A comparative acoustic analysis of purring in four cheetahs

Robert Eklund[1], Gustav Peters[2], Florian Weise[3] and Stuart Munro[3]
[1]Department of Culture and Communication, Linköping University, Linköping, Sweden
[2]Forschungsmuseum Alexander Koenig, Bonn, Germany
[3]N/a'an ku sê Foundation, Windhoek, Namibia

Abstract

This paper reports results from a comparative analysis of purring in four tame cheetahs. The results exhibited individual variation for relative phase duration and number of cycles per phase, while egressive phases were louder and had higher fundamental frequency in all four cheetahs.

Introduction

Despite the fact that the purring domestic cat (*Felis catus*, Linneaus 1758) has been a companion of humans for around 10,000 years (Driscoll et al., 2009), and despite the fact that the prominent purrer, the cheetah (*Acinonyx jubatus*, Schreber 1776), also has been kept as a pet animal for thousands of years, it is still not known exactly how purring felids produce their trademark sound, nor is its acoustics described in detail in many works.

Eklund, Peters & Duthie (2010) compared purring in the cheetah and the domestic cat, and Schötz & Eklund (2011) performed a similar analysis of purring in four domestic cats. The present paper constitutes a combination of the previous two studies, and compares purring in four adult cheetahs.

The Cheetah

The cheetah (*Acinonyx jubatus*) is probably best known for being the fastest land animal in the world with an estimated top speed of circa 112 km/h (Sunquist & Sunquist, 2002:23).

Contrary to a widespread misconception that the cheetah "is not a cat", it is a full-fledged felid, most closely related to the puma (*Puma concolor*) and the jaguarundi (*P. yaguarondi*) (O'Brien & Johnson, 2007:70) The cheetah is roughly the same size as a leopard (*Panthera pardus*) – with which it is often confused – but is of a lighter and more slender build, has a smaller head, smaller teeth, and is a poor climber. The cheetah is also distinguished by dark tear-marks in the facial fur running down its eyes, towards the muzzle.

Sexual dimorphism is not very pronounced in the cheetah: a male cheetah weighs 29–65 kg, is 172–224 cm nose-to-tail with a shoulder height of 74–94 cm; a female cheetah weighs 21–63 kg, and is 170–236 cm nose-to-tail with a height of 67–84 cm (Hunter & Hamman, 2003:141).

Although the cheetah is a relatively large carnivore, there are no records of a wild cheetah ever killing a human being (Hunter & Hamman, 2003:17).

Previous Research

The term 'purring' has been used liberally in the mammal vocalization literature, and an exhaustive review is given in Peters (2002). Using a definition of purring that *continuous sound production must alternate between pulmonic egressive and ingressive airstream (and usually go on for minutes)*, Peters (2002) reached the conclusion that until then only "purring cats" (Felidae) and two species of genets (Viverridae *sensu stricto*), *Genetta tigrina*, and most likely also *Genetta genetta*, had been documented to purr.

The subdivision of the Felidae (the cat family) into "purring cats" on the one hand, and "roaring (non-purring) cats" on the other, originally goes back to Owen (1834/1835) based on a difference in hyoid anatomy. The "roaring cats" (lion, *Panthera leo*; tiger, *P. tigris*; jaguar, *P. onca*; leopard, *P. pardus*) have an incompletely ossified hyoid, which, according to this conception, enables them to roar but not to purr.

On the other hand, the snow leopard (*Uncia uncia*, or *P. uncia*), as the fifth felid species with an incompletely ossified hyoid, allegedly purrs (Hemmer, 1972). All remaining species of the family Felidae ("purring cats") have a completely ossified hyoid which enables them to purr but not to roar. The cheetah belongs to the latter group.

However, there is no well-founded and unequivocal basis for a classification of the species in the family Felidae according to the absence/presence of purring and roaring, respectively, and differences in hyoid anatomy. Weissengruber et al. (2002) argued that the ability of a cat species to purr is not affected by the anatomy of its hyoid, i.e. whether it is fully ossified or has a ligamentous epihyoid, and that, based on a technical acoustic definition of roaring, the presence of this vocalization type depends on specific characteristics of the vocal folds and an elongated vocal tract, the latter rendered possible by an incompletely ossified hyoid.

The current classification of the Felidae is based on molecular characteristics (Johnson et al., 2006; O'Brien & Johnson, 2007) and groups the clouded leopards (*Neofelis nebulosa* and *N. diardi*), which have completely ossified hyoids, with the five cat species in which it is incompletely ossified.

Data Collection

Data were collected in December 2011 from four cheetahs, the three littermates Aiko (male), Aisha (female) and Kiki (female) in their enclosures at the N/a'an ku sê Foundation in Namibia. They were born in 2003, and were orphaned at a few weeks of age and were hand-reared and are considered tame. At the time of recording they were approximately 8.8 years old. Aiko had an estimated weight of 55 kilos, while Aisha's weight was estimated at around 35 kilos and Kiki's to around 31 kilos. The fourth cheetah, Samira (female), was raised in captivity (with two other cheetahs) and was transferred to the N/a'an ku sê Foundation in late 2008. Samira is notably underdeveloped physically due to malnutrition in her early life with layover effects still evident in her coat condition, posture and dentition. Samira was born in 1999 and was 13 years old at the time of recording, with an estimated weight of around 33 kilos.

Equipment

The equipment used was a Canon HG-10 HD camcorder with a clip-on DM50 electret stereo condenser shotgun microphone with a frequency range of 150–15,000 Hz, and a sensitivity of –40 dB. The position of the microphone varied, partly due to the cheetahs moving, but was mostly directed towards the muzzle of the cheetahs since this is where the sound emanates (see e.g., Eklund, Peters & Duthie, 2010). Photos from the data collection are given in *Plate 1* and *Plate 2*.

Data Post-Processing

Audio tracks were excerpted from the films with TMPGEnc 4.0 Xpress. Working audio format was 44.1 kHz, 16 bit, mono.

Results

The results are presented in *Table 1*, and methodology, analysis parameters/phenomena and observations are described and discussed separately in the following paragraphs.

Analysis Tools

Waveforms were created and analyzed with Cool Edit 2000/Pro 2.0, and both waveform and spectrogram analyses were carried out with WaveSurfer. Cycles per phase were counted manually from the waveform.

Statistics were calculated with SPSS 12.0.1.

Egressive–Ingressive Identification

Egressive and ingressive phases were identified according to the method described in Eklund, Peters & Duthie (2010) and proved completely unproblematic.

Amplitude

As is clearly shown in *Figure 1*, as a rule, egressive phases were louder than ingressive phases in all four cheetahs, which is in agreement with the results reported in Eklund, Peters & Duthie (2010) for cheetahs and domestic cats, and Schötz & Eklund (2011) for domestic cats. However, Aisha did produce a couple of ingressive phases that were louder than her egressive phases, which might be due to the fact that unlike the other cheetahs who were all resting during the recording, Aisha was moving about in an agitated state, and was licking the first and last authors; see *Plate 2*. This could perhaps be taken as an indication that the acoustics of purring could be dependent on the state of the cheetah during production, and could possibly also explain that Moelk (1944:188) reported that ingressive phases were "louder" than egressive phases.

Plate 1. First author recording Samira. Photo by Miriam Oldenburg.

Plate 2. First and last authors recording Aisha. Photo by Miriam Oldenburg.

Table 1. Summary Table. For all four cheetahs results are given for duration, cycles per phase and fundamental frequency. Results are presented independently for egressive and ingressive phases and for the two combined, and statistical tests are performed on differences between egressive and ingressive phonation.

	Aiko (M)		**Aisha (F)**		**Kiki (F)**		**Samira (F)**	
Phonation type	Ingressive	Egressive	Ingressive	Egressive	Ingressive	Egressive	Ingressive	Egressive
No. phases analysed	69	70	8	8	29	29	109	107
Mean duration (ms)	2014	2774	1537	2000	2426	2120	1819	1401
Mean duration egr+ingr (ms)	2397		1768		2273		1612	
Standard deviation	309.3	515.7	518.8	588.1	300.5	193.9	254.1	163.5
Maximal duration	2800	3700	2600	2850	3200	2500	3320	1830
Minimal duration	1300	1200	900	900	2000	1700	940	670
Δ *t* test (paired-samples, two-tailed)	$p < 0.001$		$p = 0.011$		$p < 0.001$		$p < 0.001$	
Δ Wilcoxon (two related samples)	$p < 0.001$		$p = 0.027$		$p < 0.001$		$p < 0.001$	
Mean no. cycles/phase	41.6	64.7	30.6	44.6	46.8	46.6	36.9	30.61
Mean no. cycles/phase egr+ingr	53.2		37.6		46.7		33.8	
Standard deviation	5.2	11.5	7.4	14.4	6.8	3.6	6.1	3.5
Maximal no. phases/cycle	51	86	45	69	65	52	78	41
Minimal no. cycle/phase	25	29	22	21	37	38	20	15
Δ *t* test (paired-samples, two-tailed)	$p < 0.001$		$p = 0.005$		$p = 0.867$		$p < 0.001$	
Δ Wilcoxon (two related samples)	$p < 0.001$		$p = 0.027$		$p = 0.982$		$p < 0.001$	
Mean fundamental frequency (Hz)	20.9	23.4	20.5	22.0	19.3	22.1	20.3	21.9
Mean frequency egr+ingr (Hz)	22.1		21.2		20.7		21.1	
Standard deviation	2.0	1.1	2.35	1.27	1.25	1.36	1.14	0.81
Highest fundamental frequency	26.7	25.8	24.4	24.2	22.3	28.3	23.5	23.3
Lowest fundamental frequency	16.7	18.3	17.3	20.9	16.2	20.8	17.8	16.7
Δ *t* test (paired-samples, two-tailed)	$p < 0.001$		$p = 0.077$		$p < 0.001$		$p < 0.001$	
Δ Wilcoxon (two related samples)	$p < 0.001$		$p = 0.093$		$p < 0.001$		$p < 0.001$	

However, Moelk does not provide detailed information as to how the egressive and ingressive phases were identified, although she mentions that she relied on “visual evidence”; (ibid.:187), so this must remain speculative.

Finally, given Aisha’s agitated state, only 16 phases in total could be reliably analyzed, and without an analysis of relaxed purring it is not possible to make any far-reaching conclusions as to potential differences concerning amplitude.

Phase Durations

Egressive phases were longer in Aiko and Aisha, while the opposite was true for Kiki and Samira. The limited number of phases obtained from Aisha makes her results less reliable. Eklund, Peters & Duthie (2010) observed longer egressive phases while Schötz & Eklund (2011) reported longer ingressive phases. The combined results clearly indicate that relative phase duration shows individual variation.

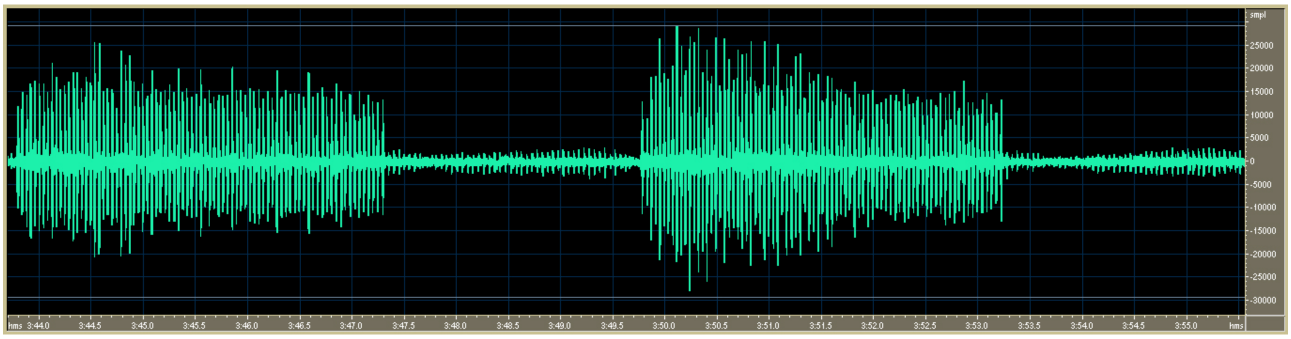

Figure 1. Purring waveform (Aiko). Egressive–Ingressive–Egressive–Ingressive. Duration 11.9 seconds.

Cycles Per Phase

As was the case with phase duration, there was considerable individual variation in the number of cycles that was produced during the phases. While Aiko and Aisha both had significantly more cycles during egressive phases, which is in agreement with Eklund, Peters & Duthie (2010), Samira showed the opposite behaviour. Kiki produced an equal number of cycles during both phases.

Fundamental Frequency

Fundamental frequency was lower in ingressive phases for all cheetahs; Aisha's limited data (N=16 phases) weakly approached significance. These observations are in agreement with the results reported in Eklund, Peters & Duthie (2010), Volodina (2000:S371) and Frazer Sissom, Rice & Peters (1991:70).

Pairwise comparisons in mean fundamental frequency revealed no significant differences between the cheetahs ($p < 0.001$, two-tailed).

Discussion and Conclusions

Comparing our results with the literature, it would seem that ingressive phases tend to have a lower fundamental frequency in the cheetah, while egressive phases tend to be louder. The other parameters examined seem to be subject to invidual variation.

Although the purring data obtained from Aisha is limited, it still hints at variation as a function of whether or not the animal is relaxed or agitated, although future corroboration is needed to verify this possibility.

Acknowledgements

Thanks to Dr Rudie and Marlice Van Vuuren at the N/a'an ku sê Foundation, Windhoek, Namibia (**www.naankuse.com**). Also thanks to Miriam Oldenburg for still photography.

References

Driscoll, C. A., J. Clutton-Brock, A. C. Kitchener & Stephen J. O'Brien (2009) The taming of the domestic cat. *Scientific American*, June 2009, 68–75.

Eklund, R., G. Peters & E. D. Duthie (2010) An acoustic analysis of purring in the cheetah (*Acinonyx jubatus*) and in the domestic cat (*Felis catus*). In: *Proceedings of Fonetik 2010*, Lund University, 17–22.

Frazer Sissom, D. E., D. A. Rice & G. Peters (1991) How cats purr. *Journal of Zoology* 223:67–78.

Hemmer, H. (1972) Uncia uncia. *Mammalian Species* 20:1–5.

Hunter, L. & C. Hamman (2003) *Cheetah*. Cape Town, South Africa: Struik Publishers.

Johnson, W. E. E. Eizirik, J. Pecon-Slattery, W. J. Murphy, A. Antunes, E. Teeling & S. J. O'Brien (2006) The Late Miocene Radiation of Modern Felidae: A Genetic Assessment. *Science* 311:73–77.

Moelk, Mildred. (1944) Vocalizing In The House-Cat; A Phonetic And Functional Study. *The American Journal of Psychology* 57(2):184–205.

O'Brien, S. J. & W. E. Johnson (2007) The Evolution of Cats. *Scientific American*, July 2007, 68–75.

Owen, R. (1834/1835) On the Anatomy of the *Cheetah, Felis jubata*, Schreb. *Transactions of the Zoological Society of London* 1:129–137.

Peters, G. (2002) Purring and similar vocalizations in mammals. *Mammal Review* 32(4):245–271.

Schötz, S. & R. Eklund (2011) A comparative acoustic analysis of purring in four cats. In: *Quarterly Progress and Status Report TMH-QPSR, Volume 51, 2011. Proceedings from Fonetik 2011*. Royal Institute of Technology, Stockholm, 9–12.

Sunquist, M. & F. Sunquist (2002) *Wild Cats of the World*. Chicago: Univ. of Chicago Press.

Volodina, E. (2000) Vocal Repertoire of Cheetah *Acinonyx jubatus* (Carnivora, Felidae) in Captivity: Sound Structure and Search of Means of Assessing the State of Adult Animals. *Entomological Review* 80, Supplement 2, S368–S378.

Weissengruber, G. E., G. Forstenpointner, G. Peters, A. Kübber-Heiss & W. T. Fitch (2002) Hyoid apparatus and pharynx in the lion (*Panthera leo*), jaguar (*Panthera onca*), tiger (*Panthera tigris*), cheetah (*Acinonyx jubatus*) and domestic cat (*Felis silvestris* f. *catus*). *Journal of Anatomy* 201:195–209.

Proceedings

FONETIK 2012

The XXVth Swedish Phonetics Conference

May 30–June 1, 2012

UNIVERSITY OF GOTHENBURG
PHILOSOPHY, LINGUISTICS & THEORY OF SCIENCE

Proceedings FONETIK 2012
The XXVth Swedish Phonetics Conference,
held at University of Gothenburg, May 30–June 1, 2012
Edited by Anders Eriksson and Åsa Abelin
Department of Philosophy, Linguistics and Theory of Science
University of Gothenburg
Box 200, SE 405 30 Gothenburg

ISBN 978-91-637-0985-2

Printed by Reprocentralen, Humanisten, University of Gothenburg.