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A comparative acoustic analysis of purring in four cats

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Abstract

This paper reports results from a comparative analysis of purring in four domestic cats. An acoustic analysis describes sound pressure level, duration, number of cycles and fundamental frequency for egressive and ingressive phases. Significant individual differences are found between the four cats in several respects.

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. Contrary to what might be believed, it is not known exactly how purring is produced, and there is a surprising lack of studies of purring, even descriptive.

This paper compares a number of acoustic characteristics of purring in four domestic cats, with focus on sound pressure level, duration, number of cycles and fundamental frequency of ingressive and egressive phases.

The domestic cat

There are 35 to 40 felid species in the world today (Sunquist & Sunquist, 2002), and the domestic cat (*Felis catus*, Linneaus 1758) is by far the most well-known and common cat with an estimated number of 600 million individuals (Driscoll et al., 2009). It was long suggested that the cat was first domesticated in ancient Egypt around 3600 years ago, but it is now believed that domestication took place 10,000 years ago in the Fertile Crescent. The closest relative of the domestic cat is considered to be the African 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).

Purring

As mentioned above, it is not known exactly how purring is produced, and the term as such has been used quite liberally in the literature. In a major review paper Peters (2002) employed a strict definition of purring as a continuous sound produced on alternating (pulmonic) egressive and ingressive airstream. Given this definition, purring is only found in the "purring cats" (i.e. all felids but the non-purring/"roaring cats" lion, tiger, jaguar, leopard; whether or not the non-roaring snow leopard can purr remains unsettled) and in the Genet.

A number of different purring theories are found in the literature. McCuiston (1966) suggested that purring was hemodynamic and that the sound consequently emanated from the bloodstream running through the thorax. This theory was proven wrong by Stogdale & Delack (1985). Moreover, both Frazer Sissom, Rice & Peters (1991) and Eklund, Peters & Duthie (2010) reported that purring maximum amplitude occurs near the mouth and nose. It has recently been suggested that purring "is caused by rapid twitching of the vocalis muscle, whereas the large pads within the vocal folds of *Pantherinæ* might impede rapid contractions of this muscle and thus make it difficult to purr" (Weissengruber et al., 2008:16; see also Weissengruber et al., 2002).

Contrary to what is often believed, cats do not exclusively purr when they are content, but also when they are hungry, stressed, in pain or close to dying, and behaviourists have suggested that the function purring serves is to signal that the cat does not pose a threat (Eldredge, Carlson & Carlson, 2008:297).

Previous research

There is a surprisingly small number or papers devoted to felid purring, and several of these papers are also impressionistic in character. One of the first papers exclusively devoted to purring the domestic cat was Moelk (1944), but the focus of her paper is a classification of different kinds of purr and how they are used, and no acoustic analysis is presented.

Frazer Sissom, Rice & Peters (1991) reported that domestic cats purr at a frequency of 26.5 Hz, while Eklund, Peters & Duthie (2010) reported the figure 22.6 Hz.

Remmers & Gautier (1972:359) reported that egressive phases in purring cats had a duration of 730 ms, while ingressive phases had a duration of 690 ms.

Data collection

Continuous calm purring was collected from the four domestic cats Donna (D; female, age 6 months, 3.0 kilos), Rocky (R; male, 6 months, 3.6 kilos), Turbo (T; male, 6 months, 3.6 kilos), and Vincent (V; male, 16 years, 5.2 kilos).

All cats were recorded in a quiet home environment using a Sony DCR-PC100E digital video camera recorder with an external Sony ECM-DS70P electret condenser stereo microphone. This microphone is small in size, and could easily be held close to the muzzle without scaring or disturbing the cat.

Figure 1 shows the microphone positions during the recording sessions with the four cats.

Videos are available at **http://purring.org**

Figure 1. The microphone positions of all four cats during data collection.

To be able to identify egressive and ingressive phases in the recorded audio files, the first author kept her hand on the side of the cats' chests during the recording session while saying the words "in" and "out" according to the expanding (in-breath) or collapsing (out-breath) rib cage several times during the recording sessions.

Method

Data post-processing

All videos were transferred to iMovie, and audio files (wav, 44.1 kHz, 16 bit, mono) of about 70 seconds for each cat were extracted with Extract Movie Soundtrack. The waveforms were normalised for amplitude with Audacity, and low-pass filtered copies were created with Praat (10–40 Hz, smoothing at 10 Hz). These copies were used together with the original normalised waveform, spectrogram and Praat's pitch analysis to facilitate manual segmentation and counting of respiratory cycles per phase.

Figure 2 shows an example of the manual segmentation in Praat.

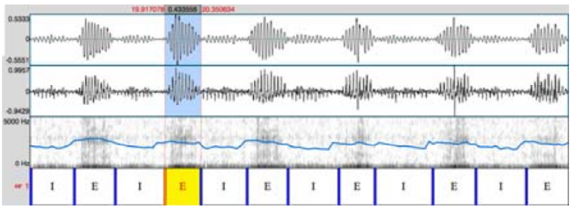

Figure 2. Manual segmentation of ingressive (I) and egressive (E) phases in Praat using the low pass filtered (top pane) and original (mid pane) waveforms as well as the original spectrogram and pitch contour (bottom pane).

The respiratory cycles per phase were labeled manually from the waveforms and counted with a Praat script. *Figure 3* shows an example of the procedure.

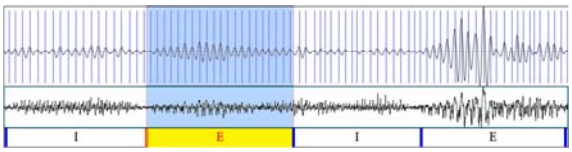

Figure 3. Manual labelling of cycles (pulses) per ingressive (I) and egressive (E) phases in Praat using the low pass filtered (top pane) and original (mid pane) waveform.

Egressive–ingressive identification

In order to ascertain that the egressive and ingressive phases were correctly identified, the parts of the recordings where the first author said "in" and "out" were located. Phases were then easily identified based on their distinct sound and waveform characteristics.

Analyses

Analyses were carried out with Praat. Statistics were calculated with SPSS 12.0.1.

Table 1. Summary Table. For all four cats results are given for sound pressure level (SPL), durations, cycles per phase, and fundamental frequency. Results are presented independently for egressive and ingressive phases, and statistical tests are performed on differences between egressive and ingressive phonation.

	Donna (D)		**Rocky (R)**		**Turbo (T)**		**Vincent (V)**	
Phonation type	Ingressive	Egressive	Ingressive	Egressive	Ingressive	Egressive	Ingressive	Egressive
No. phases analysed	39	39	40	40	61	61	61	61
Mean SPL (dB)	72.4	74.6	72.14	71.93	70.66	76.43	71.85	71.72
Mean SPL (dB) egr+ingr	73.48		72.03		73.52		71.78	
Standard deviation	0.8209	1.2974	0.9614	1.7693	1.96	3.20	1.0661	1.6260
Δ *t* test (paired-samples, two-tailed)	$p < 0.001$		$p = 0.427$		$p < 0.001$		$p = 0.426$	
Δ Wilcoxon (two related samples)	$p < 0.001$		$p = 0.249$		$p < 0.001$		$p = 0.224$	
Mean duration (ms)	673	587	819	756	604	511	511	484
Mean duration egr+ingr	632		788		558		498	
Standard deviation	120.80	82.70	169.23	130.05	58.90	45.09	85.10	69.72
Maximal duration	921	838	1038	997	773	634	719	614
Minimal duration	413	443	432	365	480	419	319	266
Δ *t* test (paired-samples, two-tailed)	$p < 0.001$		$p = 0.011$		$p < 0.001$		$p = 0.010$	
Δ Wilcoxon (two related samples)	$p < 0.001$		$p = 0.013$		$p < 0.001$		$p = 0.004$	
Mean no. cycles/phase	16.58	15.95	21.28	20.15	13.92	12.46	13.41	13.16
Mean no. cycles/phase egr+ingr	16.31		20.72		13.19		13.3	
Standard deviation	1.41	2.25	4.33	3.56	1.99	1.20	2.52	1.93
Maximal no. phases/cycle	22	22	29	28	21	15	18	17
Minimal no. cycle/phase	10	12	11	10	10	10	9	7
Δ *t* test (paired-samples, two-tailed)	$p = 0.178$		$p = 0.090$		$p < 0.001$		$p = 0.437$	
Δ Wilcoxon (two related samples)	$p = 0.132$		$p = 0.073$		$p < 0.001$		$p = 0.456$	
Mean fundamental frequency (Hz)	24.63	27.21	26.09	26.64	23.00	24.43	23.45	20.94
Mean frequency egr+ingr (Hz)	25.94		26.36		23.72		22.2	
Standard deviation	1.14	1.82	2.08	1.24	1.85	1.45	3.62	2.14
Highest fundamental frequency	27.5	33.2	33	29	27	28	28.8	24
Lowest fundamental frequency	21.6	24.2	23	24	19	20	18.2	17.1
Δ *t* test (paired-samples, two-tailed)	$p < 0.001$		$p = 0.174$		$p < 0.001$		$p < 0.001$	
Δ Wilcoxon (two related samples)	$p < 0.001$		$p = 0.067$		$p < 0.001$		$p = 0.002$	

Results

Summary results are presented in *Table 1* above.

I. Intracat analyses

We first analysed within-cat variation.

Amplitude

The normalised waveforms were used to extract the mean relative amplitude (SPL) in each ingressive and egressive phase for comparisons within each cat.

Mean relative SPL as derived from the normalised waveforms varied between 70.66 dB (T) and 72.4 (D) in the ingressive phase and between 71.72 (V) and 76.43 (T) in the egressive phase. For two of the cats (D/T), mean SPL was significantly higher in the egressive phases than in the ingressive ones, in contrast with Moelk (1944) and Peters (1981). However, no difference in mean SPL was observed for the other two cats (R/V).

Duration

Mean durations of the phases varied considerably between the four cats, ranging from 511 ms (V) to 819 ms (R) in the ingressive phase, and from 484 ms (V) to 756 ms (R) in the egressive phase.

Ingressive phases were significantly longer than egressive ones in all four cats, contrary to the results reported in Remmers & Gautier (1972:359).

Cycles per phase

The mean number of cycles per phase varied between 13.41 (V) and 21.28 (R) for ingressive phases and between 12.46 (T) and 20.15 (R) for egressive phases.

For all cats, the mean number of cycles per ingressive phase were higher than it was per egressive phase, thus replicating the results reported in Eklund, Peters & Duthie (2010) .

Fundamental frequency

All four cats showed fundamental frequencies that compare well to previous studies (Frazer Sissom, Rice & Peters, 1991; Eklund, Peters & Duthie, 2010). For the ingressive phase, mean F_0 ranged from 23.00 Hz (T) to 26.09 Hz (R), while the values for the egressive phase ranged from 20.94 Hz (V) to 27.21 Hz (D). Two of the cats (D/T) had significantly higher F_0 for the egressive phase as compared to the ingressive phase. One cat (V) showed the opposite pattern with significantly higher F_0 in the ingressive phase, while no significant difference was found for one cat (R).

II. Intercat analyses

Having performed within-cat analyses, we then turned to between-cat analyses. No intercat analyses of sound pressure level were performed since these were seriously affected by individual microphone positioning. All significance tests referred to are *t* tests (two independent samples, equal variances assumed, two-tailed).

Duration

All pair-wise comparisons revealed significant differences ($p < 0.001$) with the exception of T/V egressive duration ($p = 0.012$).

Cycles per phase

All pair-wise comparisons revealed significant differences ($p < 0.001$) with the exception of T/V number of ingressive cycles ($p = 0.305$) and number of egressive cycles ($p = 0.017$).

Fundamental frequency

All pair-wise comparisons revealed significant differences ($p < 0.001$) with the exception of D/V ingressive frequency ($p = 0.052$), T/V ingressive frequency ($p =$ 0.393) and D/R egressive frequency ($p = 0.111$). With regard to combined fundamental frequency, all pairwise comparisons were significantly different with the exception or D/R ($p = 0.127$).

Discussion

To the best of our knowledge, this paper constitutes the first comparative and quantitative report of purring in domestic cats. As was the case in Eklund, Peters & Duthie (2010), previous research was both confirmed and contradicted. The lack of quantified reports in the literature makes far-reaching conclusions difficult, but our results hint at a certain degree of variation between individual cats in how purring is manifested, even if overall figures lie within the same general range.

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