Proceedings of the International Symposium on Music Acoustics

(Associated Meeting of the International Congress on Acoustics)

25-31 August 2010, Sydney and Katoomba, Australia

Lieder singers delay vibrato onset: some acoustic evidence.

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PACS: 43.75.-z, 43.75.Bc, 43.75.Cd, 43.75.Rs, 43.75.St,

ABSTRACT

Acoustic analysis was applied to examine if a distinction could be identified between the performance of lieder as compared to opera. 18 single, quasi-unaccompanied notes from commercial recordings of two lieder were used as examples, and, for comparison, 20 single, unaccompanied notes from an opera. It was found that the vibrato rate in the lieder examples was statistically identical to opera at around 6.2Hz. The variability of vibrato rate was marginally greater for lieder, though not statistically significant. The vibrato extent showed that a narrower vibrato was used in the lieder examples of around 100 cents compared with opera which, on average, used a vibrato extent of 150 cents. The results of our acoustic vibrato onset measurements indicate that vibrato in lieder begins later within a note than in opera. The singer's formant, which is generally associated with opera, was observed in the lieder recordings at times, but was overall significantly less strong than the opera examples. It was apparent from the data that professional, commercially recorded singers exhibited considerable flexibility in adapting to the different genres. The analysis also made clear that acoustic analysis can be used to develop and make clear definitions and descriptions of singing styles.

INTRODUCTION

Teaching and learning to sing in different musical styles involves an awareness and capacity to execute characteristics that nuance the singer's output so that the requirements of that style can be met. For example, Sataloff [1] states that vibrato can be produced in a different fashion for each genre of the singing voice and that its presence is one factor which determines the character of each genre. In the present studies we were interested broadly in the view that a set of principles for all genres and styles of singing could be available to reflect what performers do, and to work towards well-defined guidelines to aid teachers and students.

This paper specifically looks at lieder, the nineteenth century German form of song. Through a variety of mediums, certain vocal techniques are identified as being important for the performance of lieder. Vibrato and the Singer's Formant (SF -a prominent spectral peak at around 3kHz) are areas which are specifically studied in voice acoustics to determine if a consensus of what leads to a good performance is evident [2]. Other genres of vocal performance have received more attention in recent studies. Research in the areas of opera and music theatre are more plentiful, examining text intelligibility [3], vibrato [4,5], formant [6] and other vocal characteristics [7,8]. Similar topics are also examined under the generic label of Classical singing [9-22]. Prame's studies [14,15] use F. Schubert's *Ave Maria* (an Art song, though not strictly a Lied) to examine vibrato because it has many sustained notes throughout the piece. In *Singing in style: a guide to vocal performance practices* [23], Martha Elliott discusses elements concerned with the singing of lieder. About vibrato and portamento she writes,

> Vibrato can be used as an expressive device in lieder and is sometimes indicated with a wavy line or a variety of accent markings. A wide, continuous vibrato, however, is still inappropriate. Portamento, on the other hand, can be used liberally in many situations for both small and large gestures. It should be employed for expressive and dramatic purposes (p. 192).

Whilst such texts state how lieder should or should not be sung, they mention these ideas briefly and do not provide specific explanations and demonstrations of how singers can use the techniques in practical situations. Nor do they apply modern technology, which can be valuable in documenting how lieder has, and can be performed. No sources were found that made explicit statements about the use of the singer's formant in lieder. However, these descriptive approaches to understanding lieder were considered important in communicating the essence of lieder performance. We therefore examined some of these issues by conducting an acoustic analysis of sound-recordings.

ACOUSTIC STUDY

Aim

The aim of this study was to determine whether an acoustic analysis supported the opinions of the literature, by comparing acoustic characteristics of lieder with opera. Specifically,

singer's formant and three aspects of vibrato —Vibrato onset time (delay from onset of note to onset of vibrato), vibrato rate (number of pulsations of pitch per second) and vibrato extent (half the maximum and minimum pitch fluctuation in vibrato) were compared (For more information see [16]). In this study we did not examine loudness, since this effect should be self explanatory—where the opera singer must project over an entire orchestra rather than a single instrument accompaniment—and therefore perhaps not as interesting. Based on our literature review it was hypothesised that, compared with opera, (1) Singer's formant would be less prevalent, (2) Vibrato onset should be the same (an interpretation based on Miller's assertion that the tone should not be started 'straight', discussed in the Introduction), (3) Vibrato extent would be smaller (not as wide) and (4) Vibrato rate would be more variable in lieder.

Method

Design: Conducting acoustic analysis presented several design challenges. Among the most important is the separation of vocal information from piano/orchestral accompaniment which is generally hard to do with commercial sound recordings. An alternative would be to recruit singers to perform lieder and opera unaccompanied. However, this would not assure us that we were working with undisputed, internationally recognised performers (or would be prohibitive in terms of cost and timing). So, we took a compromise approach. We chose sound recordings from lieder and opera where at least one note could be identified that did not have accompaniment.

Stimuli: Altogether thirty-eight single note examples were examined. Examples sung by baritones were chosen because the singer's formant was of interest to the study [24]. A single, unaccompanied note from each of Franz Schubert's songs *Der Erlkönig* [25] and *Wasserflut* [26] were used as the two lieder examples (see score extract Figure 1), and two single notes from the extended recitative before the Count's aria 'Vedrò mentr'io sospiro' in W. A. Mozart's *The Marriage of Figaro* [27] provided two examples for comparison from the operatic repertoire (see Figure 2).

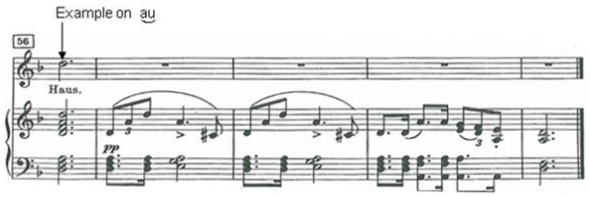

Figure 1: The example for acoustic analysis from *Wasserflut*

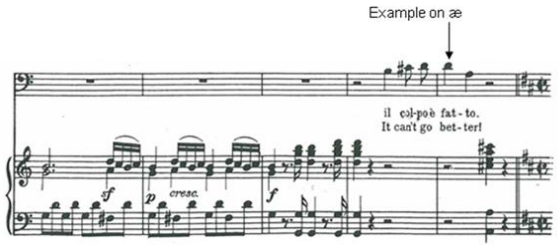

Figure 2: M1 operatic example from *The Marriage of Figaro*.

A single, sustained note was chosen from each example which was sung on a similar vowel sound, the same place in the overall phrase and in a comparable register [5]. These notes were chosen because they were unaccompanied, so that the spectral analyses were able to give a clear reading without interference from the accompaniment [5]. Examples displaying the middle to high registers were chosen because vibrato regularity is greater in higher pitches [12]. Using a portion of a recitative from a Mozart opera, instead of Wagner for example, provided a conservative analysis, in that the Mozart style possesses relatively more-subtle differences in vocal styles compared to lieder than some later operatic forms. This way we could be confident of the veracity of any measurable differences (should any be identified). See Table 1 for a list of the recordings used for the study.

Table 1: Recordings used for analysis

Wasserflut		**Erlkönig**		**The Marriage of Figaro M1 & M2**	
Performer	Release Date	Performer	Release Date	Performer	Release Date
Dietrich Fischer-Dieskau	2006	Dietrich Fischer-Dieskau	1988	Dietrich Fischer-Dieskau	1968
Dietrich Henschel	2000	Bryn Terfel	2007	Bryn Terfel	2006
Hermann Prey	2008	Hermann Prey	2008	TeddyTahu Rhodes	2003
Gehard Hüsch	1999	Gerhard Hüsch	2001	Thomas Allen	1982
Matthias Goerne	2005	Matthias Goerne	1997	Thomas Hampson	1991
Patrick Mason	1995	Ernst Bus-cagne	2002	Jonathan Lemalu	2005
Jon Vickers	1992	Marko Rothmüller	2008	Jose Van Dam	2005
Thomas Hampson	2005	Wolfgang Holzmair	1993	Bo Skovhus	2007
Carl- Heinz Muller	1988	~	~	Alfred Poell	1955
Olaf Baer	2007	~	~	William Stone	2009

The performer and release date of the CD are listed for each operatic and lieder example.

Procedures: The sound recordings were analysed at each note of interest using the spectrum and spectrogram display of sound editing and analysis software, Audacity [28]. Measurements were made in Audacity 1.3.3 Beta and 1.3.10 Beta on a spectrogram (frequency range: 44100 Hz, 16 Bit PCM, 32 Bit float, FFT Size: 4096; For format analysis, the spectrum display was used with the same settings, except Size was changed to 128 to allow easier identification of formants).

Vibrato cycles were read off the spectrogram (see Figure 3 for an example). Vibrato rate was measured by identifying each full vibrato cycle, which consisted of a consecutive peak and trough, and the total number of these cycles was counted then divided by the duration of those cycles. This produced a vibrato rate in Hertz (Hz). Vibrato extent was made by reading the peak and trough frequencies during a region of sustained vibrato. The peak frequency was divided by the trough frequency, converted into cents (a perceptual unit of pitch that divides an equal temperament semitone into a further 100 units) and halved, as is the convention for vibrato extent [15].

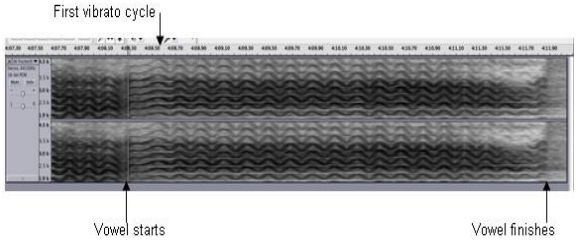

Figure 3: Example of readings taken by the spectrogram.

Singer's formant strength (hence SF strength) was quantified by subtracting the intensity reading of the first formant (hence F1, units of dB) from the intensity reading of the singer's formant (hence SF, also in units of dB) (see Figure 4) This provided information about the relative strength of the singer's formant, based on methods used by Rossing *et al* [29] and Omori *et al* [30], and mitigated the problem of using singer formant readings that were misleading due to overall sound recording level.

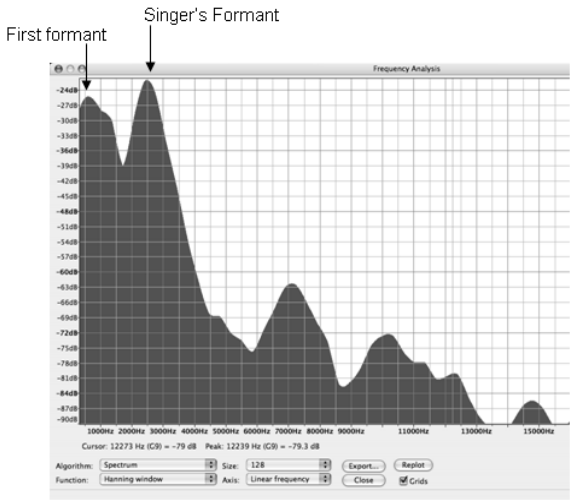

Figure 4: Example of the spectrum readings.

Results

Results of the acoustic measurements are summarised in the Appendix. The overall strongest Singer's Formant was the Tahu Rhodes A3 operatic note (SF 3.3 dB higher than F1—see Figure 4), and least SF strength was found in Terfel's Erlkönig (SF 29.4 dB below F1). On average, the opera excerpts had a stronger singer's formant (SF only 5.89 dB below formant 1) than the lieder excerpts (SF 11.6 dB below F1). On average, vibrato extent was wider for opera excerpts (148 cents, about one a half semitones) than for lieder excerpts (106 cents, about 1 semitone).

Vibrato onset was much shorter for operatic excerpts compared to lieder excerpts (63 ms and 276 ms respectively), but it should be noted that note durations for the Wasserflut excerpt were considerably longer. Erlkönig had a more comparable duration with the Mozart examples (average duration 694 ms) and the corresponding vibrato onset time was 135 ms. Upon examining the proportional time of entry of the onset with respect to the duration, this gives a ratio of 135/694 = 0.195. For the opera excerpts this ratio is 63/533 (see Appendix) = 0.118, meaning that on average, lieder excerpt notes started vibrato proportionally later (with respect to note duration) than opera excerpt notes. Vibrato extent seemed similar across the two genres (6.16 and 6.20 Hz for lieder and opera notes respectively), but variability of the vibrato (measured here as SD) was slightly greater for the lieder notes (0.394 Hz) than for the opera notes (0.351 Hz).

These descriptive results were further investigated with a statistical analysis. SF Strength, and vibrato extent, onset and rate were submitted to Mann-Whitney U tests. SF Strength, vibrato extent and vibrato onset time were all significantly different at p = 0.01, while vibrato rate was not (Table 2). An F-test was conducted to determine if the variation in vibrato rate was significantly different across genre (lieder versus opera). The result was not significant (F(17,19)=1.260, p = 0.3113).

Table 2: SF strength, vibrato extent and vibrato onset time.

	SF Strength	Vibrato extent	Time until vibrato onset	Vibrato rate
Mann-Whitney U	68.5	69	70.5	170
Z	-3.261	-3.245	-3.223	-0.293
Asymp. Sig. (2-tailed)	0.001	0.001	0.001	0.77

Mann-Whitney U tests for SF Strength, Vibrato Extent and Vibrato Onset Time with Genre (Lieder or Opera) as the independent variable.

Discussion and Conclusion

Using acoustic analysis techniques, four hypotheses were tested based on qualitative data that were obtained from the literature review. Of the first three hypotheses, two were supported, one rejected: lieder notes were performed with a weaker singer's formant and a smaller vibrato extent was used than the opera notes studied. However, there was a difference in vibrato onset time, contrary to our hypothesis, with a longer delay in lieder than in opera. The fourth hypothesis, that vibrato rate varied more in lieder than in opera was not supported by inferential statistics, although a trend was observed that supported the hypothesised difference. No difference in absolute vibrato rate was found between the genres.

The results of our acoustic vibrato onset measurements indicate that vibrato in lieder begins later within a note than in opera. In the present study Henschel's performance of the note of interest in Wasserflut had the most delayed vibrato onset of 1.850 seconds for a note of duration 2.850s. This average delay of vibrato in lieder technique suggests that vibrato may be used as a colouration, rather than as an immediate feature of vocal tone. The finding therefore questions the negative connotation in the use of delayed vibrato onset. A delay in vibrato onset has been argued to be indicative of a faulty technique, for example where Miller [31] states that a lieder singer should not let the vocal tone start straight and then let it "wiggle with vibrato" (p. 16), though Miller may have been referring to the avoidance of extreme use of vibrato *per se* with which our data concur. The contribution of the present analysis allows for a more specific, objective description of what lieder singers do.

The estimated vibrato extent showed that a narrower vibrato was used in the lieder examples of around 100 cents compared with Opera which, on average, used vibrato extent of 150 cents. These values were consistent with Prame [15]. This is also consistent with reports made in the literature. Examining the performers sampled who had notes in both genres, Fischer-Dieskau and Terfel, they demonstrated a clear distinction in vibrato onset delay across the two genres,

for lieder 100, 60 and 400 ms versus 50, 30 and 20ms for opera (i.e. lieder vibrato onset is more delayed than for opera for these signers), while other parameters measured varied less systematically (see Appendix). Perhaps a singer without specialisation in both genres can change their vibrato onset more easily than other parameters.

The singer's formant, a primarily operatic technique, was identified in both the operatic and lieder recordings. Its use on a held note at the end of a phrase in Wasserflut is apparent in a majority of the recordings. However, the statistical analysis suggests that there is an acoustically significant difference between the two genres, with lieder singers being less reliant on the strength of that formant. Again, comparing the performers who were sampled in both genres, Fischer-Dieskau and Terfel had stronger SF in the operatic examples (-7.8, -3.8, -7.4, and -8.3 dB) than in the lieder (-12.8, -5.9 and -29.4 dB, the latter by Terfel being the weakest SF in the entire sample). It is apparent from these data that professional, commercially recording signers exhibited considerable flexibility in adapting to the different genres. The results are also consistent with Sundberg & Romedahl [3] observation that a lack of the singer's formant increased text intelligibility and justifies why there is a primary focus on text and diction for the performance of this genre.

Our study provides support for some assertions made by scholars and singing teachers based on an acoustic analysis of a selection of notes performed by commercial recordings of professional singers. While previous research on lieder singing has not been burdened by the limitations of experimental method and attempts to apply scientific scrutiny, the acoustic analyses presented here, on the other hand, allow objective investigation of what singers actually do, using clearly defined terms. We argue that such research might be useful to better understand the singing of lieder and opera, and to provide further insights for singers, teachers and researchers of voice.

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Appendix

Individual measurements for acoustic analysis of selected lieder and opera vocal excerpts

Source	Performer	Year	SF Strength (dB)	Vibrato Extent (cents)	Note Duration (ms)	Vibrato onset delay (ms)	Vibrato rate (Hz)
Erlkonig	Buscagne	2002	-3.1	59	600	130	6.38
	Fischer-Dieskau	1988	-12.8	165	700	60	6.25
	Goerne	1997	-8.9	113	800	150	5.88
	Holzmair	1993	-15	130	350	50	6.67
	Husch	2001	-18.8	142	870	130	6.76
	Prey	2008	-8.6	75	330	20	6.45
	Rothmuller	1944	-8.4	41	750	140	6.56
	Terfel	2007	-29.4	132	1150	400	6.67
Wasserflut	Baer	2007	-9.4	86	3150	100	6.39
	Fischer-Dieskau	1988	-5.9	95	3600	100	5.85
	Goerne	2005	-11.8	104	3000	350	6.04
	Hampson	2005	-6.5	116	2300	50	5.71
	Henschel	2006	-9.2	131	2850	1850	5.50
	Husch	1999	-13	77	2800	450	6.38
	Mason	1995	-11	93	3500	150	6.00
	Muller	1988	-6.5	92	3080	80	5.70
	Prey	2008	-8.3	158	3800	150	5.62
	Vickers	1992	-22.2	106	4300	600	6.10
Mean (SD) of Lieder			-11.6 (6.42)	106 (33)	2107 (1377)	276 (424)	6.16 (0.394)
M1 (D4)	Allen	1982	-9.1	119	650	50	6.67
	Fischer-Dieskau	1968	-7.8	151	550	50	6.22
	Hampson	1991	-8.3	98	610	40	6.45
	Lemalu	2005	-5.2	185	700	100	6.67
	Poell	1955	-4.9	196	350	100	6.50
	Skovhus	2007	-5.1	146	260	50	5.98
	Stone	2009	-12	129	900	150	5.93
	Tahu Rhodes	2003	-2	106	470	40	5.97
	Terfel	2006	-7.4	177	220	30	6.71
	Van Dam	2005	-4.1	178	250	80	5.88
M2 (A3)	Allen	1982	-8.4	146	660	30	5.56
	Fischer-Dieskau	1968	-3.8	175	750	50	6.43
	Hampson	1991	-3.7	124	400	10	6.30
	Lemalu	2005	-3	193	750	50	6.11
	Poell	1955	-0.3	172	400	50	5.71
	Skovhus	2007	-7.7	64	220	20	6.28
	Stone	2009	-16.1	163	940	30	6.35
	Tahu Rhodes	2003	3.3	170	650	150	6.30
	Terfel	2006	-8.3	100	380	20	5.56
	Van Dam	2005	-3.8	172	550	160	6.41
Means (SD) Opera:			-5.885 (4.212)	148 (36.5)	533 (220)	63 (45.5)	6.20 (0.351)