An acoustic analysis of Swedish cattle calls, 'kulning', performed outdoors at three distances

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Abstract

Kulning is a Swedish cattle call singing style with an almost mythical status in Swedish folklore. In previous studies two of the authors (RE, AM) studied kulning produced by a kulning singer (FP) in both indoor and outdoor settings. In this paper we report kulning as produced by a second singer (the third author, KD), recorded outdoors in a forest setting, with simultaneous recordings at 1, 11 and 22 meters. The results of amplitude, FFT and LPC analyses reported, and compared to the earlier studies reported in Eklund, McAllister and Pehrson (2013) and McAllister and Eklund (2015).

Introduction

Long-distance calls have historically been created different locations around the world where there has been a need of communicating over long distances; examples include whistled languages (Busnel & Classe, 1976) and yodeling (Luchsinger, 1942); Schlömicher-Thier et al. 2009).

Such long-distance calls have been used both for communication between humans and for communication between humans and animals.

Kulning is the most commonly used term for a specific type of cattle or herding calls used in some parts of Sweden, especially in the provinces of Dalarna, Härjedalen and Jämtland (see Rosenberg, 2003:8, for a listing of other terms. Kulning is used to call free-grazing cows or goats in the mountains when it is time for milking.

The tradition of cattle calls dates far back in history and seems to have been most common in the province of Dalarna, Sweden, where young women looked after the live stock during summer in small mountain farms, away from the homestead.

Kulning characteristically has no lyrics and mainly consists of vowel-heavy syllables that feel comfortable to the singer. Kulning is mostly used by women, and is high-pitched and without vibrato to make the sound carry over long distances.

In this paper we compare results from two of our previous studies (Eklund, McAllister & Pehrson, 2013; McAllister & Eklund, 2015) with our results from recordings of a different kulning singer (KD).

Previous Research

Kulning is mentioned in both Moberg (1955:38 et passim) and Ling (1978), but mainly in passing. For example, Ling (1978:22) states that kulning is not "singing" in a traditional sense but is more like some kind of falsetto-like calling in very high registers, and that it requires a tightened larynx.

Moberg (1955:37) points out that kulning is normally sung on vowels, without lyrics (as was pointed out above). Johnson (1984, 1986:216–259) reports that kulning production is characterized by a strong correlation between frequency and amplitude in higher registers (although not so much so in lower registers) and that, contrary to classical singing, the larynx moves with the frequency, and is raised considerably when high notes are produced (an elevation of up to +39 mm). Jaw opening is also correlated with high frequency (in line with classical singing). The vocal tract length is varied with up to 37 mm, compared to 22 mm in normal singing:

Moreover, the pharynx is tightened, even to the point of making optical glottography impossible (Geneid et al. 2017). High or very high subglottal pressures up to 100 cm H_2O have been reported depending on the fundamental frequency (Johnson, Sundberg & Wilbrand 1985). Johnson (1986) also reports SPL values up to 105 dB at 1m. The results presented in Johnson are largely repeated in Rosenberg (2003:24).

As for the acoustic properties of kulning, Uttman (2002) studied partials spectra of kulning obtained from outdoor recordings, and reported strong partials up to the 16–18 kHz register, compared to ~6 kHz in normal folk singing.

Data collection

The singer

The kulning singer was Kajsa Dahlström, specialized in traditional Swedish music, educated at the Royal college of music in Stockholm. She started to make the Swedish herding call, kulning, over 20 years ago and have since then performed on stage in many different situations. She has also studied the tradition and the way kulning has been used in Sweden during the past generations and is continuously giving courses on the topic. She is based at the Swedish Museum of Performing Arts, a section of Swedish Performing Arts Agency.

Setting

Data collection was carried out on the 14 August 2016 in a forested area outside of Tungelsta, around 30 km south of Stockholm, Sweden. The time of day was between 1830 and 1930 hours. Wind speed was around 10 m/s, the temperature was 17 C° and air humidity was around 45% (data from freemeteo.se). The area was very secluded and the only disturbance was the odd aircraft preparing for landing at Arlanda Airport (which meant that they were still high up in the air).

Microphones were set up at three distances from the singer at 1 meter, 11 meters and 22 meters from the singer. The distance of 11 meters was chosen so as to enable comparisons with the recordings presented in McAllister and Eklund (2015), and the distance 22 meters was chosen to get the double distance of 11 meters. The recording equipment was placed on a slope with a very slight inclination with an equal density of tree trunks. See Plate 1.

Equipment

Simultaneous recordings of all material were made using three Canon HG-10 high-definition camcorders. Three identical Shure Beta 58A Supercardiod Dynamic microphones were used (all cameras). Amplitude was measured using two Extech 407732 sound level meters (factory calibrated), with overlapping (1/11 meters, then 11/22 meters) distances in order to enable a calibrated and normalized comparison at all three distances.

Analysis

General

All video-recordings were converted and resampled to 44.1 kHz, 16 bit, mono sound files using TMPGEnc 4.0 XPress, and were analysed using Cool Edit Pro 2.0, WaveSurfer 1.8.8p4.

Plate 1. Recording setup with singer and three camcorders/microphones at 1 meter, 11 meters and 22 meters from the singer. Photo by first author.

Amplitude analysis

The normalized and calibrated decibel measurements were compared and the results are displayed in Table 1.

Table 1. Amplitude comparison of the calibration tone (B5/908 Hz) at three distances. For the tones at 11 and 22 m, the distances are compared to the recording closer to the source (ten times and twice the distance, respectively), and the degree of compared attenuation is given.

Tone	1 m	11 m	22 m
B5	94 dB	80 dB	72 dB
Distance		10 ×	2 ×
Attenuation		–14 dB	–8 dB

Sound amplitude (theoretically) tapers off at 6 dB in a free field, which is roughly the case when comparing 11 and 22 meters in Table 1, while the sound at 11 meters is louder than would be expected from this theoretical degree of attenuation.

FFT analysis

For FFT (and LPC, see below) analyses two tones were selected: a (low) D6 and a B5 (the one used for calibration). The results are shown in Figures 1a–2c.

Compared to our previous studies of FP (Eklund, McAllister & Pehrson, 2013; McAllister & Eklund, 2015) the there is a marked difference in that upper harmonics are not visible at as high frequencies as was the case with FP, where clear partials could be observed up to 18 kHz. In our analysis of KD the highest, clearly discernible harmonics are observed at around 12 kHz. However, this ties in with the results reported by Uttman (2002), who studies four kulning singers and found that they varied between 12 kHz and 18 kHz. So there are already reported individual differences at play in kulning singing.

Compared to Eklund, McAllister and Pehrson (2013) and McAllister & Eklund, 2015), where clear upper partials were observed at 14–16 kHz, we observed that this is also the case for the “lower” B5 here, which, however, is not the case for the higher D6, where no clear upper partials are not visible about 8–12 kHz for the higher D6.

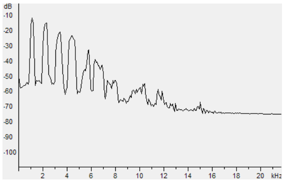

Figure 1a. FFT analysis (Hamming window) of ~D6 (1150 Hz) at 1 meter.

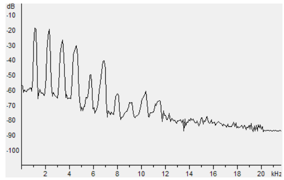

Figure 1b. FFT analysis (Hamming window) of ~D6 (1150 Hz) at 11 meters.

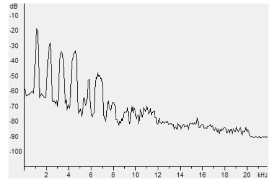

Figure 1b. FFT analysis (Hamming window) of ~D6 (1150 Hz) at 22 meters.

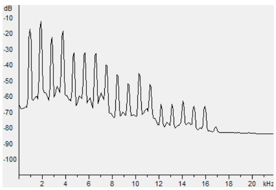

Figure 2a. FFT analysis (Hamming window) of B5 (980 Hz) at 1 meter.

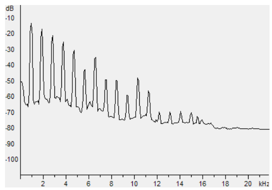

Figure 2b. FFT analysis (Hamming window) of B5 (980 Hz) at 11 meters.

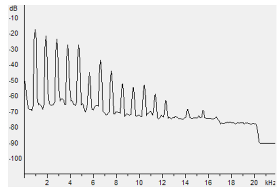

Figure 2c. FFT analysis (Hamming window) of B5 (980 Hz) at 22 meters.

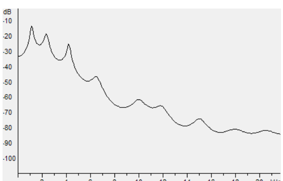

Figure 3a. LPC analysis (Hamming window) of ~D6 (1150 Hz) at 1 meter.

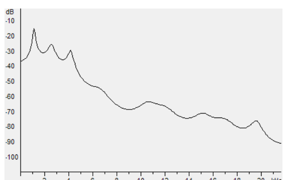

Figure 3b. LPC analysis (Hamming window) of ~D6 (1150 Hz) at 11 meters.

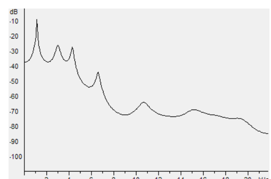

Figure 3c. LPC analysis (Hamming window) of ~D6 (1150 Hz) at 22 meters.

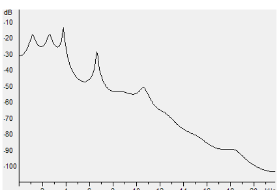

Figure 4a. LPC analysis (Hamming window) of B5 (980 Hz) at 1 meter.

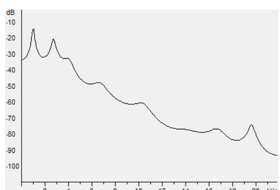

Figure 4b. LPC analysis (Hamming window) of B5 (980 Hz) at 11 meters.

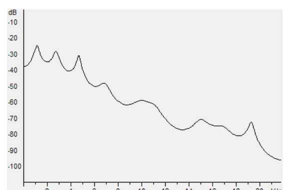

Figure 4c. LPC analysis (Hamming window) of B5 (980 Hz) at 22 meters.

Figures 1a–4c. FFT and LPC analyses of two different tones. Simultaneous recordings at three distances. Frequency range (*x* axis) is 0 Hz to 20 kHz for in all images. All analyses were carried in WaveSurfer 1.8.8p4.

LPC analysis

LPC analyses were carried out on the tones described above. Results are shown in Figures 3a–4c. Compared to our previous studies, the main difference here is that the KD data shows almost no difference in formant patterns as a function of distance, which stands in stark contrast with the FP data where formant peaks more or less completely disappeared at 11 meters, as compared to 1 meter.

Once again, it seems that there are individual differences at play, that also seem to appear independent of each other, i.e. whether or not a particular kulning singer produced higher (in frequency) or louder (in amplitude) tones does not seem to constitute predictors for e.g. harmonic och formant patterns.

Discussion and conclusions

The results comparing two kulning singers (FR and KD) show both differences and similarities. The main differences are that upper harmonics are not visible at as high frequencies for singer KD as for FP, where clear partials could be observed up to 18 kHz at 1 m. This is contrary to our initial assumption. However, such individual differences have been pointed out in previous studies and seem to be independent of fundamental frequency (Uttman 2002), and in this study, also of loudness. Another difference is the formant pattern as a function of distance where there is almost no difference between the three recoding positions, which is in clear contrast with the FP data where formant peaks almost disappeared at 11 meters.

Both singers produced high loudness levels at 1 and 11 m. At 1 m singer KD was clearly louder. Loudness at 11 m was attenuated by 9 and 14 dB respectively for singers FP and KD. Thus the sound propagating properties of kulning were confirmed. Results point to the need of further studies that should preferably include subglottal pressure and high-speed photography to further investigate production features behind these differences.

The conclusions from the present results are that, in the compared singers', higher fundamental frequency and higher vocal loudness were inversely associated with visible partials over 12 kHz.

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References

Busnel, R.-G., Classe, A. (1976). *Whistled languages* (Communication and Cybernetics 13). Berlin: Springer.

Echternach, M., Marki, M., Richter, B. (2011). Vocal tract configurations in yodelling—prospective comparison of two Swiss yodeller and two non-yodeller subjects. *Logopedics Phoniatrics Vocology* 36, 109–113.

Echternach, M., Richter, B. (2010). Vocal perfection in yodelling—pitch stabilities and transition time. *Logopedics Phoniatrics Vocology* 35, 6–12.

Eklund, R., McAllister, A., Pehrson, F. (2013). An acoustic comparison of voice characteristics in 'kulning', head and modal registers. In *Proceedings of Fonetik 2013* (pp. 21–24), Linköping, Sweden.

Johnson, A. (1986). *Sången i skogen: Studier kring den svenska fäbodmusiken*. PhD thesis, Department of Musicology, Uppsala University.

Johnson, A. (1984). Voice Physiology and Ethno-musicology: Physiological and acoustical Studies of the Swedish Herding Song. In: D. Christensen (ed.), *Yearbook for Traditional Music* 16, 42–66.

Johnson, A., Sundberg. V, Wilbrand, H. (1985). Study of phonation and articulation and in a type of Swedish herding song. In Stockholm Music Acoustic Conference, SMAC1983, 187-202.

Ling, J. (1978). *Svensk folkmusik.* Stockholm: Prisma.

Luchsinger, R. (1942). Untersuchungen über die Klangfarbe der menschlichen Stimme. *Archiv für Sprach- und Stimmphysiologie und Sprach- und Stimmheiligkunde*, 1–39.

Marten, K., Marler. P. (1977). Sound Transmission and Its Significance for Animal Vocalization. *Behavioral Ecology and Sociobiology* 2:271–290.

McAllister, A., Eklund, R. (2015). An acoustic analysis of the cattle call "kulning", performed outdoors at Säter, Dalarna, Sweden. In: *Proceedings from*

Fonetik 2015 (pp. 81–84). Lund, Sweden.

Moberg, C.-A. (1955). Om vallåtar. En studie i de svenska fäbodarnas musikaliska organisation. *Svensk Tidskrift för Musikforskning*, 1–27.

Rosenberg, S. (2003). *Kulning. Musiken och metoden*. Stockholm: Udda Toner. 1950.

Schlömicher-Thier, J., Miller, D.G. Noé, H., Herbst, C.T. (2009). *Yodelling – acoustic and physiological properties*. Poster at the 38th Annual Symposium of the Voice Foundation, Philadelphia, PA, USA, 3–7 July 2009.

Uttman, M. T. (2002). Eine Untersuchung der Teiltonspektren bei Kulning und Lockruf-techniken anhand von Beispielen aus Schweden und Finnland. *STM-Online 5*.