceptualised as Belting for such purposes, in order to further qualify a characterisation of voice. Such a characterisation aids in strategies for both teaching and performing issues. Finally, such a characterisation, with the accompanying physiological vocal tract settings, would satisfy the call for an establishing of a understanding of the vocal tract setting involved in ‘belting’ by Echternach et al.³ in their pilot study of the musical theatre voice.

One characterisation, not related to any specific genre or style, has been proposed by Sadolin²⁸ and further investigated by Brixen²⁹, in which the sounds often cited as ‘belting’ have been qualified as two distinct modes of singing, namely Overdrive and Edge – a terminology from the Complete Vocal Technique (CVT) system²⁸. The key feature of the two modes is that perceptually they have a ‘metallic’ sound³⁰ compared to the non-metallic sound termed Neutral²⁸. In the CVT system, Overdrive and Edge are described as having the common feature of a metallic sound but with differences in the vocal tract positioning required, the consequent range of vowels that can be used, the degree of loudness and tonal character²⁸. Overdrive specifically relates to a ‘*direct sound with a more shout like character*’ whereas Edge has been related to a ‘*light and somewhat aggressive sound with a more screamy character*’^{28,29}. Pedagogically, it would seem relevant to work with one term for one sound, rather than having concepts that cover multiple and potentially significantly different sounds, such is the case with the current variance in ‘belting’ definitions. Accordingly, spectral differences have been observed between all three modes (Neutral, Overdrive and Edge) in a small study by Brixen et al.^{11,24}, on which the modes Overdrive and Edge can be placed in a full-metallic end of a range, where neutral² is positioned at the other end, as a non-metallic or non-belt² sound.

The purpose of the present study was to investigate whether there is value in categorising belting sounds in terms of Overdrive and Edge by means of laryngostroboscopic imaging, acoustics combined with LTAS, and EGG. Therefore, this study aims at evaluating the following hypotheses:

- H1: There is no visual difference between the laryngeal gestures of Overdrive and Edge
- H2: There is no significant difference in the LTAS profiles of Overdrive and Edge
- H3: There is no significant difference in the multi-dimensional acoustic properties of Overdrive and Edge
- H4: There is no significant difference in the multi-dimensional EGG-derived measurements of overdrive and Edge

2. Methods

2.1. Participants

The proposed hypotheses were tested in the presented study, where 20 singers (10 males and 10 females), all of whom were accustomed to singing in Overdrive and Edge, participated. The singers had a median age of 34, ranging from 20-52, with singing experience ranging from 2-26 years, with a median of 13.5 years of experience. The singers’ specific experience with CVT²⁸ ranged from 1-15 years, with a median of 4.6 years of experience with the categorization. Singers were of various nationalities, 13 from Denmark, 4 from Norway, 1 from Iceland, and 2 from The Netherlands. The singers identified with various styles of singing, including rhythmical (1 singer), pop (9 singers),

rock (3 singers), classical (2 singers), jazz (1 singer), soul (2 singers), experimental (1 singer), and gospel (1 singer). Data was obtained from all 20 participants for the LTAS analysis. Four singers were excluded from the study with EGG and laryngostroboscopy as they could either not tolerate the examination (1) or the data quality was either not adequate for interpretation or could not be obtained (3).

2.2. Instrumentation

The study was conducted in two separate stages. The first stage was to record laryngostroboscopic images, which was obtained using a videonasendoscopic camera system (ENFV2 videoscope and OTVS7 camera from Olympus/Keymed). The Laryngostrobe system (Laryngograph ® Ltd) was used for image capture with simultaneous acquisition of the acoustic and EGG signals. The acoustic signal was recorded via a head mounted omnidirectional microphone whereas the electrolaryngograph signal (EGG) was recorded from two electrodes placed on either side of the larynx of the singer. Both the EGG and the microphone signals were inputted into the Laryngograph microprocessor, which in turn synchronised and processed the signal. The EGG signal was used to trigger the stroboscope and both waveforms were able to be displayed with the images.

The second stage of the study was focused on recording the acoustic and EGG signal with the Speech Studio software program (vers. 3.56. Laryngograph® Ltd.). The audio signal was recorded with microphone (Sony ECM 989), which was placed and kept at a constant 25 cm distance from the participant. EGG data was obtained simultaneously with the audio signal. Both the EGG and the Laryngograph microphone signals were inputted into the Laryngograph microprocessor, which in turn synchronised and processed the signal to be analysed in Speech Studio.

2.3. Vocal Task

The singers were instructed to sustain³¹ an open-mid vowel ³² [ε] in each of the two categorisations, Overdrive and Edge respectively, on C4 for males (262Hz) and B4 for females (494Hz). The singers sustained the vowels for approximately 2-3 seconds per recording.

2.4. Laryngeal Gestures

The image recording sessions were supervised by authorised CVT teachers to ensure adequate production of the sound samples. These samples were blindly checked later by one of the authors (CS) by listening to the audio recordings without viewing the images or EGG signals. Once the video sample was deemed representative for either Overdrive or Edge, a still image from the video clip during phonation was obtained using a facility within the Laryngostrobe program.

The still images of the larynxes for each singer in each mode were analysed and compared by two of the authors (JM and CS) on two occasions using a systematic approach based on 6 levels (see illustration 1.1):

1. Vocal Fold level
2. Ventricular folds (false folds)
3. Arytenoid cartilages/cuneiform, epiglottis and aryepiglottic folds
4. Piriform fossa and posterior pharyngeal wall of the hypopharynx
5. Soft palate, uvula, back wall of the throat (oropharynx) and the back of the tongue
6. The rest of the vocal tract (oral or nasal cavity)

The main focus was on levels 1-4 as a means for understanding the laryngeal gestures. Detailed evaluation and documentation of the similarities and differences between the modes was made until a consensus agreement was obtained. The stills were examined individually and each identified gestured was rated from 1 (little), 2 (more), 3 (a lot), and 4 (almost fully). 18 Stills for Overdrive and 18 Stills for Edge were examined.

Illustration 1.1 – The levels of the vocal tract

2.5. EGG and Acoustic recordings

The Laryngograph® acoustic and electroglottograph (EGG) data acquisition system was used. The acoustic signal was acquired using a head mounted omnidirectional (pressure sensitive) electret microphone (+/- 2dB 100Hz to 10kHz, noise level 26dB (SPLA), dynamic range 88dB). The EGG consists of two gold plated electrodes placed on the skin over the thyroid cartilage and provides a non-invasive method of obtaining data of the vocal fold activity during the phonation of the vowels. Both the acoustic and EGG signals were acquired simultaneously using the Laryngograph® microprocessor and recorded using the Speech Studio software program (Laryngograph®) onto a laptop.

2.6. Long-Term Average Spectrum

LTAS has been used consistently and successfully as a means to explore the spectrums of sound in evaluating voice quality^{22,33}, including ‘belting’¹⁷. Previously, Long-Term Average Spectrum analysis has been used for ‘objective voice classification’^{22,34}, initially focusing on classical singing. And yields a ‘promising tool to aid in singing-voice classification’²². The use of LTAS is a method in using vocal tract resonance for determining quality of the voice, and as a foundation for categorisation of voice source²²

In the present study, both Narrow Band and Broadband Spectra spectra were generated using the Speech Studio programme based on the acoustic signal. The LTAS covered spectra ranging from 0-8000Hz.

The Narrowband analysis yielded a detailed description of the harmonic structure of the averaged sounds for the 2-3 second utterance, whereas the Broadband gave a clearer image of the formants of the averaged sounds.

The Edge data was normalised for loudness² for each subject sample to allow better comparison between the LTAS structures. A correction factor for the loudness was based on the difference in dB for Overdrive and Edge at the target fundamental frequency of the sung note (494 Hz for females and 262 for males) for each singer. As the exact frequency value could not be obtained due to the sampling method within the Speech Studio program the closest integral value was used (250 Hz for males and 500 Hz for females).

The LTAS data was averaged for males (n=10) and females (n=10), and displayed graphically showing the loudness levels (dB) on the y-axis, and the frequency (Hz) on the x-axis for both narrow and broadband values for males and females.

Similarities or dissimilarities in harmonic structure between Overdrive and Edge for males and females was significance tested to reject or confirm hypothesis 2. A student’s t test was performed, correlating the Overdrive compared to the normalised Edge, for each gender respectively and for genders combined.

2.7. EGG and Acoustic measures

The electrolaryngograph (EGG) was used as a non-invasive method of obtaining data of the vocal fold activity during the phonation of the vowels. A multidimensional voice profile (MDVP) was obtained and EGG derived measurements was used for obtaining Qx, QxSD, Fx, FxSD, Jitter First, Jitter Second, Jitter Factor, and Relative Average Perturbation. This provided a more accurate description of the laryngeal and particularly vocal fold movements, as the EGG signal provided a resonance-free measure, compared to calculating based on the acoustic signal, where the vocal tract resonance (area function³⁴) impacts the data.

The various EGG measures were then compared in a student's paired t-test for males, females, and between gender, yielding three sets of p values, allowing analysis of whether gender impacts the variation between the two categorisations of belting.

2.8. Acoustic measurement

To quantify in detail the potential acoustic differences between Overdrive and Edge, Shimmer was measured both in terms of Shimmer+, Shimmer -, and Shimmer dB, along with the Harmonics-to-Noise Ratio, the Normalised Noise Energy, the Cepstral Peak Prominence, and the mean Sound Level Pressure.

The EGG and Acoustic measurements seen together formed a multidimensional voice profile³⁵ established based on both the EGG and the acoustic signals, which enabled a cycle-to-cycle variability of the vocal fold vibrations comparable with the acoustic measurements.

The acoustic measurements were compared in a student's paired t-test for males, females, and between genders, yielding 3 sets of p values, allowing for analysis of whether gender impacts the variations between the two categorisations

3. Results

3.1. Laryngeal Gestures

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

Level	Laryngeal Gesture	Maximum potential score (4*18)	Total score for Overdrive	Total score for Edge
2	<i>How much of the vocal folds are covered by the false folds?</i>	72	29	52
3	<i>Anterior posterior narrowing between arytenoid/cuneiform complex and petiole</i>	72	37	61
	<i>Cunei forms rolled in antero-medially</i>	72	37	65
	<i>Laryngeal inlet is triangular shaped</i>	72	34	62
	<i>Acute angle between the aryepiglottic folds and epiglottis</i>	72	43	64
4	<i>Narrowing of the piriform sinuses</i>	72	40	61
	<i>Higher Larynx</i>	72	38	66

Table 1.2 – Summary of Laryngeal Gestures and a quantified comparison between Overdrive and Edge

For Overdrive (see figure 1.3 and 1.4) there seemed to be identifiable activity in vocal tract level 3 and 4. In vocal tract level 3 an anterior and posterior narrowing between the arytenoid and cuneiform complex and the petiole was observed (37 out of 72 possible). The laryngeal inlet was triangularly shaped (34 out of 72 possible), which was also seen in the acute angle between the aryepiglottic folds and epiglottis (43 out of 72 possible). On level 4 a narrowing of the piriform sinuses was observed (40 out of 72 possible), as well as a higher larynx position (38 out of 72 possible). On vocal tract level 2 there seemed to be only minor activity in the false folds in terms of covering the vocal folds (29 out of 72 possible).

Edge in comparison has similar yet different laryngeal gestures. In vocal tract level 2 the vocal folds are covered almost fully by the false folds (52 out of 72 possible), making it difficult to visually see the vocal fold activity. In level 3 there seemed to be a further anterior and posterior narrowing between the arytenoid and cuneiform complexes and the petiole than observed in Overdrive (61 as compared to 37 in Overdrive). This was also reflected by the cuneiforms rolling in antero-medially (65 as compared to 37 in Overdrive). The laryngeal inlet was even more triangularly shaped (62 out of 72 possible), and the acute angle between the aryepiglottic folds and the epiglottis was even more pronounced than in Overdrive (64 as compared to 40 in Overdrive). In level 4 this was reflected in a distinct narrowing of the piriform sinuses (61 out of 72 possible) and a very high larynx position (66 out of 72 possible).

Illustration 1.3 - Example of videonasoscopic image of Overdrive and Edge showing the ante-posterior narrowing of the vocal tract

Illustration 1.4 – example of videonasoscopic image of Overdrive and Edge showing the acute angle, the piriform fossa and the cuneiforms

3.2. LTAS

The LTAS analysis yielded an interesting discovery for both Overdrive and Edge. Overdrive seems to show more energy up to 2kHz with a clear harmonic structure up to 3kHz in males, and 5kHz in females. Between 3kHz and 5,8kHz in males and 5kHz and 6,5kHz for females the harmonic structure is less clear. Edge, comparatively, shows less structure in the area from 2.2kHz to around 5,7kHz, but generally shows more energy, with a smaller frequency range in the female samples (see illustration 1.5 and 1.6 for males and females respectively).

There seems to be statistically significant differences between the two categorisations in various part of the narrowband spectra. Particularly, for males there seems to be a statistical difference between Overdrive and Edge in spectra energy in the interval 2531Hz-3594Hz, where a large part of the spectra varies, with p values close to 0.00, and only a few reaching 0.04. This is followed by a small interval of insignificant findings in the spectra interval 3526Hz-3669Hz, showing insignificant differences, followed by a large significant difference in the spectra from 4000Hz-5094Hz, approximating p-values of 0.00, with a few reaching 0.04.

For females, there seem to be a similar statistical difference between Overdrive and Edge, with somewhat smaller spectra intervals than that for males. Initially, there are statistical differences in smaller intervals with p values from 0.00 to 0.004 in spectra from 624Hz-875Hz, 1781Hz, and 1906-1938Hz, but the amounts of spectra are somewhat narrow in these intervals. Comparatively, there seems to be a large amount of difference in the spectra in the interval from 2575Hz-3219Hz, which shows statistical significance for a difference between Overdrive and Edge. Here, the p values are close to 0.00, and some reaching towards 0.05. Following, the intervals consist of somewhat narrow spectra, where the statistical difference between Overdrive and Edge are present in intervals between 3500-3719Hz, 4594Hz-4656Hz, and 5000Hz-5188Hz. Particularly, there seems to be some larger intervals in spectra 5406Hz-5656Hz, 5813Hz-6125Hz, 6113Hz-6344Hz, and from 7000Hz-7094Hz, where p values range from 0.00 to 0.04. These variances can be seen at a more general level in figure 1.5 (for males), and 1.6 (for females).

From both figure 1.3 and 1.4 it can be seen that there seems to be few variances in the first 9 harmonics, after which there tends to be statistically significant variances between Overdrive and Edge for both females and males (from around 2531Hz-3594Hz and 4000Hz-5094Hz for males and 4594Hz-4656Hz, 5000Hz-5188Hz, 5406Hz-5656Hz, and 5813Hz-6125Hz for females).

For both males and females, a more coherent pattern between Overdrive and Edge appears in the higher frequencies (above 5094Hz for males, and from around 6375Hz for females), which can also be seen in the insignificant differences on various spectra (p values 0.11-0.97 for males and 0.34-0.97 for females).

Similarly, the broadband shows the harmonics in relation to the double formant peaks at 2kHz, 3.8kHz, and 6kHz, where the same first formant is coinciding for both males and females (see illustration 1.7 and 1.8).

Illustration 1.7 – Male Broadband LTAS – Normalised Overdrive and Edge

Illustration 1.8 – Female Broadband LTAS – Normalised Overdrive and Edge

Again, there seems to be statistical differences between the two categorisations. For males the difference is statistically significant from around 2188Hz-5563Hz (p values from 0.00-0.03 with 48 of 55 approximating 0.00), and from 6500Hz-7063Hz (p values from 0.00-0.02). For females the differences are statistical significant from around 2125Hz-7500Hz (p values from 0.00-0.04, with 64 p values approximating 0.00). Illustration 1.7 and 1.8 show male and female broadband respectively.

There seem to be correlation between the two categorisations Overdrive and Edge with insignificant statistical difference in the area between 63Hz-2063Hz (for males this includes 2125Hz) if seen as a whole. In this area the p values range from 0.1-0.9 for males and similarly 0.1-0.9 for females. However, for males there seem to be statistical difference between 63-125Hz, particularly and similarly, females show a statistical significant difference from 313Hz-375Hz. This statistically shows a same first formant as coinciding for both males and females, where there are no significant differences between Overdrive and Edge first formants.

3.3. EGG and acoustic measurements

The same statistical significance testing was done on both EGG and acoustic measures, all of which can be seen in figure 1.7, where each pair is shown with its corresponding mean, standard deviation, and standard error mean. To statistically calculate the significance of any differences between Overdrive and Edge a student's paired two-tail t-test was performed based on the observations for each pair, initially for males and females combined, and then females and males respectively. SPSS software was used to calculate the significance of each parameters difference, with a 95% confidence level. The significance levels for male and female observations combined based on p values can be seen in figure 1.8, where 6 of the 14 hypothesised significances fall below p 0.05, and 3 significances fall below p 0.10, which may be accounted for as significant given the sample size (n=16, considering the excluded 4 subjects). Two observations were hypothesized to not show significant differences (Average Fx and Numbers of periods), which are provided showing p 0.721 and p 0.207 respectively.

		Mean	N	Std. Deviation	Std. Error Mean
Pair 1	ODShimmer dB	.4412	16	.19099	.04775
	EShimmer dB	.7500	16	.27650	.06913
Pair 2	ODShimmer-	-4.8475	16	2.05740	.51435
	EShimmer-	-8.6531	16	3.33394	.83348
Pair 3	ODShimmer+	4.7294	16	2.02024	.50506
	EShimmer+	8.3600	16	2.97991	.74498
Pair 4	ODSD Qx	2.7700	16	3.46952	.86738
	ESD Qx	4.3356	16	6.30385	1.57596
Pair 5	ODSD Fx	1.8556	16	2.44984	.61246
	ESD Fx	2.7462	16	3.89216	.97304
Pair 6	ODRAP	.7187	16	1.05344	.26336
	ERAP	.7206	16	.69816	.17454
Pair 7	ODNo. periods	871.188	16	643.6891	160.9223
	ENo. periods	845.000	16	485.9071	121.4768
Pair 8	ODNNE	-27.7450	16	6.64088	1.66022
	ENNE	-20.7031	16	6.33000	1.58250
Pair 9	ODJitter Second	.5225	16	.68137	.17034
	EJitter Second	.6294	16	.69999	.17500
Pair 10	ODJitter First	.8794	16	1.14667	.28667
	EJitter First	1.0019	16	1.00024	.25006
Pair 11	ODJitter Factor	.8287	16	1.07300	.26825
	EJitter Factor	1.0294	16	1.14764	.28691
Pair 12	ODHNR	23.7675	16	2.97477	.74369
	EHNR	18.6750	16	3.30891	.82723
Pair 13	ODCPP	7.5838	16	1.09794	.27449
	ECPP	7.5063	16	1.42708	.35677
Pair 14	ODAverage Qx	52.9500	16	9.55482	2.38871
	EAverage Qx	54.9344	16	10.23300	2.55825
Pair 15	ODAverage Fx	377.1444	16	115.02194	28.75548
	EAverage Fx	378.8938	16	116.36486	29.09122
Pair 16	ODMean SPL	101.3525	16	4.98865	1.24716
	EMean SPL	99.1063	16	3.84485	.96121

Figure 1.9 – Paired samples measures across EGG and acoustic

Paired Samples Test					
		Paired ...	t	df	Sig. (2-tailed)
		95% Confidence Interval of the ...			
		Upper			
Pair 1	ODShimmer dB - EShimmer dB	-.18681	-5.397	15	.000
Pair 2	ODShimmer- - EShimmer-	5.29448	5.448	15	.000
Pair 3	ODShimmer+ - EShimmer+	-2.29916	-5.812	15	.000
Pair 4	ODSD Qx - ESD Qx	.24486	-1.843	15	.085
Pair 5	ODSD Fx - ESD Fx	.18161	-1.770	15	.097
Pair 6	ODRAP - ERAP	.34653	-.011	15	.991
Pair 7	ODNo. periods - ENo. periods	179.5700	.364	15	.721
Pair 8	ODNNE - ENNE	-3.31998	-4.033	15	.001
Pair 9	ODJitter Second - EJitter Second	.05087	-1.444	15	.169
Pair 10	ODJitter First - EJitter First	.13957	-.996	15	.335
Pair 11	ODJitter Factor - EJitter Factor	.03118	-1.845	15	.085
Pair 12	ODHNR - EHNRR	7.10660	5.389	15	.000
Pair 13	ODCPP - ECPP	.56842	.336	15	.741
Pair 14	ODAverage Qx - EAverage Qx	1.88499	-1.093	15	.292
Pair 15	ODAverage Fx - EAverage Fx	1.07699	-1.319	15	.207
Pair 16	ODMean SPL - EMean SPL	3.93330	2.838	15	.012

Figure 2.0 – Paired Samples test for male and female combined across EGG and acoustic measures

The same t test was performed for males and female voices respectively, where female p values show 5 of 14 hypothesised measures as p below 0.05, and furthermore 4 measures show p values below 0.13. Comparatively, male voices indicate 5 hypothesised measures as p below 0.05, and further 1 p below 0.10. See figure 2.1 for males and 2.2 for females, respectively. The two hypothesised measures showing no significant difference Average Fx and Number of Periods similarly to the combined data sets show p 0.15 and 0.95 for females, and p. 0.17 and 0.68 for males.

Paired Samples Test					
		Paired ...			
		95% Confidence Interval of the ...			
		Upper	t	df	Sig. (2-tailed)
Pair 1	ODShimmer dB - EShimmer dB	-.12681	-3.755	7	.007
Pair 2	ODShimmer- - EShimmer-	7.38622	4.236	7	.004
Pair 3	ODShimmer+ - EShimmer+	-1.60791	-3.962	7	.005
Pair 4	ODSD Qx - ESD Qx	1.07757	-.837	7	.430
Pair 5	ODSD Fx - ESD Fx	.36185	-1.592	7	.155
Pair 6	ODRAP - ERAP	.57109	.714	7	.498
Pair 7	ODNo. periods - ENo. periods	372.3857	.423	7	.685
Pair 8	ODNNE - ENNE	-2.24478	-3.318	7	.013
Pair 9	ODJitter Second - EJitter Second	.17975	.177	7	.865
Pair 10	ODJitter First - EJitter First	.45786	.382	7	.713
Pair 11	ODJitter Factor - EJitter Factor	.16291	-.355	7	.733
Pair 12	ODHNR - EHNr	9.09196	6.581	7	.000
Pair 13	ODCPP - ECPP	1.12343	1.940	7	.094
Pair 14	ODAverage Qx - EAverage Qx	1.95349	-1.462	7	.187
Pair 15	ODAverage Fx - EAverage Fx	.73931	-1.038	7	.334
Pair 16	ODMean SPL - EMean SPL	4.69729	1.343	7	.221

Illustration 2.1 – Significance testing males across EGG and acoustic measures

Paired Samples Test					
		Paired ...			
		95% Confidence Interval of the ...			
		Upper	t	df	Sig. (2-tailed)
Pair 1	ODShimmer dB - EShimmer dB	-.12524	-4.242	8	.003
Pair 2	ODShimmer- - EShimmer-	4.43344	4.242	8	.003
Pair 3	ODShimmer+ - EShimmer+	-1.66945	-4.706	8	.002
Pair 4	ODSD Qx - ESD Qx	.55734	-1.891	8	.095
Pair 5	ODSD Fx - ESD Fx	.84934	-1.267	8	.241
Pair 6	ODRAP - ERAP	.42120	-.561	8	.590
Pair 7	ODNo. periods - ENo. periods	125.85971	-.073	8	.943
Pair 8	ODNNE - ENNE	-.75607	-2.622	8	.031
Pair 9	ODJitter Second - EJitter Second	.01849	-2.131	8	.066
Pair 10	ODJitter First - EJitter First	.02591	-2.128	8	.066
Pair 11	ODJitter Factor - EJitter Factor	.01083	-2.241	8	.055
Pair 12	ODHNR - EHNr	6.41864	2.758	8	.025
Pair 13	ODCPP - ECPP	.31210	-1.223	8	.256
Pair 14	ODAverage Qx - EAverage Qx	5.31124	-.304	8	.769
Pair 15	ODAverage Fx - EAverage Fx	2.39632	-1.267	8	.241
Pair 16	ODMean SPL - EMean SPL	4.81941	3.173	8	.013

Illustration 2.2 – Significance testing females across EGG and acoustic measures

To provide an overview of the p values, a summary of female, male and female + male p values can be seen in the table in figure 2.3, where the p values below 0.05 and the values which approximate 0.10 are highlighted in bold.

	Female	Male	Female+Male
Number of Periods	0,95	0,69	0,72
Average Fx	0,30	0,33	0,21
SD Fx	0,30	0,16	0,10
Average Qx	0,80	0,19	0,29
SD Qx	0,14	0,43	0,09
Jitter First	0,10	0,71	0,33
jitter Second	0,10	0,86	0,17
Shimmer+	0,00	0,01	0,00
Shimmer-	0,01	0,00	0,00
Jitter Factor	0,09	0,73	0,08
RAP	0,63	0,50	0,99
Shimmer dB	0,01	0,01	0,00
NNE	0,05	0,01	0,00
CPP	0,32	0,09	0,74
HNR	0,05	0,00	0,00
Mean SPL	0,03	0,22	0,01

Figure 2.3 – Comparative p values from two-tailed t-test

4. Discussion

The 4 above discussed measures seem to correlate the fact that the sounds understood as ‘belting’ can be distinguished as two separate modes of singing, here called Overdrive and Edge, if compared in terms of Acoustic, visual, LTAS, and EGG measures. The findings of the study can seemingly be discussed under two different headings: academic contributions and pedagogical considerations.

4.1. Academic Considerations

There has long been a focus on classical singing as the main source of data for empirical exploration of the voice, which has highlighted a need for exploring other facets of singing, such as belting ⁶. Many studies investigating ‘Belting’ have been single-subject studies, which calls the general validity into question of such studies. This article contributes to the exploration of other types of singing than classical by categorising ‘Belting’ based on 20 participants. ‘Belting’ can, according to the findings of this study, be categorised into two modes of singing that vary significantly in measures of LTAS, EGG and acoustics, with visibly different laryngeal gestures.

Both Broadband and Narrowband LTAS show a statistical difference, which supports the rejection of [H2], particularly after the ninth harmonic between Overdrive and Edge, with a coinciding first formant. The findings also corroborates previous findings on belting, namely that it entails a dominant second harmonic^{2,5,36}. Similarly, previous research has shown that the first 3 formants are the primary aspect of vowel articulation ³⁴, but even with the same vowel articulation on [ε], statistical significant difference can be observed between Overdrive and Edge, which suggests that a categorisation of voice should not only be considered on the merits of the formants of the vowel, but also on acoustics, EGG and laryngeal gestures.

In this study it has been illustrated that both Overdrive and Edge can be observed in laryngeal gestures, visible in clearly constricted settings, similar to the findings of Estill^{8,20} in her studies on belting. However, there seems to be more constriction in the setting of Edge than that of Overdrive, where an even more narrow space can be observed in the larynx, particularly, the ventricular folds seem to be covering more of the vocal folds in Edge than in Overdrive (52 in Edge as compared to 29 in Overdrive out of 72 possible), and the aeryepiglottic folds show a sharper edge in Edge than Overdrive. It would seem that the laryngeal gestures support a rejection of [H1], in the sense that

differences between Overdrive and Edge can be visually observed, particularly on levels 1-4 of the vocal tract. These findings are of a descriptive nature, and only indicate laryngeal gestures. These findings should be quantitatively addressed to further validate or refute the results. However, as the findings are in line with previous studies into belting, the findings lend support for rejecting [H1].

The above-outlined differences between vocal-tract constriction in Overdrive compared to Edge could potentially contribute to the higher amount of energy in the LTAS frequencies in Edge as compared to Overdrive. In both Broadband and Narrowband measurements there seems to be a statistical significance between Overdrive and Edge, where male subjects clearly indicate significant differences in the spectra from 2531Hz to 3594Hz, with p values ranging from 0.00-0.02, and in the spectra 4000 to 5094Hz, with p values ranging from 0.00-0.04. Similarly, female subjects indicate a statistical significant difference in the spectra from 2375Hz to 3219Hz, with p values ranging from 0.00 to 0.005. This would indicate that in the spectra from around 2300Hz to around 3500 Hz, a key difference between Overdrive and Edge can be found, supporting a rejection of [H2]. Previous studies into Belting have shown that a peak in and around the 3000Hz can be observed. This study shows similar findings on Edge, with a visible LTAS peak for female and males. However, this would not seem to be the case for Overdrive, which seems to show the opposite, with a decrease in value around 3000Hz but an increase around 3800Hz for males and 4400Hz for females.

Equally interesting, it would seem that Overdrive and Edge vary with statistical significance in relation to acoustic and EGG measures. This further substantiates the claim that the two modes of singing can indeed be perceived of as two different ways of singing. This supports a rejection of [H3] and [H4], shown for instance in Shimmer+, Shimmer-, and Shimmer dB that all significantly vary for males, females and males and females combined, with p values approximating 0.00. Similarly, the jitter Factor for females and for females and male combined show a statistical significant difference, whereas the males on their own do not. This seems to correspond with the fact that Jitter First and Jitter Second seems to vary with statistical differences for females but not for males, showing a combined insignificance of the measure. Similarly, there seems to be statistical significant differences between the overall sound pressure level for females between Overdrive and Edge, which is not the case for males, which may account for some of the above discrepancies. Contrastingly, both the HNR and the NNE show a difference that is statistically significant with p values of 0.05 and approximating 0.00.

These findings suggest that a multidimensional assessment of voice for categorisation of modes of singing is relevant. It would be interesting to apply the same measures of analysis to other styles of singing, and compare findings for a furthered understanding of Overdrive and Edge as part of a bigger whole in categorising voice. For example, Overdrive and Edge as opposed to the 'neutral' style of singing² can be argued to differ on the merits of a progressive constriction of the supraglottic structures of the larynx, with a continuous narrowing of the laryngeal inlet, where it can be assumed that both Overdrive and Edge would have higher SPL than the neutral style, supporting the claim of relative loudness as related to belting^{1,2}. It would also be interesting to compare other belting categorisations to the findings of this study, across the methods used in this study, to see whether the identified features are restrictive to Overdrive and Edge.

A final academic consideration is along the lines of statistical significance testing of large-sample LTAS data. Because multiple t testing is necessary to test the significance of findings, the family error rate (FER) increases. This FER should be noted and kept in mind when discussing the results of the study, and in future t-testing of LTAS data.

4.2. Pedagogical Consideration

Bartholomew's uttering from 1934³⁷ comes to mind when speaking of categorising voice for the purposes of teaching. He noted astutely that there is an inherent need of 'bringing order out of chaos in the field of voice-teaching' due to an 'eternal conflict of traditional methods'. This is a chaos that still seems to exist. According to recent studies in contemporary music, the lack of understanding of the functionality of the voice makes it difficult to describe, assess and train the voice³⁰. In part, understanding any sound and the way it is produced aids in illuminating the chaos, so as to bring order and categories to aid practitioners as well as researchers by offering terminology to speak of the sounds and their mechanisms. The need for addressing the sounds known as belting can be validated by the fact that the sounds have been the topic of various studies^{1,6,8,9,17,36} spanning from the present back to Estill's study in 1988. Explicitly, these studies address the need for a way to empirically explain the sounds known as belting, and how to pedagogically teach them. The first step in establishing methods of teaching a sound, must logically be to

understand the premises and conditions of the desired sound. So, even though the term ‘belting’ may have been used continuously by teachers and researchers of voice, the authors of this paper contend that disparate and incongruent findings have been proposed for ‘belting’, and that the term therefore is not used consistently. This is reflected in the notion that many sounds, and their accompanying different vocal tract settings, can be considered ‘belting’, which is for instance reflected in the multiplicity of belting as previously noted by Popeil. While ‘belting’ has solidified in various ways across genres and styles, the term conceptually may mean one thing to one person, and another thing to someone else. This constrains dialogues about the concept – particularly between researchers, practitioners, and singers.

This present study assists in shedding light on ‘Belting’ as a singing strategy by proposing that the two categorisations Overdrive and Edge can indeed be distinguished with statistical difference, and by doing so aids singing professionals by lending a conceptualisation of sound production, which can be used for teaching purposes. By relating one sound to one term regardless of genre and style to reflect anatomy and physiology rather than tradition, teaching those particular sounds becomes easier. This point is similar to the conclusion of Sundberg & Thalén in their discussion of ‘twang’, stating that *‘several different meanings appear to be attributed to the term ‘twang’. Voice Research should be capable of resolving such terminological confusion by describing the acoustic, perceptual, and physiological characteristics’*. This study proposes Overdrive and Edge as significantly different categorisations, each relating to their own sound and anatomical position, each of which can be obtained independently; Overdrive by achieving a direct sound with a shout-like character, and Edge by achieving a light and somewhat aggressive sound with a screamy character. These descriptions of Overdrive and Edge are comparable to the descriptions of ‘belting’ as ‘yell-like’, ‘shout-like’, ‘natural’, etc. Additionally, the two categorisations Overdrive and Edge have been described as ‘metallic’, which is relatable to the findings of Hanayama et al. in (2009)³⁰. Hanayama et al. trace the concept of ‘metallic voice’ back to Barnes (1932), where the term has since been related to singing in such genres as ‘belt’, ‘pop’, ‘Broadway Vocal Styles’, and jazz and blues. The metallic features of Overdrive and Edge should be further studied, particularly in relation to other findings on the metallic voice, however such studies should be conducted irrespective of genre as Overdrive and Edge are not confined to one particular genre. To pedagogically teach the two modes of singing, namely Overdrive and Edge, tools for achieving the physiological settings and the acoustic characteristics described above are needed. Some tools are addressed below.

In the present study the vowel [e] was used for both Overdrive and Edge, and it might be interesting to see whether similar statistical differences between the two modes exist across other vowels and volumes. It would seem that Overdrive has a somewhat narrow constriction in the vocal tract, with Edge even more constricted. This finding is similar to the finding of Yanagisawa et al.²⁰ that an aryepiglottic constriction of the vocal tract is involved in ‘belting’. The study of Yanagisawa reports similar findings all the way back to 1855, where Garcia reported similar intentional contractions to give brilliance and widening volume. This brilliance may be what is currently referred to as ‘metal’, however, this would have to be investigated in further detail in future studies. Said brilliance may also be related to ‘twang’ as discussed by Sundberg & Thalén³⁸ in terms of a shortening of the pharynx involved in larynx elevation and pharyngeal narrowing, however, this would also have to be investigated in further detail in future studies. Intentional constriction has also been successfully correlated with the ‘singer’s formant’²⁰ and as such, may also be related to perceived loudness and/or ‘ring’.

The current study proposing Overdrive and Edge as substitutes for ‘belting’ describes the laryngeal settings for the two observed ways of producing sound, as well as the laryngeal movements and differences between them. Moreover, the study reports the vowel, pitch and character of the sounds included in the study. This is in line with other studies into voice, such as the work by Sundberg & Thalén (2015) focusing on the vowel /æ/, or the study by Bestebreurtje & Schutte (2000) studying the vowels /e/ and /i/. Similarly to these and other studies, the included participants in the present study have some similar training background in one vocal method, as well as having a varied training background from other methods. In the present study, all of the participants were trained by various singing teachers, and only some of them were trained directly by Ms. Sadolin. Similarly, participants in other studies on ‘belting’ have been reported with some similar and some dissimilar training backgrounds based on various vocal methods. By including LTAS findings accompanied by image stills and laryngeal gestures in the study, comparable analysis across vocal methods is enabled.

For now, it would seem that an intentional constriction of the vocal tract for Overdrive, and an even more constricted vocal tract for Edge can be sought to obtain the settings, which may be aided by the use of the vowel [e], a ‘bright’ sound³⁹, and the following constriction in the vocal tract: an anterior posterior narrowing between the arytenoid/cuneiform complex and the petiole, an antero-medially rolled in cunei form, a triangular-shaped laryngeal inlet, an acute angle between the aryepiglottic folds and the epiglottis, a narrowing of the piriform sinuses and a

higher larynx. Moreover, the LTAS spectra analysis shows that higher frequencies play a part of obtaining the modes Overdrive and Edge, which may be assisted by loudness in terms of SPL. For future study it would be interesting to further explore the two conceptualisations ‘Overdrive’ and ‘Edge’ to establish the limitations of the sounds in relation to pitch, volume, and vowels. Moreover, studying other ‘belting’ sounds according to the proposed method and comparing the findings to the present study might yield interesting discussions on the future categorisation of voice. Studies of this kind may aid in solving the problem of the ‘many ways to belt’. Finally, as the CVT system currently accounts for the largest agreeing group of singing teachers in the world and is being used consistently in universities, conservatories, ear nose and throat physicians’ clinics, university hospital clinics, and in singing schools across Europe, more research into this dominant way of teaching and working with the voice is called for.

5. Conclusion

Based on the five proposed measures; audio perception, laryngostroboscopic imaging, Acoustics, LTAS, and EGG, it would seem that the sounds known as belting can in fact be distinguished into two separate categories of sounds and two modes of singing; Overdrive and Edge. This warrants a consideration whether or not the applied method of analysis would show similarly findings if used on other types of singing than belting, and how Overdrive and Edge would compare statistically to other types of singing. Moreover, the findings of this study should be further investigated, and potentially correlated with other types of measurements, to further investigate their validity.

6. Acknowledgements

The authors wish to recognise and thank all the participants for their willingness to undergo examination as well as Christina Lyngholm Nielsen and Nicolai Bæk Trautner for their time and effort. The authors would also like to thank the reviewers for their suggestions and astute observations. The research study was funded by Complete Vocal Institute.

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