Agonistic vocalisations in domestic cats: a case study

Susanne Schötz
Dept. of Logopedics, Phoniatrics and Audiology, Lund University

Abstract
Introducing a new cat to a home with resident cats may lead to stress, aggression and even fights. In this case study 468 agonistic cat vocalisations were recorded as one cat was introduced to three resident cats in her new home. Six vocalisation types were identified: growl, howl, howl-growl, hiss, spit and snarl. Numerous other intermediate and complex vocalisations were also observed. An acoustic analysis showed differences within and between all types. Future studies include further acoustic analyses of cat vocalisations produced by a larger number of cats.

Introduction
The cat (*Felis catus,* Linneaus 1758) was domesticated about 10,000 years ago, and is now one of the most popular pets of the world with more than 600 million individuals (Driscoll et al., 2009; Turner & Bateson, 2000). Domestic cats have developed a more extensive, variable and complex vocal repertoire than most other members of the Carnivora, which can be explained by their social organisation, their nocturnal activity and the long period of association between mother and young (Bradshaw, 1992). Still, we know surprisingly little about the phonetic characteristics of these sounds. The few existing studies of cat vocalisations report findings from only a limited number of cats, vocalisation types, or methods (e.g. Moelk, 1944; Brown et al., 1978; McKinley, 1982; Shipley et al., 1988, 1991; Farley et al., 1992, Nicastro & Owren 2003, Yeon et al., 2011).

Cat vocalisations are generally divided into three categories: sounds produced with the mouth closed, sounds produced with an opening–closing mouth, and sounds produced with the mouth held tensely open (Moelk, 1944; McKinley, 1982). Many previous studies have focused on purring, on human– or prey–directed cat sounds or on kitten vocalisations (e.g. Moelk, 1944; Brown et al., 1978; Nicastro & Owren 2003; Eklund et al., 2010). There are few studies on agonistic sounds. Yeon et al. (2011) found that non-socialised cats produced far more aggressive and defensive calls than socialised cats. Brown et al. (1978) studied mother-kitten interaction and found that kittens produced howls and growls at about 3-4 weeks of age, and hissing and spitting around the age of 30 days.

The main purpose of this study was to learn more about the acoustic-phonetic characteristics of agonistic cat vocalisations. In earlier studies, I have recorded and analysed only non-agonistic vocalisations of my own cats (Schötz & Eklund, 2011, Schötz, 2012, 2013, Schötz & van de Weijer, 2014). However, an opportunity to record agonistic sounds came when I introduced my new cat to my three previous cats. In this small case study I wanted to find out 1) what agonistic sounds the cats produced, 2) what types were the most frequent ones, and 3) what their acoustic-phonetic features in terms of duration, F_0 and spectral centroid were.

Agonistic cat vocalisations
Vocal communication between cats is largely restricted to three types of interactions; mother-young, sexual and agonistic. Agonistic sounds are aggressive and defensive sounds used to warn, shock or startle an intruder or attacker. Most agonistic sounds are strained-intensity calls, produced while the cat is tensing its whole body in preparation for a fight. They are often used in combination with visual body posture signals, both attempting to persuade an opponent that the cat is bigger than it really is. For instance, cats can combine a low pitched growl or a long yowl with drawing themselves up to their full height, turning partially sideways and making their hair stand on end (Bradshaw & Cameron-beaumont, 2000). Several types of agonistic sounds have been described in earlier literature, including the growl, the howl, the snarl, the hiss, and the spit.

Growl

The growl is a guttural, harsh, regularly and rapidly pulse-modulated, low-pitched (100-225 Hz) sound of usually long duration. It is produced during a slow steady exhalation while the mouth is held slightly open in the same position (Moelk, 1944; McKinley, 1982; Bradshaw & Cameron-beaumont, 2000; Beaver, 2003; Eklund et al., 2012, Bradshaw, 2013). Brown et al. (1978:556) describe growls as largely fricative and long in duration. The growl is transcribed as [grrr..] with a vocalic [rrr...] or rhotic [ʌ], occasionally beginning with an [m] by Moelk (1944) and sounds a bit like a prolonged low pitched English alveolar approximant or retroflex produced with creaky voice; [ɹ̰]. It is mainly used to signal danger or to warn or scare off an opponent. Variations in duration and F_0 are common, and often the growl is either intertwined with howls/moans/yowls and hisses, or an intermediate vocalisation between e.g. a growl and a howl. Growls during a fight may vary between 400 and 800 Hz in F_0 (Houpt, 2004).

Howl, moan, yowl, anger wail

Howls, moans, yowls, or anger wails are long and often repeated vocalic warning signals usually produced by gradually opening the mouth wider and closing it again. During a threatening situation, they are often merged or combined with by growls in long sequences with slowly varying F_0 and intensity (Brown et al., 1978; Eklund et al., 2012). Moelk (1944) transcribes the anger wails [wɑːouː], with the vowel intensifying toward [æ], and points out that “[s]lighter wailing [...] occurs occasionally in connection with the growl in highly annoying situations which do not lead to fighting”. Brown et al. (1978:566) found howls to be tonal sounds occurring in threatening or defensive responses with a wide variation in frequency distribution and modulation. Moans are described by McKinley (1982) as long, often slowly frequency-modulated vowel sounds of “o” or “u” occurring in the same situations as the growls. Bradshaw & Cameron-beaumont (2000) distinguish howls from yowls in that howls are typically shorter in duration (howls: 0.8-1.5 s., yowls 3–10 s.), and higher in F_0 (howls: 700 Hz, yowls 200–600 Hz).

Snarl and pain shriek

Snarls and pain shrieks are loud, harsh and high-pitched vocalisations produced during active fighting (McKinley, 1982:13). Snarls are used to startle or scare an opponent, and are described by Moelk (1944) as “rapid inhalations harshly vocalised and marked by a heavy initial intake of breath and stopped suddenly with a slight [o] sound, [ˈœːo]”. Pain shrieks are short intense cries of tense vowels, often [æ], [ɛ] or [i], and are characterised by “great strain at mouth and throat and the force of breath” (Moelk, 1944).

Hiss and spit

Hissing and its more intense variation spitting are involuntary reactions to when a cat is surprised by an (apparent) enemy. The cat changes position with a startle and breath is being forced rapidly through the slightly open mouth before stopping suddenly; [fft!] (Moelk, 1944:194). McKinley (1982) describes the hiss as an “agonistic vocalization given with the mouth wide open teeth exposed, and sounding like a long exhalation”, and the spit as “a very short explosive sound, given in agonistic situations frequently before or after a hiss”.

Other sounds

Occasionally other sounds are produced in (apparent) agonistic situations. These include chirps, meows and chirrups. Cats usually chirp at birds or insects (prey), and dominant cats may chirp at the sight of an inferior or smaller cat. Meows can be produced during play with other cats, or if a situation is perceived as playful rather that threatening by one of the cats. Moreover, distinctive coaxing calls or chirrups may be used by tomcats to lure young or neutered males out of their homes to fight.

Method

Preparation and data collection

Vimsan (V, female, about 2 years old) was found outside our home injured in October 2014, and after recovering she was slowly introduced to the other cats of her new home. The first few weeks she was confined to an area of the house to which the other three cats Donna, Rocky and Turbo (D, R and T; 1 female, 2 males, all 4.5 year old siblings from the same litter) had no access. They were, however, slowly given increased opportunities to smell blankets and toys that had been used by the other cat(s), and then allowed into each others areas without the resident cat(s) being present, and after a week they were able to look at and smell each other through a narrow opening of a door. When V was let out to the other cats for the first time on November 13, 2014, I began recording the cats' vocalisations several hours every day and I continued for eight days until the cats had become so used to one another that they hardly used any agonistic vocalisations anymore.

The equipment consisted of a Sony HDR-CX730E video camera recorder with a Sony ECM-CG50 electret condenser shotgun microphone. Additional recordings were done with an Apple iPhone 3G. All recordings were transferred to a computer (Wave, 44,1 kHz/16 bit) for further analysis.

Table 1. The six agonistic vocalisation types recorded in the study.

Type	Descriptive term
Gr	*Growl*
Ho	*Howl, moan, yowl, anger wail*
HoGr	*Combination of howl(s) and growl(s)*
Hs	*Hiss*
Sn	*Snarl*
Sp	*Spit*

Table 2. Number of vocalisations of the four cats (D, R, T, V) by vocalisation type (for type descriptions, see Table 1).

Cat	*Gr*	*Ho*	*HoGr*	*Hs*	*Sn*	*Sp*	*Total*
D	13	175	114	38	3	22	*365*
R	2	47	1	4	0	2	*56*
T	13	2	4	7	0	1	*27*
V	3	6	0	5	4	2	*20*
Total	*31*	*230*	*119*	*54*	*7*	*27*	*468*

Preprocessing, categorisation and analysis

All recordings were transferred to a computer, and audio files (wav, 44.1 kHz, 16 bit, mono) extracted. The waveforms were normalised for amplitude and the vocalisations segmented and labelled in *Praat* (Boersma & Weenink, 2014). Out of 516 recorded vocalisations 48 were discarded as they were non-agonistic (chirps, meows), too weak in intensity or contained overlapping sounds. The remaining 468 agonistic vocalisations were categorised into six types (see Table 1) and used in the acoustic analysis. Measures of duration as well as of F_0 for the voiced sounds, and of centre of gravity (centroid or spectral mean) for the voiceless sounds were obtained with a *Praat* script and manually checked. The acoustic results were then further analysed and summarised using R (R Core Team, 2015). The six vocalisation types are listed in Table 1. Figure 1 and Table 2 display the number and proportion of vocalisations of each type by the four cats.

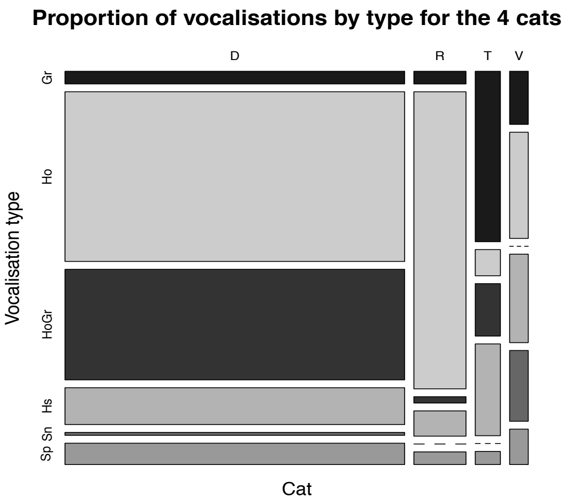

Figure 1. Mosaic plot of the proportions of the six vocalisation types growl *(Gr),* howl *(Ho),* howl-growl *(HoGr),* Hiss *(Hs),* Snarl *(Sn) and* Spit *(Sp) for the four cats (D, R, T, V).*

Results

D was by far the most vocal cat of this case study with a total of 365 vocalisations. R produced only 56, T 27 and V 20 sounds. Not all cats produced all six types of vocalisations. The most frequent vocalisation type was howl with 230 tokens, followed by howl-growl (119 tokens), hiss (54 tokens), growl (31 tokens), spit (27 tokens) and snarl (7 tokens). The results of the acoustic analysis of the six agonistic vocalisation types are described below. Median values were very close to mean values, and therefore only mean values are presented here.

Growl

The growls were often low [ɹ̥]-like sounds with fairly level F_0, around 70-200 Hz. Growls were produced as warnings as one cat came too close to one of the other cats. Some tokens seemed to be produced with falsetto voice quality with higher F_0. Durations varied between 0.83 and 4.46 sec, with an overall mean of 2.50 sec. These values, as well as individual values for each cat, are shown in Table 3. Figure 2 shows the waveform, broadband spectrogram and F_0 contour of a typical growl.

Table 3. Mean durations, as well as minimum, maximum and mean F_0 of growl (Gr).

Cat	*meanDur*	*minF_0*	*maxF_0*	*meanF_0*
D	2.27 s	128 Hz	475 Hz	285 Hz
R	1.15 s	70 Hz	78 Hz	73 Hz
T	2.77 s	46 Hz	482 Hz	283 Hz
V	3.25 s	70 Hz	99 Hz	79 Hz
All	*2.50 s*	*46 Hz*	*482 Hz*	*250 Hz*

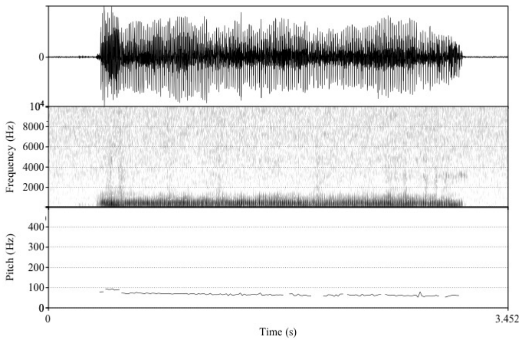

Figure 2. Example waveform, broadband (300 Hz) spectrogram and F_0 contour of growl (Gr).

Howl, moan, yowl, anger wail

The howls and similar sounds recorded in this case study varied in duration between 0.22 and 8.79 sec. They often displayed a tonal rising-falling pattern with an F_0 ranging from 128 to 842 Hz, and also varied in their vowel quality. Closed vowel qualities like [ɪ], [ɨ] or [ɤ] as well as diphthongs like [au], [ɛɔ] or [ɑo] were common, but also semivowel qualities were observed. Howls were uttered as warnings and often accompanied by growls and howl-growls in long sequences of repetitions as one cat had moved too close to an opponent. Figure 3 displays the waveform, broadband spectrogram and F_0 contour of an example howl, and numeric values for this type are shown in Table 4.

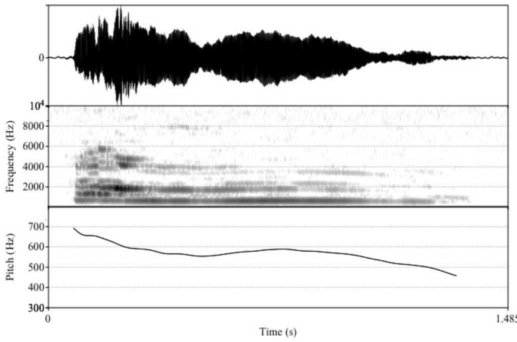

Figure 3. Example waveform, broadband (300 Hz) spectrogram and F_0 contour of howl (Ho).

Table 4. Mean durations, as well as minimum, maximum and mean F_0 of Howl (Ho).

Cat	*meanDur*	*minF_0*	*maxF_0*	*meanF_0*
D	2.27 s	128 Hz	692 Hz	285 Hz
R	1.82 s	241 Hz	797 Hz	624 Hz
T	0.87 s	263 Hz	579 Hz	367 Hz
V	1.64 s	603 Hz	842 Hz	769 Hz
All	*1.90 s*	*143 Hz*	*907 Hz*	*684 Hz*

Howl-growl combinations and transitions

Combinations of howls and growls were produced mainly by D in this case study, although R and T uttered a few tokens of this type. These sounds were used in similar contexts as growls and howls, and were between 1.30 and 9.47 sec. in duration. F_0 typically increased and decreased with the transitions from howl to growl and ranged between 56 and 974 Hz. Figure 4 shows a typical howl-growl example, and Table 5 displays the numeric values for the acoustic analysis of this vocalisation type.

Table 5. Mean durations, as well as minimum, maximum and mean F_0 of howl-growl (HoGr).

Cat	*meanDur*	*minF_0*	*maxF_0*	*meanF_0*
D	3.66 s	121 Hz	974 Hz	519 Hz
R	1.93 s	151 Hz	459 Hz	274 Hz
T	6.28 s	56 Hz	837 Hz	324 Hz
V	-	-	-	-
All	*3.73 s*	*56 Hz*	*974 Hz*	*510 Hz*

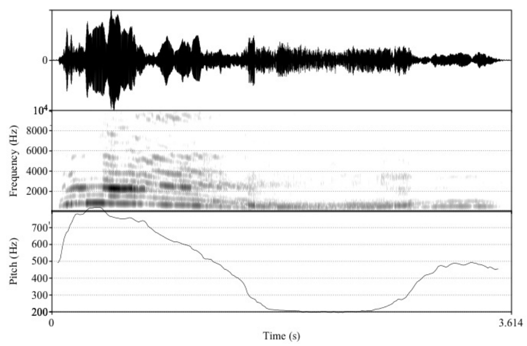

Figure 4. Example waveform, broadband (300 Hz) spectrogram and F_0 contour of howl-growl (HoGr).

Snarl and pain shriek

Snarls and pain shrieks were produced only during actual fights, and were harsh, short and loud calls with durations ranging from 0.19 to 0.64 sec, and F_0 varying between 301 and 521 Hz, as shown in Table 6. Vowel qualities included [a] and [æ]. As these sounds occurred only in actual fights between the two female cats, it was impossible to judge which of the cats produced the vocalisations, and although my guess is that D produced three and V four snarls, it is possible that V produced all of them, as they are very similar in voice quality and F_0. Figure 5 shows an example of a snarl, and numeric values for this type are shown in Table 6.

Table 6. Mean durations, as well as minimum, maximum and mean F_0 of snarl (Sn).

Cat	*meanDur*	*$minF_0$*	*$maxF_0$*	*$meanF_0$*
D	0.46 s	301 Hz	521 Hz	461 Hz
R	-	-	-	-
T	-	-	-	-
V	0.34 s	301 Hz	521 Hz	464 Hz
All	*3.73 s*	*56 Hz*	*974 Hz*	*510 Hz*

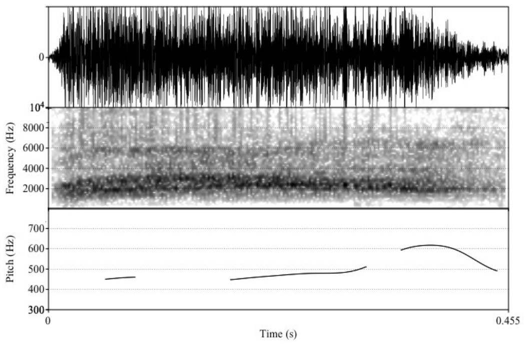

Figure 5. Example waveform, broadband (300 Hz) spectrogram and F_0 contour of snarl (Sn).

Hiss and spit

Hisses and spits are voiceless vocalisations. The hisses produced by the cats in this case study were uttered as warnings and sounded a bit like the fricatives [ʂ], [ç], or [h]. Spits (hisses) were used as intense warnings or to shock an opponent and often sounded more like affricates [tʂ] or [tç]. However, hisses and spits were not always easy to tell apart, as they sometimes sounded very similar. Hisses (0.42–1.05 sec.) were generally longer than spits (0.27–0.70 sec.), with a lower centre of gravity, as shown in Table 7. Centre of gravity standard deviations varied between 2080 and 2507 Hz, suggesting a wide dispersion of the noise energy in both types. Figure 6 shows the waveform and spectrogram of one hiss and one spit.

Table 7. Mean durations (mDur) and centres of gravity (cog) of Hiss (Hs) and Spit (Sp).

Cat	*mDurHs*	*cogHs*	*mDurSp*	*cogSp*
D	0.68 s	1186 Hz	0.52 s	2116 Hz
R	0.69 s	820 Hz	0.62 s	1506 Hz
T	0.80 s	937 Hz	0.55 s	1464 Hz
V	0.66 s	957 Hz	0.62 s	1562 Hz
All	*0.70 s*	*1105 Hz*	*0.54 s*	*2006 Hz*

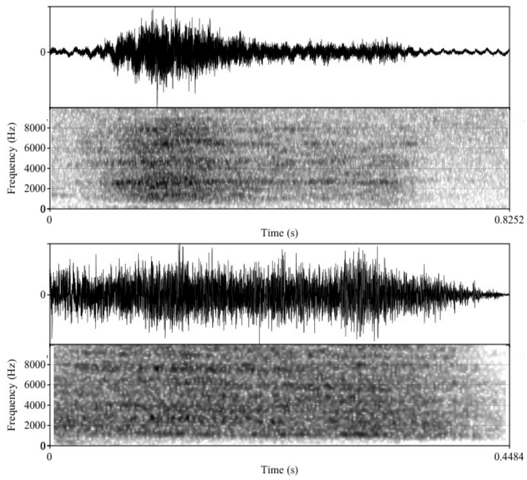

Figure 6. Example waveforms and broadband (300 Hz) spectrogram of hiss (HS) (top) and Spit (sp) (bottom).

Discussion and future work

In this case study, the main purpose was to find out what types of agonistic vocalisations were used by the participating cats, and what some of their acoustic-phonetic features were. From the 468 analysed tokens, at least six different vocalisation types were identified. Moreover, several intermediate patterns between e.g. hiss and spit, snarl and pain shriek, and between howl and growl were not uncommon. Such sounds were harder to subdivide into types. Furthermore, complex vocalisations, including combinations of howls and growls, growls and spits were observed. In futures studies, intermediate and complex vocalisations will be analysed in greater detail.

Most of the vocalisations (78%) were produced by one cat (D), who was the most active and aggressive cat of this case study. Still, the fact that so many agonistic types were identified suggests that cats are able to vary their vocal signals to a large extent even in such a narrowly defined behavioural context. This is in line with Moelk (1944:185), who found that the vocal repertoire of the domestic cat is characterised by “an indefinitely wide variation of sound and of patterning”.

Large variations in F_0 and durations within and between the different types were also found. Especially howls and howl-growls comprised a large number of intonation patterns, which is in line with previous studies (Schötz, 2012; 2013; 2014). It is possible that cats use variations in F_0 to signal paralinguistic information. This will be studied further in future experiments.

Agonistic vocalisations are not easy to record naturally without human–cat interaction. The present study used a particular case where one new cat was introduced to three cats already living in her new home and without any human–cat interaction. This method was found to be adequate for recording cat–cat agonistic vocalisations, and will be used again if possible in future studies with other cats. In this study none of the cats were forced to do anything against their will. They could retreat to a safe place whenever they wanted to (and they often did). After two weeks of mainly aggressive and defensive behaviour, the cats calmed down, and they now seem to tolerate each other and are getting along better.

The results of this pilot study should be regarded as tentative, due to the often limited number of tokens analysed of each type. Future work includes a larger study of cat vocalisations, including intonation and an initial formant analysis of the different vocalisation types, especially the vowels.

Acknowledgements

A warm thanks goes to Donna, Rocky, Turbo and Vimsan for their patient participation in this case study. [m̩hrn]!

References

Beaver B V (2003). *Feline Behaviour: A Guide for Veterinarians*. W. B. Saunders: ST. Louis, MO.

Boersma, P, Weenink, D (2014). *Doing phonetics by computer* [Computer program]. Version 5.4.01, retrieved 9 November 2014 from http://www.praat.org/.

Bradshaw, J (1992). *The Behaviour of the Domestic Cat*. Redwood Press, Bristol.

Bradshaw, J, Cameron-beaumont, C, (2000). The signalling repertoire of the domestic cat and its undomesticated relatives. In: Turner, D C, Bateson, P (Eds.), *The Domestic Cat: The Biology of its Behaviour*. Cambridge University Press, Cambridge, 67–793.

Bradshaw, J (2013). *Cat Sense: The Feline Enigma Revealed*, London: Allen Lane.

Brown, K A, Buchwald, J S, Johnson, J R, Mikolich, D J (1978). Vocalization in the cat and kitten. *Developmental Psychobiology*, 11: 559–570.

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

Eklund, R, Peters, G, Duthie, E D (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, 2–4 June 2010, Lund, 17–22.

Eklund, R, Peters, G, Weise, F, Munro, S (2012). A comparative acoustic analysis of purring in four cheetahs. In: *Proceedings from FONETIK 2012*. Gothenburg, 2012, 37–40.

Farley, G R, Barlow, S M, Netsell, R, Chmelka, J V, (1992). Vocalizations in the cat: behavioral methodology and spectrographic analysis. *Exp. Brain Res*. 89: 333–340.

Houpt, K (2004). *Domestic Animal Behavior for Veterinarians and Animal Scientists*, 4th edition. Blackwell Publishing: Ames, IA.

McKinley, P E (1982). *Cluster analysis of the domestic cat's vocal repertoire*. Unpublished doctorial dissertation. University of Maryland, College Park.

Moelk, M (1944) Vocalizing in the House-Cat; A Phonetic and Functional Study. *The American Journal of Psychology*. 57:2: 184–205.

Nicastro, N, & Owren, M J (2003). Classification of domestic cat (Felis catus) vocalizations by naïve and experienced human listeners. *Journal of Comparative Psychology*, 117: 44–52.

R Core Team (2015). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria. http://www.R-project.org/.

Shipley, C, Buchwald, J S, Carterette, E C. (1988). The role of auditory feedback in the vocalization of cats. *Exp. Brain Res*. 69: 431–438.

Shipley, C, Carterette, E C, Buchwald, J S (1991). The effects of articulation on the acoustical structure of feline vocalizations. *J. Acoust. Soc. Am*. 89: 902–909.

Schötz, S, Eklund, R (2011). A comparative acoustic analysis of purring in four cats. In *Proceedings of Fonetik 2011*, Speech, Music and Hearing, KTH, Stockholm, TMH-QPSR, 51: 9–12.

Schötz, S (2012). A phonetic pilot study of vocalisations in three cats. In *Proceedings of Fonetik 2012*, Department of Philosophy, Linguistics and Theory of Science, University of Gothenburg, 45–48.

Schötz, S (2013). A phonetic pilot study of chirp, chatter, tweet and tweedle in three domestic cats. In *Proceedings of Fonetik 2013*, Linköping University, 65–68.

Schötz, S & van de Weijer, J (2014). A Study of Human Perception of Intonation in Domestic Cat Meows. In *Proceedings of Speech Prosody 2014*, Dublin.

Schötz, S (2014). A pilot study of human perception of emotions from domestic cat vocalisations. In *Proceedings of Fonetik 201*, Department of Linguistics, Stockholm University, 95–100.

Turner, D C & Bateson, P eds. (2000). *The domestic cat: the biology of its behaviour*, 2nd edn. Cambridge University Press, Cambridge.

Yeon, S C, Kim, Y K, Park, S J, Lee, S S, Lee, S Y, Suh, E H, Houpt, K A, Chang, H H, Lee, H C, Yang, B G, Lee, H J (2011). Differences between vocalization evoked by social stimuli in feral cats and house cats, *Behavioural Processes* 87, Issue 2, 183–189.