An acoustic analysis of purring in the cheetah (*Acinonyx jubatus*) and in the domestic cat (*Felis catus*)

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Abstract
This paper analyses purring in a cheetah and a domestic cat from an acoustic point of view. The results are discussed in the light of previously published studies.

Introduction

The domestic cat is one of the most popular pet animals in the world, and virtually everyone is familiar with its trademark "purring" sound. Less known is that most other felids (cats) also purr, some relatively loudly. This paper will describe purring in the domestic cat, and compare that with purring in one of the biggest purrers, the cheetah.

Felids: an overview

Felids are among the most successful carnivores ever to develop within the mammal lineage. The number of felid species varies between the sources, and different attempts of classifications have been made based on morphology, behavior and genetics, but the number of species normally lies in the range of 35 to 40 species (Wilson & Reeder, 2005; Sunquist & Sunquist, 2002).

Almost all of the wild cats are considered endangered today (*IUCN Red List*).

The domestic cat

The domestic cat (*Felis catus*, Linneaus 1758) is by far the most well-known cat, and with an estimated number of 600 million individuals worldwide (Driscoll et al., 2009) it far outnumbers all its relatives. It was long believed that the cat was first domesticated in ancient Egypt around 3600 years ago, but recent evidence suggests that domestication took place much earlier, perhaps 10,000 years ago, in the Fertile Crescent. The closest relative of the domestic cat is considered to be the African (Middle Eastern) wildcat (*F. silvestris lybica*) (Driscoll et al., 2007; Driscoll et al., 2009). Today around 60 breeds of domestic cats are recognized (Menotti-Raymond et al., 2008).

Although varying considerably in size and weight, a domestic cat normally weighs between 4 and 5 kilos, and is around 25 centimeters high and 45 centimeters long. Males are significantly bigger than females, and are on average 20% heavier than are females (Pontier, Rioux & Heizmann, 1995).

The cheetah

The cheetah (*Acinonyx jubatus*, Schreber 1776) is probably best known for being the fastest land animal in the world with an estimated top speed of around 105–110 km/h (Sharp, 1997; Sunquist & Sunquist, 2002, p. 23).

The cheetah is roughly the same size as a leopard (*Panthera pardus*) – with which it is most 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 running down its eyes and has short fur. Cubs are also characterized by a pronounced mane at the nape and shoulders, which to some extent can persist into adulthood. The cheetah's claws are only weakly retractile, a rare trait in felids, shared only with only three other species of cat, the fishing cat (*Prionailurus viverrinus*), the flat-headed cat (*P. planiceps*) and the Iriomote cat (*P. iriomotensis*) (Leyhausen & Pfleiderer, 1999).

Sexual dimorphism is not very pronounced in the cheetah. A male cheetah weighs 29–65 kg, a female 21–63 kg. A male is 172–224 cm nose-to-tail, a female 170–236 cm. A male has a shoulder height of 74–92 cm, and a female 67–84 cm (Hunter & Hamman, 2003).

A major characteristic of the cheetah is the lack of genetic variation (O'Brien et al., 1985), most likely due to a near-extinction event during the late Pleistocene (c. 10,000–12,000 years ago), when all but a handful of cheetahs went extinct – along with a large number of large mammals (Menotti-Raymond & O'Brien, 1993). Modern cheetahs show an extremely high frequency of spermatozoal abnormalities, and infant mortality is high (O'Brien et al., 1987).

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

Around 1900 the population of wild cheetahs was estimated to be around 100,000 (Marker-Kraus, 1997) while the estimated number of wild cheetahs today is around 4000 (Sunquist & Sunquist, 2002, p. 30).

For further information on the cheetah the reader is referred to Sunquist & Sunquist (2002, pp. 19–36) and Krausman & Morales (2005).

Previous research

This section summarizes previous research on egressive–ingressive phonation and purring.

Egressive–ingressive phonation

Although most vocalization in mammals and humans occurs on a pulmonic egressive airstream, pulmonic *ingressive* phonation is not uncommon, both in human speech and phonation and in animal phonation (Eklund, 2008), an example of which being felid purring.

Purring

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) and was definitely introduced by Pocock (1916), 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, 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 two cat species studied here, the domestic cat and the cheetah, belong 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) decidedly 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*) – with completely ossified hyoids – together with the five cat species in which it is incompletely ossified.

Data collection

Data were collected from two felids, one domestic cat, and one cheetah. The animals, the equipment and data post-processing are described in the following paragraphs.

Equipment

Both animals were recorded with the same equipment. A Canon HG-10 high-definition video camera was used with an external professional high-fidelity Audiotechnica AT813 cardoid-pattern, condenser mono microphone.

Moreover, a long extension cord was used so as to permit video capture from a distance and avoid the risk of the camera constituting a disturbing factor for the animals.

Plate 1. Cheetah data collection. Third author operated a high-definition camcorder while first author adjusted the microphone to different positions relative to the cheetah's muzzle. Egressive–ingressive phonation was synchronized for sound-only version by keeping the hand on the side of the animal's chest while saying "in" and "out" according to expanding (in-breath) or collapsing (out-breath) rib cage. Film available at http://purring.org

Cheetah data

The cheetah (Caine) was a male, 7 years old at the time of the recording (11 December 2009) and weighing 67.5 kilos (i.e. an exceptionally big cheetah). He was recorded in his enclosure at Dell Cheetah Centre, next to his shelter, in a setting very familiar to the animal. Caine is a constant purrer, and also a very loud purrer, and can easily be heard at a distance of more than 40 meters in an outdoor setting with background noises. Video duration was 1m55s. Film captures and a detailed description of the data collection are given above in *Plate 1*.

Domestic cat data

The domestic cat (Misha) was a female, 14 years old at the time of the recording (31 January 2010) and weighing 3.7 kilos. She was recorded in her home, with her owner holding and caressing her to elicit purring, in a setting Misha was used to. The recording procedures were similar to the ones described above, with the exception that the first author operated the video camera, and that good video footage was not obtained (nor aimed for). Except for a slight background noise from a radiator, the room was silent at the time of recording. Video duration was 1m47s.

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 analysed with Cool Edit, and both waveform and spectrogram analyses were carried out with WaveSurfer. In order to create discernible waveforms, the sound files were amplified with the *Amplify* function in Cool Edit.

In order to obtain number of respiratory cycles per phase and to calculate frequency, the number of respiratory cycles was counted manually from the waveform.

Statistics were calculated with SPSS 12.0.1.

Egressive–ingressive identification

The first analysis that was carried out was to ascertain that the egressive and ingressive phases were correctly identified in both animals. This was done by locating the parts of the recording sessions – in both the audio and video files – when the first author said the words "in" and "out" while holding his hand on the side of the chest of the animals, in synchrony with the breathing, as described in the *Plate 1* caption above. Identification proved completely unproblematic, and the rest of the files were labeled on the basis of sound and waveform characteristics.

Amplitude

It was reported by Frazer Sissom, Rice & Peters (1991) that purring is strongest right in front of muzzle, showing that the purring sound emanates from the mouth and nose. This was confirmed in both cases in that the strongest signal was obtained by holding the microphone right in front of the animals' muzzles.

Some previous sources report that ingressive phases are louder than egressive phases, e.g. Moelk (1944) and Peters (1981).

Table 1. Summary Table. For both the cheetah and the domestic cat results are given for durations, cycles per phase, and frequency. Results are presented independently for egressive and ingressive phases, and statistical tests are performed on differences between egressive and ingressive phonation.

	Cheetah		Domestic cat	
Phonation type	Egressive	Ingressive	Egressive	Ingressive
No. phases analysed	20	20	16	16
Mean duration (ms)	3049	2491	576	573
Mean duration egressive+ingressive	2770		575	
Standard deviation	270	294	90	72
Maximal duration	3450	2900	700	740
Minimal duration	2400	2000	360	450
Δ *t* test (paired-samples, two-tailed)	$p < 0.000$		$p = 0.926$	
Δ Wilcoxon (two related samples)	$p < 0.000$		$p = 0.615$	
Mean no. cycles/phase	63.45	45.35	12.43	13.19
Mean no. cycles/phase egressive+ingressive	54.4		12.8	
Standard deviation	4.83	3.50	1.21	1.64
Maximal no. phases/cycle	70	53	15	15
Minimal no. cycle/phase	53	40	10	10
Δ *t* test (paired-samples, two-tailed)	$p < 0.000$		$p = 0.118$	
Δ Wilcoxon (two related samples)	$p < 0.000$		$p = 0.071$	
Mean fundamental frequency (Hz)	20.87	18.32	21.98	23.24
Mean frequency egressive+ingressive (Hz)	19.6		22.6	
Standard deviation	1.34	1.37	3.36	3.58
Highest fundamental frequency	23.0	20.0	30.5	28.8
Lowest fundamental frequency	17.1	16.2	17.1	18.2
Δ *t* test (paired-samples, two-tailed)	$p < 0.000$		$p = 0.418$	
Δ Wilcoxon (two related samples)	$p = 0.001$		$p = 0.427$	

This was not confirmed in either of the two species of felid here. The egressive phases were clearly louder in the cheetah, while they were roughly equal in amplitude in the domestic cat, as is shown in *Figure 1a* and *Figure 1b*.

Cycles per phase

The number of cycles per egressive and per ingressive phase was much higher in the cheetah than in the domestic cat.

Phase durations

Phase durations were much longer in the cheetah than in the domestic cat. While the egressive and ingressive phases were roughly the same length in the domestic cat, egressive phases were significantly longer in the cheetah.

Phonation and frequency

Phonation in both animals was relatively regular, and not as noisy as described in some of the previous reports on purring, e.g. Frazer Sissom, Rice & Peters (1991, p. 76).

The transitions between egressive and ingressive phases were short in both animals, with durations in the range of 50–200 ms in the cheetah, and 30–50 ms in the domestic cat. Transitions from egressive to ingressive phonation for both the cheetah and the domestic cat are shown in *Figure 2*.

Turning to fundamental frequency, both animals purr well below the lowest note on the piano. Given a weight difference between the two animals with almost a factor twenty, the observation that the two animals are very close in fundamental frequency might perhaps seem somewhat surprising, but it is well established that fundamental frequency can be an unreliable predictor of body weight/size in mammals (Ey, Pfefferle & Fischer, 2007).

Discussion

Our results show that egressive phases in the cheetah are louder and longer (air is expelled slower than inhaled) than ingressive phases.

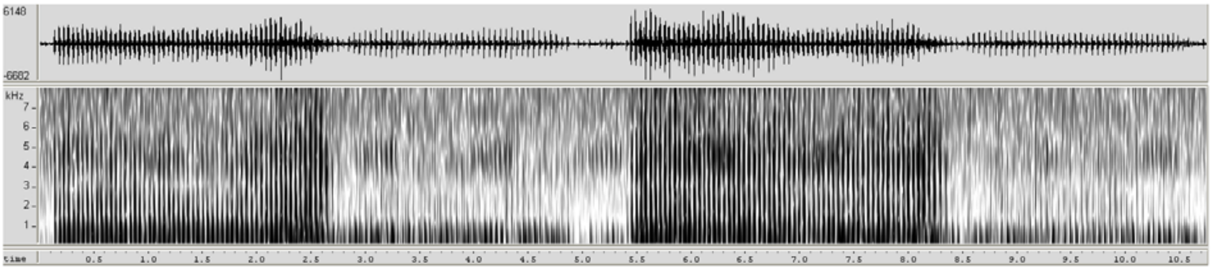

Figure 1a. Waveform and spectrogram of cheetah purring. Egressive–Ingressive–Egressive–Ingressive phases. Hamming window. Window duration 10.5 seconds.

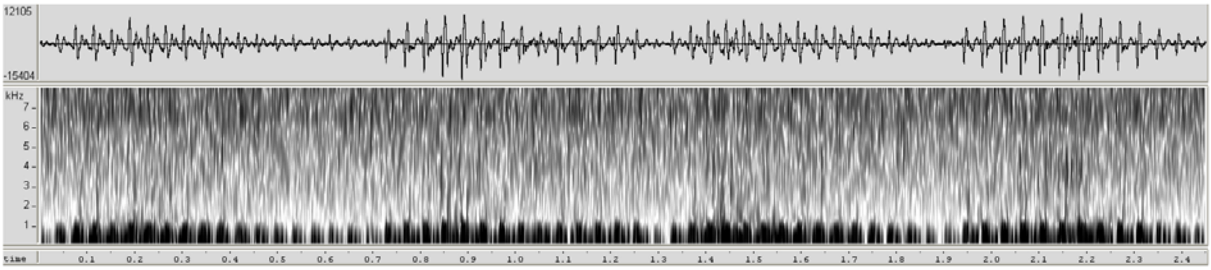

Figure 1b. Waveform and spectrogram of domestic cat purring. Egressive–Ingressive–Egressive–Ingressive phases. Hamming window. Window duration 2.4 seconds.

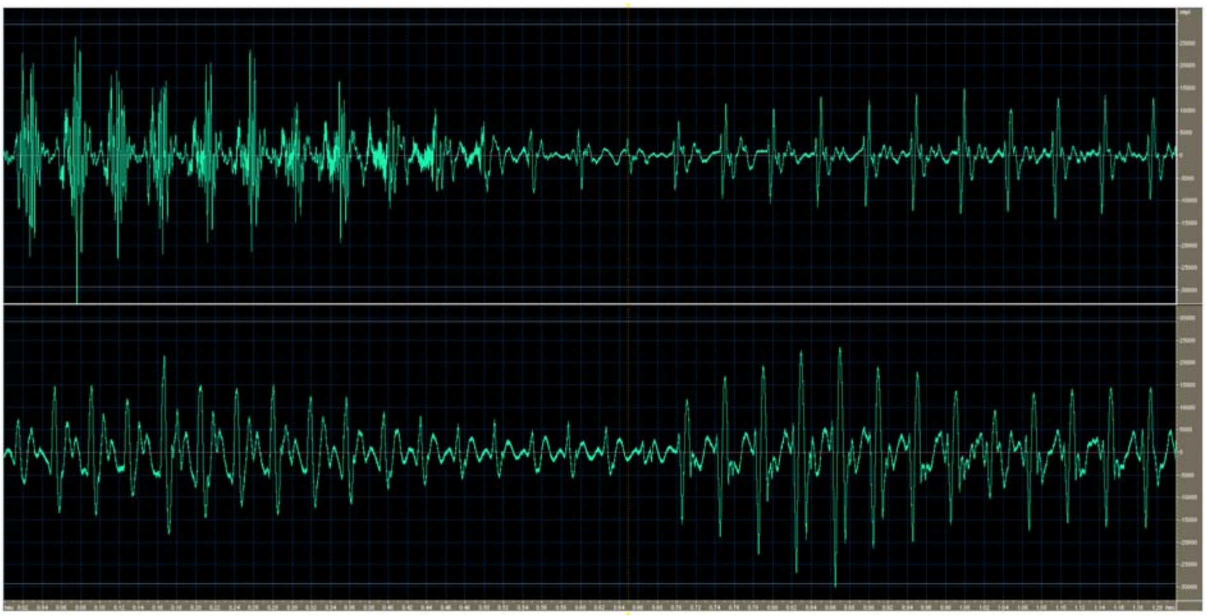

Figure 2. Waveforms showing transitions from egressive (left half) and ingressive (right half) phases of purring in both cheetah (upper waveform) and domestic cat (lower waveform). Window duration 1.2 seconds.

One possible explanation for this is that there might be some physiological asymmetry in the vocal organs involved, creating louder vibration in one direction than the other. This was shown to be case for human beings, by e.g. Catford (1988, p. 57) who pointed out that the asymmetrical shape of the glottis makes egressive phonation very different from ingressive phonation in human speech.

Our observation that egressive phases in the cheetah are louder then ingressive phases is contrary to the results presented in Peters (1981), and that there is no palpable difference in amplitude in the domestic cat at least does not confirm Moelk (1944) who also claimed that ingressive phases were louder. While the latter perhaps can be explained on a purely impressionistic basis in that ingressive phases indeed might sound louder in the domestic cat (due to their “harsher” sound quality), the observed differences between our results for the cheetah and some of the previous reports on felid purring (Frazer Sissom et al., 1991; Peters, 2002) in respect of relative amplitude of egressive and ingressive phases and their respective frequency components warrants further research.

Conclusions

The analyses in this paper both confirmed and differed from some of the previously published reports on purring in felids. Whether this hints at species or individual differences can only be answered by further analyses of felid purring.

Web resources

Data files are available at http://purring.org

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