

Kulning: Acoustic and Perceptual Characteristics of a Calling Style Used Within the Scandinavian Herding Tradition

Susanne Rosenberg,^{†,,5} Johan Sundberg, and ||Filipa M.B. Lã,^{*,†,§} Stockholm, Sweden, and || Madrid, Spain

Summary: *Kulning*, a loud, high-pitched vocal calling technique pertaining to the Scandinavian herding system, has attracted several researchers' attention, mainly focusing on cultural, phonatory and musical aspects. Less attention has been paid to the spectral and physiological properties that characterize Kulning tones, and also if there is a physiologically optimum pitch range. We analyzed tones produced by ten participants with varying experience in Kulning. They performed a phrase, pitch range G5 to C6 (784 to 1046 Hz), in three different conditions: starting (1) on pitch A5, (2) on the participant's preferred pitch, and (3) after the deepest possible inhalation, also on the participant's preferred pitch subglottal pressure (P_{sub}) was measured as the oral pressure during /p/-occlusion. The quality of the Kulning was rated by a group of experts. The highest-rated tones all had a sound pressure level (SPL) at 0.3 m exceeding 115 dB and a pitch higher than 1010 Hz, while the SPL of the lowest rated tones was less than 108 dB at a pitch below 900 Hz. A multiple regression analysis was performed to evaluate the relationship between the ratings and P_{sub} , SPL, level of the fundamental and the frequency at which a spectrum envelope dip occurred. Highly rated tones were started at maximum lung volumes, and on participants' preferred pitches. They all shared a high frequency of the spectrum envelope dip and a high level of the fundamental. In decreasing order of ratings, Condition 3 showed the highest values followed by Condition 2 and Condition 1. Each singer seemed to perform best within an individual P_{sub} and pitch range. The relevance of the results to voice pedagogy, artistic, and compositional work is discussed.

Key Words: Kulning—Spectrum characteristics—Tone quality—Subglottal pressure—Sound pressure level.

INTRODUCTION

The Scandinavian *fåbod* system has its roots in the Middle Ages.^{1,2} Ever since then, it has been a tradition to let the cattle graze in the forest during the summer season, far away from the arable land of the village. The cattle, representing an important asset, were herded and cared for by shepherdesses, mostly young girls or old women, who permanently stayed and worked in simple chalets (*fåbod*), milking the cows and making butter and cheese.^{2–4} In the Scandinavian *fåbod* system, women have been responsible for keeping the cattle, suggesting that Kulning has been tailored to female voice.

The voice was used continuously as a working tool for communication, and in this environment, a unique improvisatory vocal calling technique was developed, known as *Kulning*.¹ It served the purpose of communicating with the cattle as well as with fellow shepherdesses, both sometimes several kilometers away; however, it has also been used for enjoyment. For example, according to the shepherdess Anna Andersdotter Broman, “We sang constantly. The

mountains answered back so nicely that we just couldn't resist.”⁵

The term *Kulning* usually refers not only to herding songs, calling, spoken phrases, and imitations of animal sounds, but also to high-pitched melismatic short melodic phrases,⁶ improvised in a herding tune mode.^{7–9} As *Kulning* in the *fåbod* context needs to travel long distances in the forest, it is performed at extreme degrees of vocal loudness in the top part of the female pitch range, between approximately 800 and 1300 Hz. This obviously raises excessive demands on the phonatory apparatus.^{10–12}

Today *Kulning* is also widespread in settings outside the *fåbod* culture, still taught by oral tradition as before. Indeed, *Kulning* has become part of an improvisatory repertoire for today's folk singers. It is performed both outdoors and indoors by professionals as well as for pleasure by amateur singers. Courses in *Kulning* are given at all levels, including university level.¹³ Moreover, *Kulning* has received interest worldwide^{11,14}; around 120,000 video and audio hits can be found on the internet.

The phonatory characteristics of *Kulning* have also attracted the attention of researchers. Johnson and her co-workers describe the physiological and acoustic characteristics of *Kulning* performed by two traditional singers who were born in the beginning of the 20th century, experienced in performing *Kulning* outdoors, as in the original setting of the *fåbod* culture.^{15,16} In this study, *Kulning* was compared with church choir singing, revealing substantial phonatory differences. Using X-ray imaging, the authors found that the jaw and lips opened wider, and the corners of the lips were retracted to a greater extent when performing *Kulning* than in choral singing. In *Kulning*, the hyoid bone and the larynx were generally in an elevated, pitch-dependent

Accepted for publication November 30, 2021.

From the *Department of Folk Music, Academy 1, Royal College of Music in Stockholm (KMH), Stockholm, Sweden; †Department of Speech Music Hearing, School of Electrical Engineering and Computer Science, Royal Institute of Technology (KTH), Stockholm, Sweden; ‡Department of Linguistics, Stockholm University, Stockholm, Sweden; §Voice Department, The Stockholm University College of Music Education (SMI), Stockholm, Sweden; and the || Faculty of Education, Department of Didactics, School Organization and Special Didactics, The National Distance Education University (UNED), Madrid, Spain.

Address correspondence and reprint requests to Susanne Rosenberg, Department of Folk Music, Royal College of Music in Stockholm, Valhallavägen 105, Stockholm SE-115 91, Sweden. E-mail: susanne.rosenberg@kmh.se

Journal of Voice, Vol. ■■■, No. ■■■, pp. ■■■–■■■
0892-1997

© 2021 The Authors. Published by Elsevier Inc. on behalf of The Voice Foundation. This is an open access article under the CC BY-NC-ND license

<http://creativecommons.org/licenses/by-nc-nd/4.0/>

<https://doi.org/10.1016/j.jvoice.2021.11.016>

position, the epiglottis mostly tilted posteriorly, and the tongue shape varied depending on pitch. Johnson also recorded the same participants in an anechoic room. Subglottal pressure, henceforth P_{sub} , captured as the oral pressure during /p/ occlusion, was found to increase with pitch, reaching almost 60 cm H₂O at the highest tones with fundamental frequencies above 1000 Hz. The maximum sound pressure level (SPL) at 0.3 m amounted to 110 dB. The formant frequencies, estimated from area functions derived from the X-ray material, varied depending on their fundamental frequency (f_0). The first formant was tuned to a frequency close to that of f_0 , while the second and third formants remained rather constant.¹

Tellenbach analyzed Kulning as performed by Finnish, Swedish and Norwegian participants acoustically and found unbroken series of harmonic partials continuing up to 18 kHz in some cases.¹⁷ In a single-participant study, Eklund and associates compared Kulning with singing in head register and concluded that Kulning could be regarded as a special vocal register.¹⁸ McAllister and Eklund showed that, in the same singer's Kulning, the partials of the vowel /a/ could reach greater distances than when the same singer sang the same vowel in head voice.¹⁹ By applying electroglottography and stroboscopy, Geneid and associates showed that, as compared to falsetto, their participant's Kulning exhibited a longer vocal-fold contact phase and a longer glottal closure.²⁰ Comparing Kulning with head register and using high-speed imaging, they further observed a marked adduction of both the ventricular and the vocal folds and also a narrowed epilaryngeal tube inlet in Kulning.

The results of most previous studies have failed to answer several important questions. For instance, what spectral and physiological properties characterize Kulning tones, according to today's experts in Kulning? In particular, do individual performers of Kulning make use of a preferred pitch-range? These questions are relevant not only to the teaching of Kulning technique, but also to the use of Kulning in non-ecological settings such as concert performances of contemporary compositions. To find answers to these questions, we recruited participants in a Kulning course and made recordings of their performances from which single Kulning tones were excerpted. We analyzed the acoustic and physiological properties of these recorded tones and an expert panel rated their quality. We then analyzed the relationships between the acoustic and physiological properties of the tones and the experts' ratings. Thus, the focus of our

study was acoustic and physiological properties of single Kulning tones of high quality according to expert ratings.

METHOD

Participants

Nine women, aged between 22 and 31 years, participated in the study. Seven were bachelor students of Swedish folk singing in the Department of Folk Music at the Royal College of Music in Stockholm (KMH) and two were students on other programs at KMH. They were all taking part in a course on Kulning that lasted five afternoons. In addition, one of the co-authors of this article was the teacher delivering the course, having been a performer and teacher of Kulning for several decades.

Within the group of participants, acquaintance with Kulning varied substantially; some had extensive experience of performing Kulning while others had never performed it before. Three participants were familiar with the techniques of both folk singing and Kulning; four were familiar with folk singing but not with Kulning; and two were beginners in both singing and Kulning. Because of technical problems, recordings of three participants needed to be discarded.

Procedure

Kulning performers typically choose their own pitch ranges; in contemporary compositions, by contrast, pitch range is often predetermined. Thus, pitch is an important consideration in Kulning. In a pedagogical setting, also respiratory behavior is important; for less trained singers, high lung volumes often lead to loud singing. To explore the relevance of these factors to the performance and teaching of Kulning, participants were asked to perform a Kulning phrase under three conditions, and in the following order: Condition 1: starting on A5 (880 Hz); Condition 2: starting on a pitch of their own preference; Condition 3: starting on a pitch of their own preference, but after the deepest possible inhalation. The phrase, which was presented to participants in the first session of the course, is shown in Figure 1. It consists of 12 tones and took about 5 seconds to be performed. Its pitch range is a fourth. In Condition 1 the lowest note was G5 while the highest was C6, and the phrase beginning and ending on the fifth in the mode of the present example (A5). All participants learned this phrase by ear.

During the fifth session of the course, participants performed this phrase in the three conditions described above

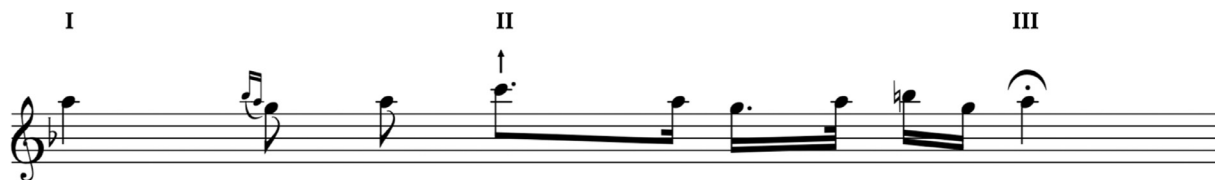


FIGURE 1. The Kulning phrase performed by the shepherdess Elin Lisslass, recorded in 1949, and transcribed from CD.²¹ The arrow above note II, C5, indicate sharp intonation.

and the recordings were made. In Condition 1, they were given the starting pitch of A5 before they sang.

From a perceptual point of view, Kulning is loud, and therefore this type of singing is associated with great vocal effort. It was therefore important to measure P_{sub} : participants were asked to apply the standard procedure for this purpose, of singing each tone on the syllable /pæ/. In this way, P_{sub} could be measured in terms of the oral pressure during /p/ occlusion.

Recordings

The recordings were made in an office room. The audio signal was picked up at a distance of 0.3 m by a calibrated B&K condenser microphone type 4165 (Nærum, Denmark). The oral pressure was picked up by means of a thin plastic tube that was held by the participant in the corner of her mouth. This tube was attached to a pressure transducer (Glottal Enterprises, Syracuse, New York). Using Soundswell software (HighTech, Solna), the audio and pressure signals were digitized at 16,000 Hz and recorded into separate computer channels.

SPL was calibrated as follows. The experimenter sang a constant tone, the SPL of which was measured at the recording microphone by means of an LA-210 sound level meter (OnoSokki, Japan) and announced at the beginning of the recording. For pressure calibration, a set of pressures, determined by means of a manometer, was recorded, and the respective pressure values were announced by the experimenter during the recording.

The Kulning phrase chosen for the experiment contained short and long tones, all at high pitches. The initial consonant /p/ of the /pæ/ syllable sometimes produced a clearly

tilting pressure peak, indicating a non-constant and hence unreliable measure of P_{sub} .²² Such data were discarded, yielding acceptable pressure data from six participants in all three experimental conditions. Furthermore, one participant was unsatisfied with her Kulning in the recording. She was allowed to do a second recording, thus adding to the quality variation of the material. This yielded a total of 7 recordings x 12 tones x 3 conditions = 252 tones.

VOICE ANALYSIS

The recorded files were analysed using the *Soundswell* software. SPL and f_0 were determined by means of the *Extract* and *Corr* modules, respectively. Figure 2 shows an example of the analyses. Pressure signals with reasonably flat peaks were obtained from 115 of the 252 tones. The spectra of the tones were analyzed by the *Line spectrum* module, applying a 20 Hz bandwidth, and using a Blackman analysis window of 200 ms and a 0 to 8 kHz frequency range. Thus, the seventh partial for all f_0 values was included (adopting the terminology typically used in voice science, ‘partial’ refers to a spectrum component of a complex tone, numbered from low to high, so that partial number 1 is the fundamental).

Apart from P_{sub} , SPL, f_0 and the durations of the tones, five spectrum properties seemed to vary considerably and were selected for analysis. One was the deviation from a smooth spectrum envelope. Such deviations (D_n) were measured as the difference between the level of partial number n (L_n) and the average levels of its surrounding partials, number $(n-1)$ and $(n+1)$, i.e., $L_{(n-1)}$ and $L_{(n+1)}$, respectively. This deviation was computed for three spectral ranges: (1) all partials up to the seventh (S_7); (2) partials number 3 to 7 (S_{3-7}); and (3) partials number 3 to 5 (S_{3-5}). The level of the

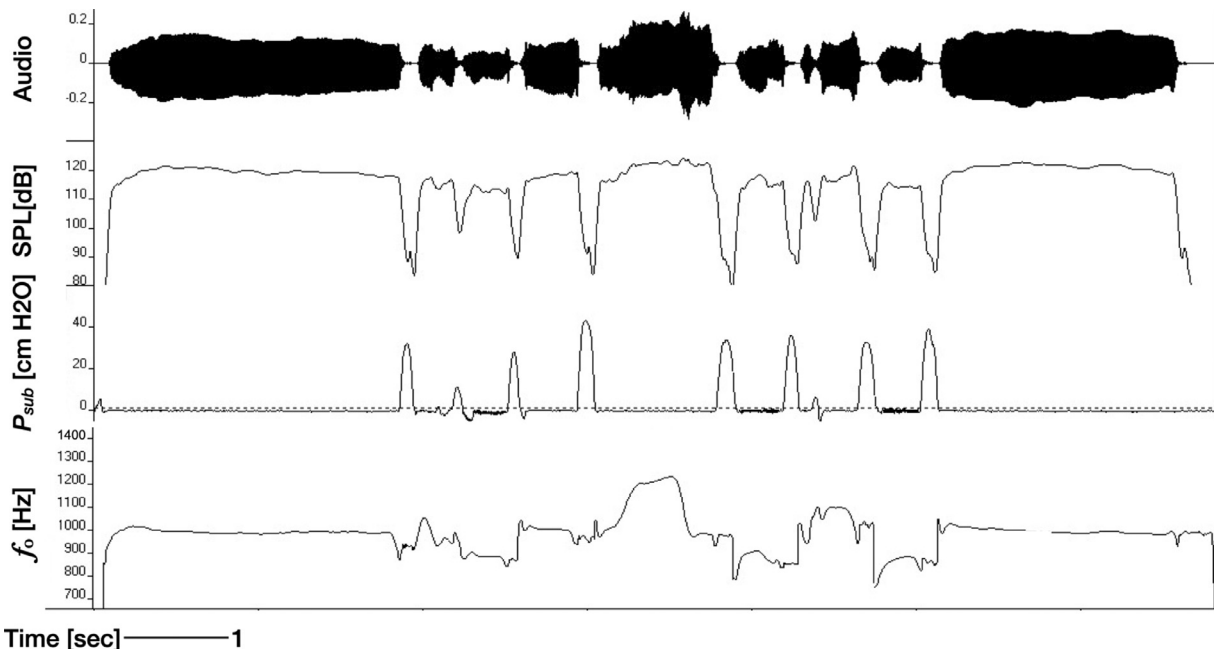


FIGURE 2. Display of audio, sound pressure level (SPL) at .3 m, subglottal pressure (P_{sub}) and fundamental frequency (f_0) for the Kulning phrase as performed by one of the participants.

fundamental ($L_{fundamental}$) and the frequency of the partial that produced the largest dip in the spectrum envelope (f_{dip}) were also measured.

Perceptual analysis

As mentioned above, participants' skill in performing Kulning varied considerably, producing substantial variations in the quality of the recorded Kulning performances. A listening test was carried out where experts rated, along a 20 cm visual analogue scale (VAS), the quality of Kulning tones, which were selected, according to the following criteria: (1) duration exceeding 940 ms, and (2) a reliable recording of P_{sub} (flat top). Twenty tones meeting these criteria were selected, of which 17 were the final tone in the phrase. Their SPL varied within a range of ± 8 dB.

The panel consisted of five experts, including co-author SR, all with a minimum of 15 years of experience in teaching, and singing in concerts and other public performances of Kulning. The recorded tones were collated into a single test file in .wav format. Each tone occurred four times in the file, thus allowing rater consistency to be evaluated. The resulting $4 \times 20 = 80$ stimuli were arranged in the same randomized order for members of the expert panel.

The file containing the stimuli was copied to memory sticks, which were distributed to the panel members with an accompanying response sheet. This included the VAS with extremes *Does not agree at all* (Inte alls) and *Agrees exactly* (Överensstämmer exakt). The experts listened to the recordings using their own listening equipment and were asked to show, by a marker on the line, how well they found that the tone agreed with an optimal Kulning tone. Each expert performed the test independently.

Statistical analyses

To assess intra-rater reliability between the four presentations of the 20 stimuli, one-way within-subject analyses of

variance (ANOVA) with a Bonferroni correction were carried out for each rater. To assess inter-rater reliability, an intra-class correlation coefficient (ICC) was computed using a two-way mixed-effect model and a 95% confidence interval. To find out if ratings differed significantly according to experimental condition, a one-way within-subject ANOVA was carried out. Finally, a stepwise multiple-regression analysis was carried out to find which voice metric could predict the obtained ratings. All data were inspected with regard to normal distribution and identification of outliers and extreme values. All statistical tests were carried out using SPSS version 21 for Macintosh.

RESULTS

Voice analysis

The left panel of [Figure 3](#) shows the SPL at 0.3 m of all Kulning tones as a function of f_o , in semitones above A4. The general trend is that SPL increases with increasing f_o . The right panel of [Figure 3](#) shows P_{sub} as a function of f_o for the participants. As expected, it tended to increase with rising f_o . The pressures are mostly quite high, varying between 12.1 and 68.9 cmH₂O, the majority of the data points occurring within the range of 25 to 45 cmH₂O. Participant 4 showed the highest pressures and participant 3 the lowest.

Slopes, intercepts, and determination coefficients of the trend-lines that approximate the relationship between P_{sub} and SPL and between P_{sub} and f_o are listed in [Table 1](#). With respect to the former, the increase rate varied between .8 and 2.3 dB/ST. Participant 4, who used the highest pressures, showed the steepest increase of SPL. The other participants produced much lower SPL values for a given P_{sub} . For all participants except participant 1, the determination coefficient exceeded .35. The increase was more than 2 dB/ST for participants 3 and 6, who also showed the lowest intercepts. As an increase of P_{sub} tends to increase f_o , other things being equal, [Table 1](#) also shows both the constants

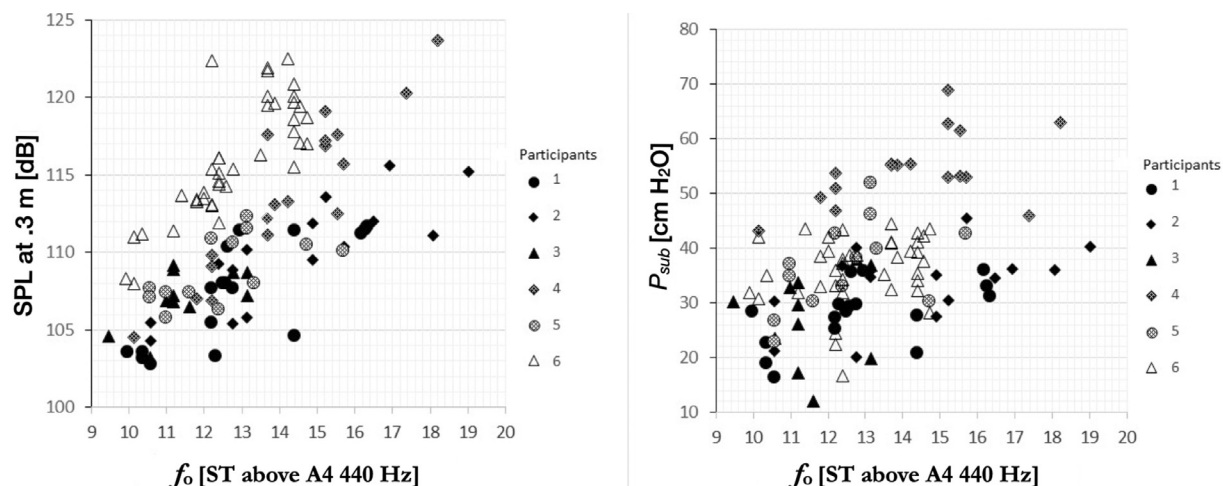


FIGURE 3. Left panel: SPL at .3 m of all Kulning tones, plotted as a function of f_o , in semitones above A4. Right panel: Subglottal pressures (P_{sub}) plotted as a function of f_o , in semitones above A4.

TABLE 1.

Slope, Intercepts (lcpt) and Coefficient of Determination (r^2) of the Trend-Lines Approximating Relations Between: (1) Subglottal Pressure (P_{sub}), in cmH_2O , and Fundamental Frequency (f_0), in Semitones (ST) Above A4 (440 Hz); and (2) P_{sub} and SPL at .3 m

Participant	P_{sub} vs SPL at .3 m			P_{sub} vs f_0		
	Slope [dB/ ST]	lcpt [dB]	r^2	Slope [$\text{cmH}_2\text{O}/$ ST]	lcpt [cmH_2O]	r^2
1	1.6	91.1	.29	1.6	7.9	.31
2	1.2	93.0	.70	1.3	14.5	.24
3	2.3	80.5	.85	0.8	17.6	.01
4	1.0	95.7	.35	1.6	31.3	.27
5	0.8	98.5	.37	2.6	4.8	.24
6	2.2	87.8	.66	0.9	24.0	.05

for the trend-line equations for this relationship for each participant. For participants 1, 2, 4 and 5 the coefficient of determination r^2 exceeded .24. These participants tended to increase P_{sub} with pitch at a rate between 1.3 and 2.6 cmH_2O per semitone.

As mentioned, in Condition 1 the participants were asked to start the phrase at a given pitch (A5, 880 Hz), while in Conditions 2 and 3, they were free to choose the starting pitch according to their own preference. Figure 4 shows the participants' starting pitch of the tones included in the listening test. The left panel displays the f_0 , averaged across participants, for the three conditions; the right panel shows each participant's deviations in Conditions 2 and 3 from the starting pitch of Condition 1. On average, the starting pitch was highest in Condition 3, and lowest in Condition 1, and the starting pitch was 96 Hz (1.7 ST) higher in Condition 2 and 135 Hz (2.4 ST) higher in Condition 3. This

demonstrates that participants had individual preferences regarding the starting pitch. Furthermore, there were substantial differences between participants; participant 2 started Condition 3 at f_0 319 Hz, 5.2 semitones higher than in Condition 1, which resulted in a starting pitch near C#6; for participant 5, the difference between starting pitches in these conditions was no more than half a semitone.

Perceptual analysis

The averages of the ratings obtained for the 20 stimuli are listed in Table 2.

Prior to analysis, four outlier ratings in Condition 3 were removed. The listening test produced a total of 400 ratings (4 presentations x 20 stimuli x 5 raters). Results showed a high correlation between experts' ratings: ICC (2, k) = .88 (confidence interval .79 - .95), Cronbach's α = .94. All but

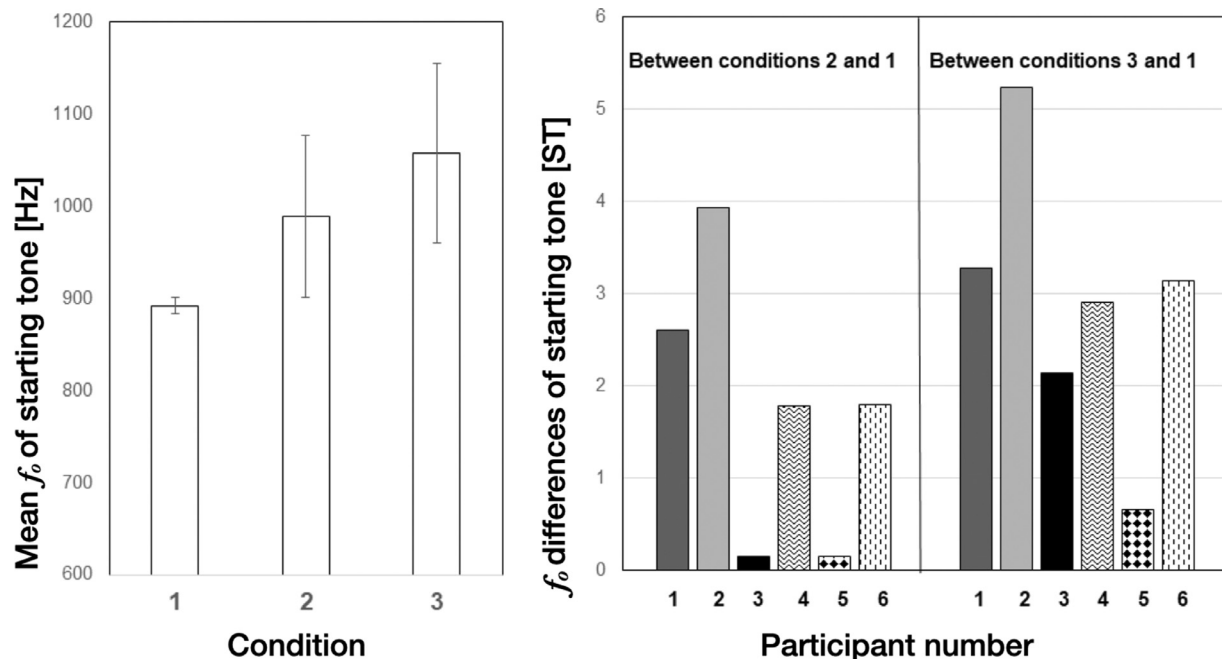


FIGURE 4. Left panel: starting f_0 , averaged across participants for the indicated conditions. Right panel: participants' individual deviations from their starting pitch in condition 1.

TABLE 2.
Averages of the Ratings (M) and Standard Deviation (SD), Measured as % of VAS Length, Obtained for the 20 Stimuli

Participant #	Tone #	Condition	M	SD
1	3	1	77.9	21.6
2	3	1	64.0	23.1
3	3	1	58.8	30.9
5	3	1	44.0	31.0
5	2	1	47.6	30.9
6a	3	1	62.2	23.5
6c	3	1	77.5	21.3
1	3	2	70.8	30.4
3	3	2	55.0	28.2
4	3	2	63.8	27.6
5	1	2	48.7	22.9
5	3	2	56.0	30.6
6a	3	2	64.7	27.0
6c	3	2	87.7	9.3
1	3	3	61.4	31.2
2	3	3	90.7	14.7
4	3	3	87.1	14.9
6a	3	3	92.4	11.1
6b	3	3	83.3	19.3
6c	3	3	86.7	10.2

Notes: The values are ordered according to participant number, number of the tone in the phrase, and conditions. Participant 6 made two trial recordings, the first one labelled 6a, and the second one including 6b and 6c.

one of the raters showed good agreement between ratings of the four presentations of identical stimuli, as shown in Table 3. As expected, SD associated with values near the middle of the VAS scale were high.

The spectra of the three highest and three lowest-rated Kulning tones varied considerably, as illustrated in Figure 5. The spectrum envelope was smoothly sloping in some spectra, whereas for other spectra, it contained a marked dip at different overtones. In addition, the level difference between the first and second partials varied considerably.

As mentioned, participants performed the Kulning phrase in three conditions: (1) starting on A5; (2) starting on a pitch of their own preference; (3) starting on a pitch of their own preference, but after the deepest possible inhalation. The results of the one-way within-subjects

TABLE 3.
Results of the One-Way ANOVA Within-Subject Analysis for Evaluating Intra-Rater Reliability

Rater	One-Way Within-Subject ANOVA
1	$F(3) = 0.39, P = 0.759$
2	$F(3) = 0.49, P = 0.480$
3	$F(3) = 3.507, P = 0.021$
4	$F(3) = 0.97, P = 0.410$
5	$F(3) = 0.65, P = 0.590$

ANOVA suggested that condition had a significant effect on the ratings, $F(2) = 77.539, P < 0.001$, a Bonferroni post hoc test revealing significant differences between all conditions ($P < 0.005$), with an effect size of .425. The lowest mean ratings were given for performances in Condition 2 ($M = 58.12, SD = 29.04$) with only marginally higher ratings given for performances in Condition 1 ($M = 65.97, SD = 27.47$). The mean rating for performances in Condition 3, by contrast, was clearly higher than those given for performances in the other two conditions ($M = 88.5, SD = 12.88$). Thus, most of the highest-rated Kulning tones were produced in Condition 3, initiated at maximum lung volume at the participant's preferred pitch. Figure 6 shows box plots of the ratings for each condition. There were significant differences between each pair of the three conditions ($P \leq 0.005$).

The ratings were significantly correlated with several voice metrics: f_o ($r = .67$), SPL ($r = .73$), f_{dip} ($r = .83$), S_{3-5} ($r = -.43$), and $L_{fundamental}$ ($r = .66$). However, some metrics were highly correlated with each other, collinearity levels exceeding $r > .7$ for: SPL - $L_{fundamental}$; $S_7 - S_{3-5}$; $S_7 - f_{dip}$; $S_3 - 7 - f_{dip}$; $S_7 - S_{3-5}$; $S_7 - f_{dip}$; and $S_{3-7} - f_{dip}$. Because of these collinearities, only P_{sub} , f_o , f_{dip} , and $L_{fundamental}$ were selected for a multiple regression analysis. The results revealed that the ratings could be predicted by two models (Table 4). The first one contained only the f_{dip} , adjusted $r^2 = .67$, with a multiple regression equation of $Predicted\ mean\ rating = 30.5 + .008 \times f_{dip}$. The second model also included $L_{fundamental}$, with adjusted $r^2 = .747$, and a multiple regression equation of $Predicted\ mean\ rating = 30.6 + .007 \times f_{dip} + .743 \times L_{fundamental}$. Thus, 74.7% of the variation in mean rating could be explained by the f_{dip} and $L_{fundamental}$.

DISCUSSION

The present study suggests that Kulning requires an extreme use of the voice; P_{sub} values reached up to 61 cmH₂O, higher than 40 cmH₂O observed in classically trained dramatic sopranos, in *twang* and in *belt*.^{23,24} However, P_{sub} was not correlated with the highest ratings of Kulning quality. The highest-rated tones had high SPL, high f_o , strong $L_{fundamental}$, and spectrum envelopes that lacked dips below 4 kHz. Most of these tones were produced in Condition 3; the second-highest rated tones were produced in Condition 2.

The center frequency of the spectrum envelope dip predicted the ratings of Kulning quality, according to both models 1 and 2 of the multiple regression analysis (Eq. 2 and 3). In all stimuli with ratings lower than 64.1, the f_{dip} appeared at partials number 2, 3, or 4, while in all other stimuli the dip occurred either at partials 5 or 6. Given that the amplitude of spectrum partials generally decreases with rising frequency, the perceptual relevance of high frequency partials could be expected to be small. On the other hand, sensitivity of hearing increases with frequency up to about 5 kHz. Hence, the reason for the missing effect of the f_{dip} at partials number 5 and 6

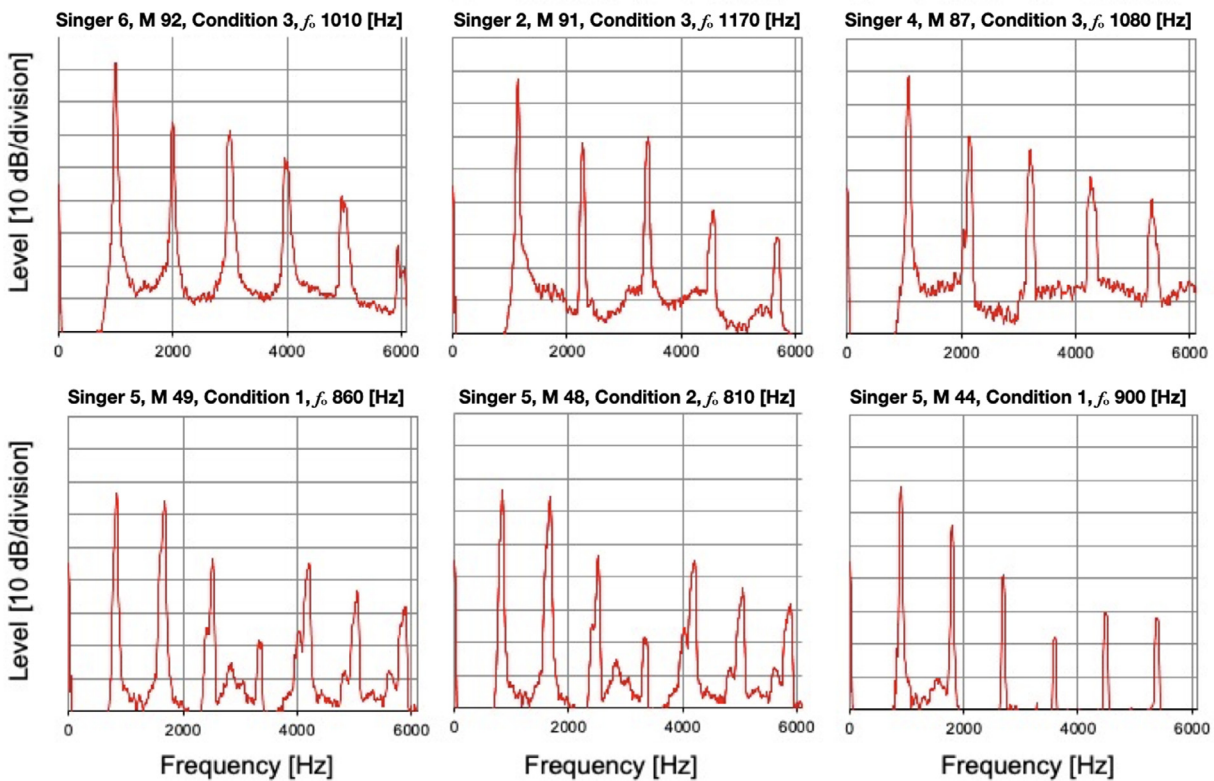


FIGURE 5. Spectra of the tones indicated, showing the lowest four to seven partials on identical sound level scales. M is the mean rating value and f_0 is the fundamental frequency, S is the Singer's code.

invites the speculation that the effect is related to the critical bands of hearing. These bands are approximately a minor third wide for frequencies above 500 Hz. Thus, partials 5 and 6 share the same critical band. It would therefore be of limited relevance to perceived tone

quality if one of these partials caused a dip in the spectrum envelope. Partial 5, by contrast, excites one single critical band each, and should thus be more relevant to the perceived timbre. According to Model 2 of the regression analysis, a strong fundamental

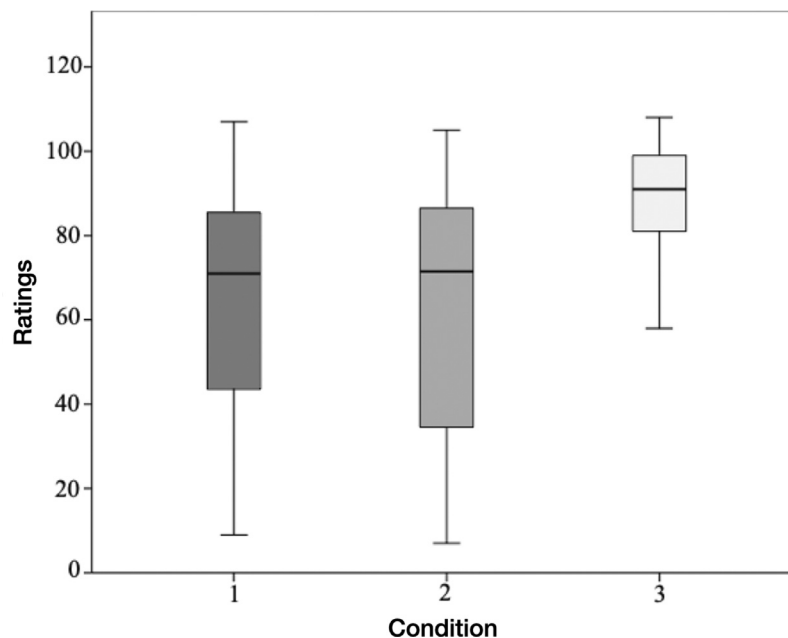


FIGURE 6. Distribution of ratings for performances in the three conditions. Each box plot represents the part of the rating distribution that falls between the 25th and 75th percentile, the horizontal lines in the boxes represent the median, and the vertical lines outside the boxes connect the smallest and the largest values that are not outliers.

TABLE 4.
Summary of Unstandardized and Standardized Multiple Regression Coefficients for the Two Models Obtained

Model		Unstandardized Coefficients		Standardized Coefficients		
			Std. Error	Beta	<i>t</i>	<i>P</i>
1	(Constant)	30.533	6.337		4.818	< 0.001
	f_{dip}	0.008	0.001	.832	6.361	< 0.001
2	(Constant)	30.64	5.595		5.476	< 0.001
	f_{dip}	0.007	0.001	.677	5.146	< 0.001
	$L_{\text{fundamental}}$	0.743	0.301	.325	2.468	0.024

also contributed significantly to the prediction of the ratings; the stronger the fundamental, the higher the rating. This parameter is related to phonation type; phonatory pressedness tends to be associated with a weak $L_{\text{fundamental}}$.²⁵ A weak fundamental belongs to the characteristics of emotional excitement.²⁶ It seems obvious that Kulning needs to be perceived as attractive by cattle if it is to fulfil the purpose of gathering the herd. It is likely that dairy cattle are familiar with the emotional code of the human voice, as suggested by the Kulning singer Karin Edvardsson (1909-1997). According to her, the way one uses the voice is determined by whom is addressed to, for example, one's dog or one's cattle.²⁷ Indeed, experimental evidence supports this suggestion. Pajor and associates had dairy cattle pass through a Y-shaped crush; at the end of one arm, the cows could hear the voice of a handler shouting angrily, and at the end of the other arm they could hear the voice of a handler speaking gently. The cattle showed a significant preference for the latter.²⁸ It is tempting to speculate that a strong fundamental belongs to the set of voice characteristics that make the cattle gather. Some support for this speculation can be found in the study of Merrill and Ackermann, who analyzed examples of voices that were disliked by cattle. They obtained qualitative results in the form of adjectives. Disliked voices were described as "squeaky," "nasal," "pressed," "suffering from imprecise and ordinary articulation," and having an "uniform expression."²⁹ While these qualitative results cannot be compared meaningfully with our quantitative results, it seems reasonable to assume that the adjective "pressed" may correspond to the perceptual effect of a weakened fundamental, a characteristic that we found significantly related to less preferable Kulning tones.

The highest-rated tones were all produced in Condition 3, in which the participants started at maximum lung volume. A physiological correlate of a strong fundamental is a generous glottal airflow, a characteristic that has been found to accompany phonation at high lung volumes.^{25,30} Interestingly, Kulning is typically performed at high lung volume, promoted by the characteristically short duration of Kulning phrases (7 to 8 seconds.).

As shown above, the starting pitch in Conditions 2 and 3 differed between participants. This suggests that,

when given the opportunity, they chose the starting pitch according to their personal preference. This would be an important strategy, particularly since Kulning is extremely loud and produced at extremely high pitches. Under such circumstances, pitch differences, even as small as a semitone, may be relevant.

High lung volume and the participants' personal choices of starting pitch co-varied with the expert ratings; performances in Condition 3, in which the singer could freely choose the starting pitch from a maximum lung volume, received significantly higher ratings than those in Conditions 1 and 2. A factor possibly contributing to this result may have been the order of the recording conditions. This order was necessary for pedagogical reasons; some participants were naïve learners requiring a structured order of tasks. Choosing an optimal pitch range seems therefore relevant to both teaching and composing of Kulning.

It is noteworthy that there was no correlation between P_{sub} and ratings of Kulning quality. For example, participant 1 used the lowest P_{sub} range, from 29.4 to 29.7 cmH₂O, while the corresponding range for participant 4 was between 46.8 and 61.4 cmH₂O. Both these participants received high ratings. Thus, high Kulning tone quality seems to be related to an favourable relationship between P_{sub} and SPL, an important consideration in pedagogical approaches that promote vocal economy.

As noted above, Johnson and Sundberg analyzed SPL, f_0 , and P_{sub} in two Kulning singers.²¹ In the f_0 range 800 to 1150 Hz, SPL varied between 100 to 110 dB at .3 m and the trend-line showed an average increase of 6.8 cmH₂O for a 100 Hz rise of f_0 . The corresponding values in the present study are comparable. We found that, for 100 Hz increase of f_0 and 4.9 cmH₂O, the SPL range was between 107 and 119 dB. Incidentally, similar values have been observed also in dramatic sopranos' fortissimo singing, with an average P_{sub} of 40 cmH₂O at 1 kHz and 113 dB SPL at .3 m.³¹ The Kulning singers who took part in the study reported by Johnson et al. were both born at the beginning of the 20th century and were typical representatives of the Kulning tradition in the early part of that century.¹⁶ The agreement with our findings suggests that essential characteristics of Kulning tones from this era are similar to those currently cultivated, even if the performance setting of Kulning in our time is more often indoors than outdoors.¹³

The value of $L_{fundamental}$ is dependent also on the nearest formant; the smaller the frequency distance to the first formant, the higher the $L_{fundamental}$. Indeed, according to Johnson et al., the first formant was close to the fundamental in a professional Kulning singer.¹⁶ Probably, the Kulning singers also in the present investigation applied the same strategy.

The lack of spectrum envelope minima in the highest rated tones may reflect the tendency to tune a formant to each of the lowest partials. This will enhance these partials, while placing a formant away from a partial will cause a spectrum envelope dip. The self-chosen starting pitch could then have contributed to the perception of higher Kulning quality tones. The relevance of pitch to the Kulning tone quality may be due to the spectral importance of the Kulning singer's personal formant frequencies, that is, the dimensions of the singer's vocal tract. As mentioned, singers freely choose the pitch on which they start phrases in both older and current Kulning traditions. On average, formants are spaced around 1000 Hz apart. Thus, in the pitch range studied here, the number of partials would be approximately the same as the number of formants.

CONCLUSIONS

Our investigation has provided evidence of acoustic and physiological characteristics of Kulning tones. Tones receiving high ratings of Kulning quality shared a strong fundamental and a lack of spectrum envelope dips among the five lowest spectrum partials. Conversely, a weak fundamental and a spectrum envelope dip between the lower partials significantly predicted low ratings of Kulning quality. The highest-rated tones had an SPL at 0.3 m between 115 and 121 dB and a pitch range between 1010 and 1170 Hz. The SPL of the lowest rated tones was lower than 111 dB and their pitch ranged between 810 and 970 Hz. Kulning tone quality was rated significantly higher when started at a high lung volume and at a pitch of the participant's own choice. The P_{sub} range differed substantially between participants and was not related to the quality of the Kulning tones. Knowledge of this information is relevant to composition and artistic work, as well as to voice pedagogy. In the case of Kulning, even small pitch differences may be relevant for optimizing the relationship between vocal technique and personal morphology.

DECLARATION OF INTERESTS

None.

REFERENCES

- Johnson A. *Sången i Skogen, Studier Kring Den Svenska Fäbodmusiken*. Uppsala, Sweden: Dissertation Uppsala University; 1986.
- J. Larsson, Fäbodväsendet 1550 –1920. Dissertation Sveriges Lantbruksuniversitet Acta Universitatis Agriculturae Sueciae; 2009:51, 1652-6880 ISBN 978-91-86195-98-4.
- Johnson A. Sången i skogen - skogen i sången. Om fäbodarnas musik. In: Ling J, Ramsten M, Ternhag G, eds. *Folkmusikboken*. Stockholm: Prisma; 1980:66–103.
- Rosenberg S. *Kulning - Musiken och tekniken*. Stockholm: Udda Toner; 2007.
- Rosenberg S. *Kulning - Herding Call - The Music and Vocal Technique*. Stockholm: Udda Toner; 2010.
- Moberg C-A. Om vallåtar II. *Swed J Musicol*. 1959;41:1–57.
- Ahlbäck S. *Tonspråket i Äldre Svensk Folkmusik*. Stockholm: Udda Toner; 1989.
- Ahlbäck S. The hidden modes: a computer-assisted approach to tonality analysis of Swedish folk music. *Paper presented at the 8th International Workshop Folk Music Analysis*. Thessaloniki, Greece; 2018.
- Ahlbäck S. Den nordiska vallätens tonspråk. In: Tiderman-Österberg J, Thorell E, eds. *Fäbodlandskap och vallmusik*. 89, Falun: Dalarnas Fornminnes- och Hembygdsförbund; 2019:115–119.
- Rosenberg S, Sundberg J, Hertegård S. What is Kulning? Physiological and acoustic characteristics of a singing style from the Scandinavian herding environment. *Paper presented at the The Voice Foundation's 37th annual symposium*. Philadelphia; 2008.
- Rosenberg S, Sundberg J. En utsmyckning av oändligheten runt omkring. På jakt efter kulningens dragläge. *Noterat*. 2008;16:83–91.
- Rosenberg S. Kulning - an ornamentation of the surrounding emptiness: about the unique Scandinavian herding calls. *Voice Speech Rev*. 2014;8:100–105. <https://doi.org/10.1080/23268263.2013.829712>.
- Rosenberg S. Kulning nu. In: Tiderman-Österberg J, Thorell E, eds. *Fäbodlandskap Och Vallmusik*. 89, Falun: Dalarnas Fornminnes- och Hembygdsförbund; 2019:161–169.
- Rosenberg S, Sundberg J, Björkner E. Attracting cows –what is the decibel price in kulning. *Paper presented at the PEVOC 6*. London; 2005.
- Voice physiology and ethno-musicology: physiological and acoustical studies of the Swedish herding song. In: Johnson A, ed. *Yearbook for Traditional Music*. Cambridge University Press; 1984:16.
- Johnson A, Sundberg J, Wilbrand H. "Kölning". Study of phonation and articulation in a type of swedish herding song. *Paper presented at the SMAC - Stockholm Music Acoustics Conference*. Stockholm; 1983.
- Tellenbach MUW. *Lockrufe in Skandinavien: Funktion, Klang, Revival. Diploma thesis*. Vienna, Austria: Vienna University; 1999.
- Eklund R, McAllister A, Pehrson F. An acoustic comparison of voice characteristics in 'kulning', head and modal registers. *Paper presented at the XXVth Annual Phonetics Meeting*. Sweden: Linköping University Linköping; 2013. June 12–13.
- McAllister A, Eklund R. An acoustic analysis of the cattle call "kulning" performed outdoors at Säter, Dalarna, Sweden. *Paper presented at the Phonetic Conference, Phonetics department*. Sweden: Lund University; 2015.
- A. Geneid, A.-M. Laukkanen, A. McAllister, et al., Kulning (Swedish cattle calls): acoustic, EGG, stroboscopic and high-speed video analyses of an unusual singing style paper presented at INTERSPEECH September 2016, San Francisco, USA. 10.21437/Interspeech.2016-1082.
- Lisslass E. *Kulning: III On Folk Music in Sweden Lockrop & Vallåtar CD*. Stockholm: Caprice; 1995.
- Perrine B, Scherer R, Whitfield J. J. Signal interpretation considerations when estimating subglottal pressure from oral air pressure. *J Speech Lang Hear Res*. 2019;19:1–12. https://doi.org/10.1044/2018_JSLHR-S-17-0432.
- Sundberg J, Thalén M. What is "Twang"? *J Voice*. 2010;24:654–660. <https://doi.org/10.1016/j.jvoice.2009.03.003>.
- Sundberg J, Thalén M. Respiratory and acoustical differences between belt and neutral style of singing. *J Voice*. 2015;29:418–425.
- Sundberg J. Objective characterization of phonation type using amplitude of flow glottogram pulse and of voice source fundamental. *J Voice*. 2020. <https://doi.org/10.1016/j.jvoice.2020.03.018>.
- Salomão GL, Sundberg J, Scherer KR. Emotional coloring of the singing voice. *Paper presented at the 11th PEVOC (Pan-European Voice Conference)*. 2015. [https://doi.org/10.1016/S0168-1591\(02\)00119-3](https://doi.org/10.1016/S0168-1591(02)00119-3).

27. B. Ersson, M. Ramsten, A. Johnson, et al., Sköna, älgrosa. video, svenskt visarkiv (visarkivet@musikverket.se), 1977.
28. Pajor EA, Rushena J, de Passillé AMB. Dairy cattle's choice of handling treatments in a Y-maze. *Appl Anim Behav Sci.* 2003;80:93–107. [https://doi.org/10.1016/S0168-1591\(02\)00119-3](https://doi.org/10.1016/S0168-1591(02)00119-3).
29. Merrill J, Ackermann T-I. Like static noise in a beautiful landscape: a mixed-methods approach to rationales and features of disliked voices in popular music. *Psychol Aesthet Creat Arts.* 2020. <https://doi.org/10.1037/aca0000376>. Advance online publication.
30. Iwarsson J, Thomasson M, Sundberg J. Effects of lung volume on the glottal voice source. *J Voice.* 1998;12:424–433.
31. J. Molinder, Akustiska och perceptuella skillnader mellan röstfacken lyrisk och dramatisk sopran. Thesis, Logopedics department, Lund Universitet, Lund, Sweden, 1997.