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OCCURRENCE OF NONLINEAR PHENOMENA (NLP) IN SIBERIAN AND NEVA MASQUERADE CATS' VOCALISATION

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ABSTRACT

Cats speak by using complex combinations of body language, vocalisation, and scent cues. Cats have been regarded for centuries as mysterious, solitary, unpredictable creatures, perhaps because humans have difficulty understanding what they're saying. One of the acoustic parameters where the information for another individual can be encoded are nonlinear phenomena (NLP). Nonlinear phenomena are now emerging as a common occurrence in mammals. Although NLP are widespread, very little is known about their function. The purpose of this work was to check whether the NLP occur in cats' communication, and whether individual features and situation influence them.

Vocal recordings from 20 adult Siberian Cats and 10 Neva Masquerade cats were collected and used in a phonetic study in order to test some recording and analysis methods. Cats' responses to behavioural stimuli in two test situations were recorded: vocalisation before serving food and isolation calls (closing the cat in a cage for 3 minutes). Vocalisations were detected and segmented, with voiced and unvoiced vocalisations being differentiated. The recordings were processed using PRAAT, Raven Pro and Audacity software. The vocalisations were analysed for subharmonics, biphonation, deterministic chaos, frequency jumps, bursts, non-tonal moments or any subset of these events.

1. INTRODUCTION

Domesticated cats all come from wildcats called *Felis silvestris lybica* that originated in the Fertile Crescent which was a Neolithic region in the Near East. Cats have been with us for centuries, but in recent years there has been a dramatic increase in the number of these animals. Exact population figures are changing and inaccurate because of the wild population, but it has been estimated that the number of cats living in the whole world is between 23.100.000 and 61.000.000 [1]. With the growing number of cats, the understanding of their needs by owners does not increase. This is demonstrated by the statistics. Scientists estimated that 4 to 9 million cats die each year in the shelters. Of all cats euthanized in shelters, 18% to 33% die because of behaviour problems [1]. Research shows that we need a better understanding of cat needs and behaviour. A good step to understanding the cats' need is to better understand their communication

towards humans. A better understanding of how cats communicate their feelings is fundamental for all aspects of their welfare.

Cats speak by using complex combinations of body language, vocalisation, and scent cues. Cats have been regarded for centuries as mysterious, solitary, unpredictable creatures, perhaps because humans have difficulty understanding what they're saying. Cats use vocalisations to express emotion. Meowing, purring, hisses, growls, and more are included in the feline repertoire, each with special meanings depending on their context. Cats are said to have one of the widest 'vocabularies' of all carnivore species, and this may be related to the fact that in the natural environment vocal communication is important when they spend much active time in poor lighting conditions. There is some evidence that cats are able to modify their vocalisations when communicating with people.

One of the acoustic parameters where the information for another individual can be encoded are nonlinear phenomena (NLP). This term refers to a set of vocal features which are normative events in mammalian vocalisations, being directly connected with the nonlinear nature of vocal folds dynamics.

Nonlinear phenomena are common in mammals' vocalisation. Although NLP are widespread, very little is known about their function. It has been suggested that nonlinear phenomena increase the individual distinctiveness of vocalizers, boost the auditory salience and impact of vocalisations on listeners, or have no specific function but provide cues as to vocalizer fitness [2, 3]. The purpose of this work was to check whether the NLP occur in cats' communication, and whether individual features and situation influence them.

2. MATERIALS AND METHODS

All the results presented in this research were obtained at the Faculty of Animal Breeding and Biology of the University of Agriculture in Krakow, at the Department of Genetics, Animal Breeding and Ethology - from March 2016 to April 2020.

Vocal recordings from 20 adult Siberian Cats and 10 Neva Masquerade cats were collected. Cats' responses to

behavioural stimuli in two test situations were recorded: vocalisation before serving food and isolation calls (closing the cat in a cage for 3 minutes).

2.1. Cat's breeds

Although cats have been with us for thousands of years, the breeding of purebred cats lasts just two hundred years. Two breeds were selected for the experiment – Siberian cats (SIB) and Neva Masquerade cats (NEV). They are recognized as sister breeds; it means that according to the breeding law they can interbreed with each other.

The Siberian Russia's native forest cat first appeared in recorded history around the year 1000 and hails from the unforgiving climate of Siberia (natural variety). After living in the cold Russian climate for many generations, the breed has developed a hardy constitution and a dense triple fur coat that is water resistant. A few Siberian Forest cats were imported into Britain in the late 1800s but its popularity waned in favour of the heavily coated Persian [4]. The Siberian personality is usually friendly and adventurous. This breed does especially well with people, other cats, and even dogs. Siberians enjoy the company of their family and make excellent companions with their calm demeanour and quiet sounds. However, while Siberians are mellow and easy-going, they do have a very playful personality. They are known for their sense of adventure and agile ability.

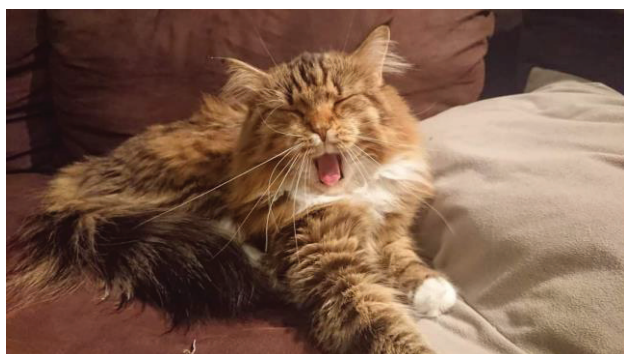


Photo 1. Siberian Cat

Neva Masquerade is a very intelligent and curious colorpoint variation of the Siberian cat breed. Like the Siberian cat, the Neva Masquerade breed origins from Russia and it is named after the river Neva in St. Petersburg, where it first was developed somewhere around the late-1970s / early-1980s. Neva Masquerades were the result of cross breeding between Siamese and Siberians in Russia. Some sources claim other breeds such as Birman, Himalayan and Balinese were bred into the Neva Masquerade as well, but that remains unclear. In January 2009 the Neva Masquerade was accepted into the Federation International Felines' registry as a new breed known as Siberian Color Point.

2.2. Sound recording and processing method

All cats were recorded in a quiet home environment using a condenser shotgun microphone RODE NTG-1 and a handy recorder ZOOM H4Pro. Vocalisations were manually segmented, with voiced and unvoiced vocalisations being differentiated, using Audacity software.

The first author manually annotated NLP in the recordings basing on visual inspection of spectrograms. One additional scientist reanalysed the data to provide a quantified reliability check for visual categorization of NLP subtypes. A quantitative comparison of the classification results of the two analysers revealed 86% level of agreement. The doubtful results were not included in this research.

Following nonlinear phenomena were looked for in the recordings:

- *Frequency jumps* - are sudden fundamental frequency changes caused by unstable oscillation of the vocal folds [5]
- *Subharmonics* - are additional spectral components that can suddenly appear at integer fractional values (1/2, 1/3, etc.) of an identifiable fundamental frequency [5]
- *Biphonations* - refers to the occurrence of two simultaneous but independent fundamental frequencies, which can be visible in a spectrogram as two distinct and autonomous frequency contours or as sidebands adjacent to harmonics that are associated with cyclic amplitude fluctuations in the time-series waveform [5]
- *Deterministic chaos* - refers to episodes of nonrandom noise with audible tonal sounds [5]
- *A1* - short tonal unit, 3 or fewer harmonics present
- *A2* - tonal units of longer duration than category A1, always harmonically structured
- *Non-tonal* - voiceless moments, without fundamental frequencies

For frequency jumps, their number in a recording was analysed. For other phenomena, their duration (absolute in seconds and relative to the length of the recording) was the subject of analysis. Binary indicators of presence of each of the phenomena in each of the recordings were also analysed.

2.3. Statistical analysis

To determine whether a parameter exhibits different average value in different conditions (be it cat breed, age, or other factor), a following procedure was applied:

1. Average values from each cat separately to get one value per cat (unless indicated otherwise in the Results section)
2. Group the results according to the condition
3. Check normality of each results group using a Shapiro-Wilk test
4. Test for equality of means of the result groups. Depending on the result of normality test and the number of groups, use a following test:
 - a. If the normality test didn't reject the normality hypothesis for any of the groups:
 - i. If there are 2 groups of results, use Welch t-test
 - ii. If there are more than 2 groups of results, use Kruskal-Wallis test (K-W)
 - b. If the normality test rejected the hypothesis of normality for any of the groups:
 - i. If there are 2 groups of results, use Mann-Whitney U-test (M-W)
 - ii. If there are more than 2 groups of results, use Kruskal-Wallis test (K-W).

All statistical tests were performed with the statistical significance level of 0.95.

3. RESULTS

3.1. Association between individual features and NLP parameters

Only the isolation calls were used for these comparisons due to the small amount of background noise. In this comparison, the two breeds were analysed together. The study included 15 females and 15 males (5 females and 9 males were neutered). Averaged data per cat was used for comparison.

In age test, the cats (all breeds) were grouped into three groups: less than 3 years old, 3 to 7, older than 7 years old. There were 6 cats in the first group, 14 in the second one and 10 in the third one. A significant relationship (K-W, $p < 0.05$) was found between average duration of A1 and cats' age – the shortest occurrences were observed in middle-aged cats, while in younger and older individuals the average duration of A1 in calls was higher. Another parameter also changes interestingly – occurrence of A2. This phenomenon appeared in the youngest group of cats (less than 3 years old) in 100% recordings. As the cat gets older, the frequency of this parameter appearing in

individual recordings decreased. This parameter appeared only in 84.2% of recordings of cats older than 7 years old.

Another test (M-W, $p < 0.05$) did not show the existence of a significant relationship between cats' sex or sterilisation and analysed NLP parameters. However, there were differences in the frequency of occurrence of these phenomena (not tested for statistical significance). Results showed dissimilarity in frequency of occurrence of the A1 and deterministic chaos in all recordings. A1 has appeared in 56.5% males' recordings, and 38.3% females' recordings. Deterministic chaos has appeared in 43.5% males' recordings, and 18.8% females' recordings.

3.2. Association between breed and NLP parameters

As before only the transporter recordings were used for these comparisons. Averaged data per cat was used for comparison.

The result of test (M-W, $p < 0.05$) shows the existence of a significant relationship between biphonation duration and cats' breed [fig. 1].

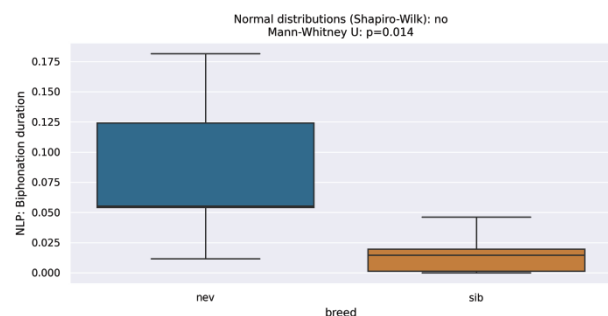


Figure 1. Association between breed and biphonation duration (s)

Comparing the Siberian (SIB) and Neva Masquerade (NEV) cats also showed differences in the frequency of occurrence of the following NLP parameters in all recordings [tab. 1].

NLP:	NEV	SIB
A1	38.5%	49.3%
A2	91.7%	88.0%
Biphonation	42.7%	22.0%
Chaos	40.6%	20.0%
Frequency Jump	22.9%	11.3%
Non-tonal	25.0%	32.7%
Subharmonic	9.4%	6.0%

Table 1. Association between breed and frequency of occurrence of NLP parameters

3.3. Association between situation and NLP parameters

Recordings from both situations were used for comparisons. In these results, the two breeds were analysed together. Averaged data per cat per situation

was used. In total, 143 recordings of cats were compared (75 during feeding, 68 during isolation).

The result of test (M-W, $p < 0.05$) shows the existence of a significant relationship between situation and following NLP parameters: A2 duration and deterministic chaos duration [fig. 2, fig. 3].

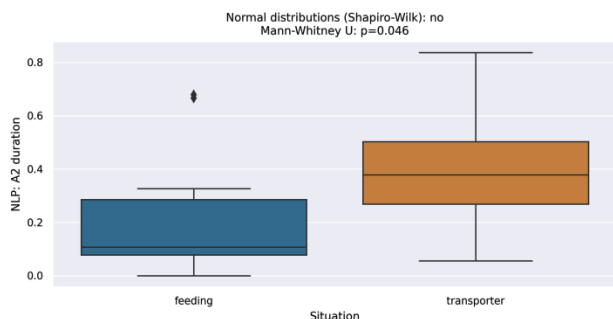


Figure 2. Association between A2 duration (s) and situation.

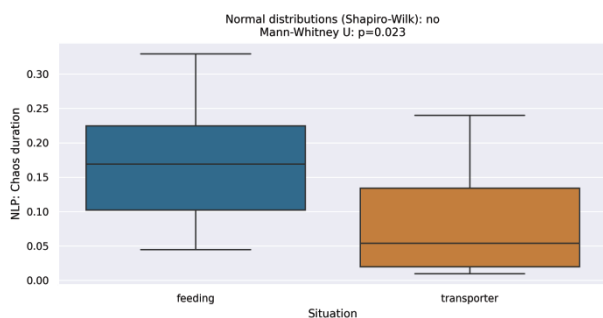


Figure 3. Association between deterministic chaos (s) and situation.

Comparing these two situations (feeding and isolation) results showed differences in the frequency of occurrence of the following phenomena in all recordings too [tab. 2].

NLP:	Feeding	Isolation
A1	21.1%	42.7%
A2	62.5%	82.2%
Biphonation	21.1%	26.1%
Chaos	68.0%	35.0%
Frequency Jump	2.3%	12.1%
Non-tonal	51.6%	42.0%
Subharmonic	5.5%	11.5%

Table 2. Association between situation and NLP parameters

4. CONCLUSIONS AND DISCUSSION

The study has shown that some vocal parameters of cats depend on their breed and individual features.

The results showed that the frequency of occurrence of A2 in cat's vocalisation decreases with age. Additionally,

in the youngest group of cats there were also much more frequently occurring parameters such as biphonation and frequency jump. However, subharmonics occurred only in groups II (cats' age between 3-7 years) and III (cats older than 7 years). It can be hypothesized that young cats use these parameters to communicate the need for care for themselves.

The differences between SIB and NEV seem surprising. For many years treated as sister breeds and mixed with each other, they differ in some parameters. It is difficult to say whether these differences were created in the years since the breeds were officially separated or even earlier as a result of crossbreeding of Siberian cats with other point breeds.

NEV cats behaved more stressful during recordings (isolation). Perhaps different parameters also indicate the stress and arousal of the individuals.

It also seems interesting that there are differences in NLP in different situations. Maybe the NLP contains information about the situation, or maybe the difference is related to different emotions of cats.

All results are just the beginning of the research. Tip on what to look for in further studies. Communication of cats is a very difficult and hard to study topic due to the small access to the recordings of cat sounds. The research will be continued. Future work includes a larger study of vocalisation of cats of different breeds.

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