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THE OCCURENCE OF NONLINEAR VOCAL PHENOMENA IN FRUSTRATION WHINES OF THE DOMESTIC DOG (*CANIS FAMILIARIS*)

NAVZOČNOST NELINEARNIH ZVOČNIH POJAVOV PRI FRUSTRACIJSKEM CVILJENJU PRI PSIH (*CANIS FAMILIARIS*)

ELENA V. VOLODINA, ILYA A. VOLODIN & OLGA A. FILATOVA

ABSTRACT

The ocurrence of nonlinear vocal phenomena in frustration whines of the Domestic Dog (*Canis familiaris*)

We analyzed quantitatively the occurrence of nonlinear vocal phenomena in whines of 9 Domestic Dogs of 6 breeds. The dogs produced whines in response to a frustration-provoking situation (impossibility to perform the desired action), designed with their owners. The whines could consist two fundamental frequencies – the low (f0) and the high (g0), that could occur both singly as separate vocalizations and together within the same vocalization. The f0 varied between individuals from 0.4 to 1.4 kHz and either lacked nonlinear phenomena or bored deterministic chaos, subharmonics or frequency jumps within the f0. The g0 varied between individuals from 3.1 to 11 kHz and also either lacked nonlinear phenomena or bored sidebands. The simultaneous occurrence of f0 and g0 within the same whine resulted in biphonation, whereas the f0 following g0 resulted in frequency jump between the fundamentals. We found, that in whines of our object dogs nonlinear phenomena occurred significantly more often within the f0 than within the g0, and significantly more rarely in whines consisting both f0 and g0 than in whines consisting f0 or g0 singly. The occurrence of nonlinear phenomena showed the noticeable interindividual variability. We discuss mechanisms for production of the f0 and g0 in the Domestic Dog. Also, we propose, that the strong variability in whines of Domestic Dogs has a function to attract attention of the dog owners in situation of frustration, when a dog can't cope with a problem. In this relation, the nonlinear phenomena may represent a mechanism, supporting the high unpredictable variability in the structure of whines.

Key words: Vocal communication, call structure, individual variability, sound production.

IZVLEČEK

Navzočnost nelinearnih zvočnih pojavov pri cviljenju zaradi frustracij pri psih (*Canis familiaris*)

Kvantitativno smo analizirali navzočost nelinearnih zvočnih pojavov (dvojna tvorba glasov, medharmonične frekvence, deterministični kaos, stranski frekvenčni pasovi in frekvenčni preskoki) pri cviljenju 9 psov iz 6 legel. Kadar psi ob prisotnosti svojih lastnikov niso mogli izvesti željenega dejanja, je nastala frustracijsko-izzivalna situacija, zaradi katere so cvilili. Cviljenje gradita dve osnovni frekvenci, nižja (f0) in višja (g0), ki se lahko pojavljata posamezno kot ločeni oglašanji ali skupaj v istem oglašanju. Frekvenca f0 obsega pri različnih osebkih od 0,4 do 1,4 kHz, g0 pa od 3,1 do 11 kH. V f0 nelinearni zvočni pojavi niso vedno prisotni ali pa vsebuje deterministični kaos, medharmonične frekvence ali frekvenčne preskoke. Tudi v g0 nelinearni zvočni pojavi lahko manjkajo ali pa vsebujejo stranske frekvenčne pasove. Pri istočasnem pojavljanju frekvenc f0 in g0 v istem cviljenju nastane, dvojna tvorba glasov kjer osnovna frekvenca g0 sredi cviljenja preskoči v f0. Ugotovili smo, da v cviljenju proučevanih psov nelinerni zvočni pojavi nastajajo statistično značilno bolj pogosto v f0 kot pa v g0 in statistično značilno manj pogosto v cviljenju, ki vključuje f0 in g0, kot pa v cviljenju, ki vsebuje le posamezni frekvenci f0 in g0. Prisotnost nelinearnih zvočnih pojavov je zelo variabilna pri posameznih osebkih. Razpravljamo tudi o mehanizmu nastajanja frekvenc f0 in g0 pri psih. Po našem mnenju je velika variabilnost v zgradbi cviljenja namenjena privabljanju lastnikove pozornosti v situaciji, ko pes zaradi frustracije ne more rešiti problema. Navzočnost nelinearnih zvočnih pojavov je eden od možnih mehanizmov, ki lahko pojasni veliko in nepredvidljivo variabilnost v strukturi cviljenja.

Ključne besede: vocal communication, call structure, individual variability, sound production.

Addresses – Naslovi

Elena V. Volodina
Scientific Research Department
Moscow Zoo
B. Gruzinskaya, 1
Moscow, 123242
Russia
E-mail: volodinsvoc@yahoo.com

Olga A. Filatova
Scientific Research D Department
Moscow Zoo
B. Gruzinskaya, 1
Moscow, 123242
Russia

Ilya A. Volodin
Department of Vertebrate Zoology
Faculty of Biology
Lomonosov Moscow State University
Vorobievy Gory
Moscow, 119992
Russia
E-mail: volodinsvoc@yahoo.com

INTRODUCTION

The vocal nonlinear phenomena (biphonations, subharmonics, deterministic chaos, sidebands and frequency jumps), arising from small variations in the work of sound production apparatus, have been found in many mammalian species (reviews: WILDEN et al. 1998, FITCH et al. 2002, VOLODIN et al. 2005). In canids, the nonlinear phenomena were found in whines and howl of the Timber Wolf (*Canis lupus*) (SCHASSBURGER 1987, NIKOL'SKII & FROMMOLT 1989, TOOZE et al. 1990), chatter of the African Wild Dog (*Lycaon pictus*) (WILDEN 1997, WILDEN et al. 1998), yap-squeaks of the Dhole (*Cuon alpinus*) (VOLODIN et al. 2001, VOLODIN & VOLODINA 2002, VOLODINA et al. 2006), howl of the Golden Jackal (*Canis aureus*) (A.D. POJARKOV, pers. comm.), barks and howl of the Domestic Dog and dog-wolf hybrids (RIEDE et al. 2000b, 2001). A particular interest represents an ability of canids to produce simultaneously a high-frequency squeak and voice sounds, that results in appearance of call spectra with two fundamental frequencies, traditionally designated as f0 and g0 (NIKOL'SKII & FROMMOLT 1989, WILDEN et al. 1998, VOLODIN & VOLODINA 2002, VOLODIN et al. 2005, VOLODINA et al. 2006). However, most studies focused on nonlinear phenomena provide only their descriptions and hypotheses concerning their probable functions, without the analysis of their occurrence in individual animals (FITCH et al. 2002, VOLODIN et al. 2005).

Among canids, the vocal behaviour of the Timber Wolf and Domestic Dog was studied most thoroughly. This was related primarily with research interest to comparison between vocal repertoires of the domesticated form and its wild ancestor, and to hypertrophy in use of barks in the Domestic Dog in comparison with other canids (COHEN & FOX 1976, FEDDERSEN-PETERSEN 2000, YIN 2002, YIN & MCCOWAN 2004, CHULKINA et al. 2006). Comparing to barks, other dog vocalizations were poorly studied. On the other hand, the anatomy of dog larynx and vocal tract are studied in details, and the dog is one of the object species for physiological experiments focused on sound production mechanisms and factors, evoking the appearance of the nonlinear phenomena in mammalian calls (SOLOMON et al. 1995, BERRY et al. 1996, RIEDE & FITCH 1999, FITCH 2000, RIEDE et al. 2000a). The structural variability of the Domestic Dog calls is so strong, that provides illustrations to all nonlinear phenomena, existing in mammals (VOLODIN et al. 2005). However, the occurrence of nonlinear phenomena in the Domestic Dog was not yet studied to date. The purpose of this study was to provide quantitative data on the occurrence and individual preferences in use of different nonlinear phenomena in frustration whines of the Domestic Dog.

MATERIAL AND METHODS

Our subjects were 9 dogs of different breeds aged from 3 months to 7 years (Table 1). The principle for selection of animals for this study was based on suggestions of their owners, that their dogs may be easily provoked to whine. From March 2000 to January 2004 we recorded calls from each of the nine dogs during 1-2 recording sessions, separated with a time span not longer than one year. The dogs produced whines in response to a frustration-provoking situation (impossibility to perform the desired action), designed by their owners. The call recordings were made in the habitual for the dogs environment, usually at home. The recording situations were rather variable, depending on individual dog: begging for food, for walk, for opening a door etc. However, all of them were uniform in the underlYINg emotional state of each subject dog – the state of frustration, when the dog was unable to make the desired action and addressed its' whines to the owner, who could help in coping with the problem.

The sound recordings were made with SONY WM-D6C recorder and Tesla-AMD-411N cardioid dynamic microphone. Frequency responses of both systems were 40-12000 Hz. Sometimes, we also registered the behaviour of a calling dog with camera SONY TRV-65E. The whines were digitized with sampling rate 22.05 kHz. For 8 dogs, we selected first 300 whines of good quality, for the ninth dog – only 243; so in total 2643 whines from 9 dogs were included into analysis (Table 1).

The call structures were analyzed visually from spectrograms created with Avisoft-SASLab Pro v. 4.3 (© R. SPECHT), with Hamming window, FFT-length 512; frame 50%; overlap 87.5%. For each call, we registered presence or absence of the low and/or high fundamental frequency as well as presence of different nonlinear phenomena (in cases when they covered not less than 10% of call length and duration of the section with the given nonlinear phenomenon was not less than 30 ms). The estimated percentages were compared with 2X2 χ^2 test. All statistical analyses were made in STATISTICA, version 6.0 (StatSoft, Inc).

RESULTS

In whines of nine Domestic Dogs we found two fundamental frequencies – the low (f0) and the high (g0), each with its own set of harmonics. Depending on presence or absence of the two fundamental frequencies, all whines could be subdivided into three types: whines, consisting f0 singly (f-whines), whines, consisting g0 singly (g-whines), and whines consisting both frequencies (f&g whines) (Fig. 1).

The low fundamental frequency of whines (f0) varied between individuals from 0.4 to 1.4 kHz, whereas the high fundamental frequency (g0) – from 3.1 to 11 kHz. Thus, the ranges for the low and high fundamentals did not overlap even between the dogs, strongly differing in body weight, that is, the low fundamental frequency for the dog weighed 1.5 kg (Pek) was anyway lower than the high fundamental frequency of the dog weighed 70 kg (Darjal).

Nonlinear phenomena in whines of Domestic Dogs could arise just for the account of joining the two fundamental frequencies f0 and g0 into a single call, resulting in creation of f&g-whines (biphonations or frequency jumps between the f0 and g0). Other forms of nonlinear phenomena (such as subharmonics, deterministic chaos, sidebands and frequency jumps within the same fundamental frequency) could arise separately within f0 or within g0, and could occur both in f- and g-whines, and in f&g-whines. These possibilities could lead to combination of different nonlinear phenomena within a call and resulted in a great diversity of whine structures. Here we do not provide the detailed description for structural peculiarities of different nonlinear phenomena in dog whines, because it was given at a preceding study (VOLODIN et al. 2005).

Fig. 1 presents some structural forms of Domestic Dog whines. The f-whines either lacked nonlinear phenomena and thus represented purely tonal calls (Fig. 1a), or consisted subharmonics, deterministic chaos or frequency jumps within the f0 (Fig. 1b-f). The g-whines, representing high-frequency squeaks (Fig. 1g-i), usually did not bore nonlinear phenomena except sidebands, that were clearly noticeable in some calls (Fig. 1i). Production of the two fundamental frequencies one after another in f&g-whines resulted in appearance of frequency jumps from one fundamental to another (Fig. 1j-k), whereas the simultaneous production of both the frequencies – to appearance of biphonations (Fig. 1l).

From the total sample of 2643 whines for nine dogs, the f-whines consisted 42.6% (1125 whines), g-whines – 32.9% (869 whines), and f&g-whines – 24.5% (649 whines), with 451 (17.0%) biphonic calls, and – 198 (7.5%) calls representing a frequency jump from one fundamental to another (Fig. 2). Analysis of occurrence for different whine types of each dog separately showed, that two of them (Laska and Pek) produced almost exclusively f-whines, and that in another one (Hloya) such whines consisted 68% of all whines. Three other dogs (Grach, Hilda and Rid) produced mainly g-whines (more 50% of all their whines). In the last three dogs (Darjal, Kris and Hrum), the f&g-whines consisted more 39% (Fig. 2). Thus, the use either the low or high fundamental frequency, or both of them in dog whines, showed strong interindividual variability.

Then we calculated percentages of occurrence of nonlinear phenomena for all three whine types in total (f-whines, g-whines and f&g-whines). In this case, we registered all forms of nonlinear phenomena, including the presence of two fundamental frequencies f0 and g0 within a call, as well as nonlinearities within f0 and within g0. For the total sample of 2643 calls, percentages of whines, boring any nonlinear phenomena, varied from 17 to 53.3% between individuals, 37.5% on average (Table 2).

To compare the occurrence of nonlinear phenomena between the two fundamental frequencies, we estimated appearance of nonlinear phenomena separately within f0 and within g0. To make this, we analyzed separately two samples – of whines with the low fundamental frequency (f-whines and f&g-whines) and whines with the high fundamental frequency (g-whines and f&g-whines). For this case comparison, we did not registered the presence of two fundamental frequencies as a nonlinear phenomenon. Thus, for whines with the low fundamental frequency we registered as nonlinear phenomena only subharmonics, deterministic chaos and frequency jumps within f0 (Table 3). We found that the f0 presented in 1774 whines, and of them 1441 (81.2%) whines did not bore nonlinear phenomena. The 173 whines (9.8%) consisted subharmonics, 177 (10%) – deterministic chaos, and 81 (4.6%) – frequency jump; and 91 whines consisted two, and 3 whines – all the three nonlinear phenomena. Similarly, for whines with high fundamental frequency (g-whines and f&g-whines), we registered as a nonlinear phenomenon only sidebands, which were found only in 42 (2.8%) whines of 1518 (Table 4). Thus, within f0, the nonlinear phenomena occurred significantly more often (18.8%), than within g0 (2.8%) (χ^2=206.0, *df*=1, *p*<0.001).

Also, we found, that in whines with two fundamental frequencies (f&g-whines) the occurrence of nonlinear phenomena within either of frequencies was significantly lower, than in whines, consisting f0 singly (f-whines) or g0 singly (g-whines). So, within f0, nonlinear phenomena were presented in 304 (27.0%) of 1125 f-whines, and only in 29 (4.5%) of 649 f&g-whines (differences are significant, χ^2=135.8, *df*=1, *p*<0.001) (Table. 3). Similarly, within g0, nonlinear phenomena were presented in 38 (4.4%) of 869 g-whines, in comparison with 4 (0.6%) of 649 f&g-whines (differences are significant, χ^2=18.1, *df*=1, *p*<0.001) (Table 4).

As for total sample of whines, (Table 2), we found strong interindividual differences in the occurrence of nonlinear phenomena within either of fundamental frequencies. So, whines with nonlinear phenomena within f0 did occur most often in four dogs (Table 3). Three of them (Laska, Hloya and Pek) produced mainly f-whines (Fig. 2), however, in the forth (Darjal), g-whines and f&g-whines have prevailed (Fig. 2). The overwhelming majority of whines with nonlinear phenomena within g0 belonged to a single dog (Hilda), whereas in two other dogs (Grach and Rid), which also produced mainly g-whines (Fig. 2), nonlinear phenomena within g0 did not occur practically (Table 4).

DISCUSSION

Our data suggest the strong interindividual variability for the occurrence of nonlinear phenomena in whines of Domestic Dogs, produced at the state of frustration. On the other hand, we found some rules in appearance of non-linear phenomena in whines: they occurred significantly more often within the low fundamental frequency in comparison with the high one, and significantly more rarely in whines with both the fundamental frequencies than in whines with only one of them. Below we discuss mechanisms for production of the low and high fundamental frequencies in whines of Domestic Dogs, the occurrence of nonlinear phenomena in calls of other mammalian species, and proposal functions of the discovered high structural variability in whines of the Domestic Dog.

The vocal fold based mechanism for production of the low fundamental frequency was confirmed by experimental research studying the sound production in relation to activity of laryngeal muscles and subglottal pressure, carried on anesthetized Domestic Dogs (SOLOMON et al. 1995, BERRY et al. 1996). Also, there are evidences that small asymmetries in tension of right and left vocal folds, in conjunction with changes in the subglottal pressure, were responsible for all diversity of nonlinear phenomena (subharmonics, chaos, frequency jumps within the lower frequency), occurring in the Domestic Dog whines (BERRY et al. 1996). Besides, in some individual Domestic Dogs and dog-wolf hybrids tiny vocal fold extensions – vocal membranes were found; and the animals possessing the vocal membranes produced the nonlinear phenomena in more number of calls and more prolonged in duration, than the animals lacked the membranes (RIEDE et al. 2000a, 2000b).

The existing hypotheses concerning production mechanism for the high fundamental frequency have not yet received any experimental support. So, SOLOMON with coworkers (1995) consider unlikely the production of frequency over 3 kHz (appeared in their experiments), by vocal folds. They proposed that these sounds resulted from vorticity of airflow in vocal tract narrows. The high speed cineradiography of vocalizing Domestic Dogs showed, that the high fundamental frequency of whines was emitted through nose, whereas the low fundamental frequency of barking – through mouth (FITCH 2000). We also observed, that the Domestic Dogs emitted the whines, consisting only the high fundamental frequency, with a closed mouth, whereas the appearance of the low fundamental frequency (resulting in appearance of the biphonic whine) was accompanied by mouth opening (our unpubl. data). These observations support indirectly the hypothesis that vocal folds do not participate in production of the high fundamental frequency of whines.

Thus, there are good experimental evidences, that the low fundamental frequency of dog whines is produced with vocal folds, alongside with some observations, allowing to propose, that the high fundamental frequency of whines is produced by independent from vocal folds sound source, as a result of airflow vorticity in nasal tract or at the edge of nasal and oral cavities. The indirect evidences in support of such sound production mechanisms for the high and low fundamental frequencies comes also from our data that the low fundamental frequency six times more often bears nonlinear phenomena in comparison with the high one, as soon as paired vocal folds provide much more possibilities for appearance of vocal nonlinearities than the airflow, blowing through vocal tract narrows.

A few works, studied the occurrence of the nonlinear phenomena in individual animals, showed very high interindividual variability both in occurrence and in preference of using particular nonlinear phenomena in vocalizations. So, in nine juvenile Japanese Macaque (*Macaca fuscata*) subharmonics, sidebands and frequency jumps occurred in 3.5 to 42% calls in context of lost contact with a mother, and proportions of these three phenomena in calls of each juvenile were individual-dependent (RIEDE et al. 1997). In four of five dog-wolf hybrids, subharmonics, deterministic chaos and biphonations were presented in 3 to 32% vocalizations of pack howling, but lacked in the fifth animal (RIEDE et al. 2000b). In contact calls of 14 DHOLES, the proportion of calls with biphonations and frequency jumps varied from 21 to 95%, and was not related to age or sex (VOLODIN & VOLODINA 2002). These results are in good accordance with our data on the Domestic Dog whines, also showing strong individuality in use of different whine structures. Therefore, nonlinear vocal phenomena create a potential base for infinite diversity of vocalizations both in a particular individual and between individuals. And such large variability is achieved with only slight changes in tension of right and left vocal folds, subglottal pressure and other tunings of vocal apparatus (WILDEN et al. 1998, MERGELL et al. 1999).

The revealed strong structural variability of whines may be used by Domestic Dogs in order to attract the attention of their owners in situations, when the dog can't cope with a problem. For this study, we designed just such kinds of frustration-provoking situations. Whereas the repeatedly produced monotony vocal sequences suppress responding in listeners (HAUSER 1993, HARE 1998, FITCH & KELLY 2000), the nonlinear phenomena can function as a mechanism, supporting the high unpredictable structural diversity of calls.

This allows to support attention of listeners to a caller constantly "in tonus" (FITCH et al. 2002, VOLODIN et al. 2005). Such function for vocal diversity was discussed for parent-offspring interactions in the Vervet Monkeys (*Cercopithecus aethiops*) (HAUSER 1993, FITCH et al. 2002) and for parent-chick interactions in the Siberian Crane (*Grus leucogeranus*) (KASIROVA et al. 2005). It is interesting, that judging from their individual preferences, the Domestic Dogs use different ways for enhancing diversity of vocal sequences: they either use calls with two fundamental frequencies in a spectrum (biphonations and frequency jumps), or produce monophonic calls with a great amount of nonlinear phenomena within the exploitable frequency.

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Table 1: Animals and number of calls included into analyses.

Name	Breed	Sex	Age	Weight	Number of calls
Laska	toy dachshund	female	5 years	4 kg	300
Hilda	dachshund	female	7 years	7 kg	300
Hloya	dachshund	female	2 years	7 kg	300
Rid	Collie	male	5 years	20 kg	243
Kris	toy dachshund	male	3 years	4 kg	300
Pek	Pekinese	male	3 months	1.5 kg	300
Hrum	mongrel	male	4 months	6 kg	300
Grach	riesenschnautzer	male	7 years	50 kg	300
Darjal	Caucasian shepherd	male	2 years	70 kg	300

Table 2: The occurrence of all nonlinear phenomena in nine Domestic Dogs for all three types of whines (f-whines, g-whines and f&g-whines).

Dog	f-whines		g-whines		f&g-whines		All whines	
	total	with nonlinear phenomena	total	with nonlinear phenomena	total	with nonlinear phenomena	total	with nonlinear phenomena
Laska	298	158 (53.0%)	0	0	2	2 (100%)	300	160 (53.3%)
Hilda	19	0	187	36 (19.3%)	94	94 (100%)	300	130 (43.3%)
Hloya	204	66 (32.4%)	22	0	74	74 (100%)	300	140 (46.7%)
Rid	60	0	134	0	49	49 (100%)	243	49 (20.2%)
Kris	81	1 (1.2%)	102	1 (1.0%)	117	117 (100%)	300	119 (39.7%)
Pek	300	59 (19.7%)	0	0	0	0	300	59 (19.7%)
Hrum	132	4 (3.0%)	34	0	134	134 (100%)	300	138 (46.0%)
Grach	1	0	249	1 (0.4%)	50	50 (100%)	300	51 (17.0%)
Darjal	30	16 (53.3%)	141	0	129	129 (100%)	300	145 (48.3%)
All dogs	1125	304 (27.0%)	869	38 (4.4%)	649	649 (100%)	2643	991 (37.5%)

Table 3: The occurrence of nonlinear phenomena (excluding the presence of two fundamental frequencies in a call spectrum) in nine Domestic Dogs, for whines with the low fundamental frequency (f-whines and f&g-whines).

Dog	f-whines	f&g-whines	All whines with f0			
	total	with nonlinear phenomena	total	with nonlinear phenomena	total	with nonlinear phenomena
Laska	298	158 (53.0%)	2	0	300	158 (52.7%)
Hilda	19	0	94	3 (3.2%)	113	3 (2.7%)
Hloya	204	66 (32.4%)	74	17 (23.3%)	278	83 (29.9%)
Rid	60	0	49	1 (2.0%)	109	1 (0.9%)
Kris	81	1 (1.2%)	117	3 (2.6%)	198	4 (2.0%)
Pek	300	59 (19.7%)	0	0	300	59 (19.7%)
Hrum	132	4 (3.0%)	134	0	266	4 (1.5%)
Grach	1	0	50	0	51	0
Darjal	30	16 (53.3%)	129	5 (3.9%)	159	21 (13.2%)
All dogs	1125	304 (27.0%)	649	29 (4.5%)	1774	333 (18.8%)

Table 4: The occurrence of nonlinear phenomena (excluding the presence of two fundamental frequencies in a call spectrum) in nine Domestic Dogs, for whines with the high fundamental frequency (g-whines and f&g-whines).

Dog	g-whines	f&g-whines	All whines with g0			
	total	with nonlinear phenomena	total	with nonlinear phenomena	total	with nonlinear phenomena
Laska	0	0	2	0	2	0
Hilda	187	36 (19.3%)	94	1 (1.1%)	281	37 (13.2%)
Hloya	22	0	74	0	96	0
Rid	134	0	49	0	183	0
Kris	102	1 (1.0%)	117	1 (0.9%)	219	2 (0.9%)
Pek	0	0	0	0	0	0
Hrum	34	0	134	0	168	0
Grach	249	1 (0.4%)	50	0	299	1 (0.3%)
Darjal	141	0	129	2 (1.6%)	270	2 (0.7%)
All dogs	869	38 (4.4%)	649	4 (0.6%)	1518	42 (2.8%)

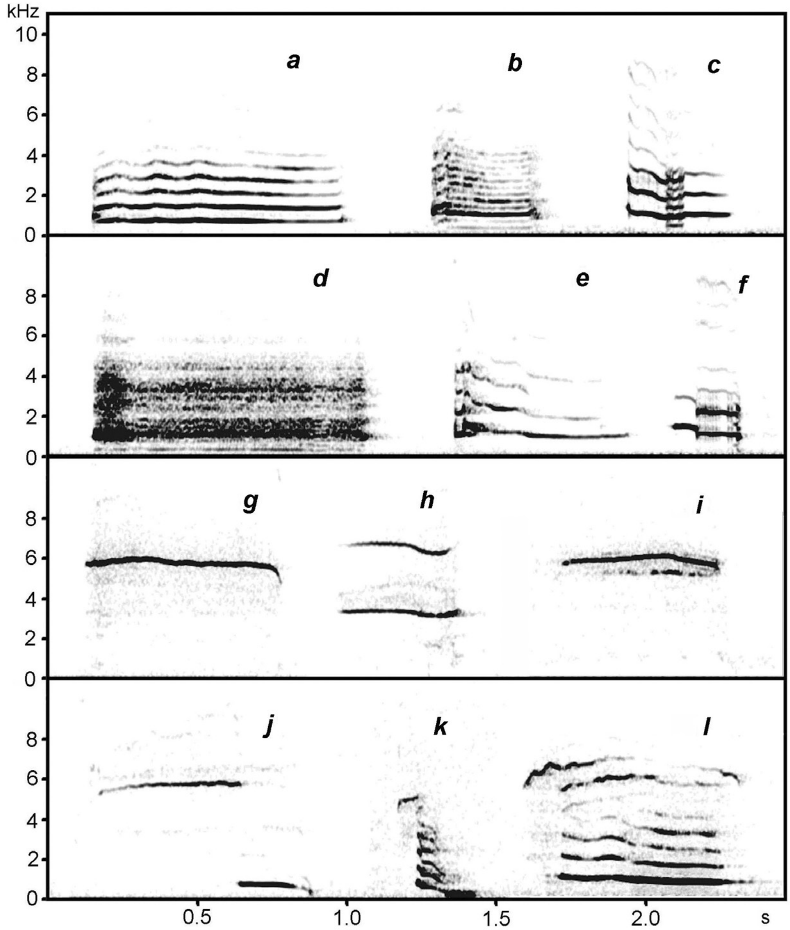

Figure 1: Structural variability of whines in the Domestic Dog: *b-f* – f-whines, consisting only the low fundamental frequency (f0); *g-h* – g-whines, consisting only the high fundamental frequency (g0); *j-l* – f&g-whines, with two fundamental frequencies (f0 and g0) within the same call. *a* – f-whine without nonlinear phenomena (Kris); *b* – f-whine, consisting subharmonics (Laska); *c* – f-whine, consisting subharmonics (Pek); *d* – f-whine, consisting deterministic chaos (Laska); *e* – f-whine with frequency jump within the low fundamental frequency (Laska); *f* – f-whine with frequency jump within the low fundamental frequency (Pek); *g* – g-whine without nonlinear phenomena (Hilda); *h* – g-whine without nonlinear phenomena (Darjal); *i* – g-whine, consisting sidebands (Hilda); *j* – f&g-whine, frequency jump from the high to the low fundamental frequency (Hilda); *k* – f&g-whine, frequency jump from the high to the low fundamental frequency (Hloya); *l* – f&g-whine, biphonation, additional frequency bands in the spectrum resulted from nonlinear interaction between the low and the high fundamental frequencies (Hilda).

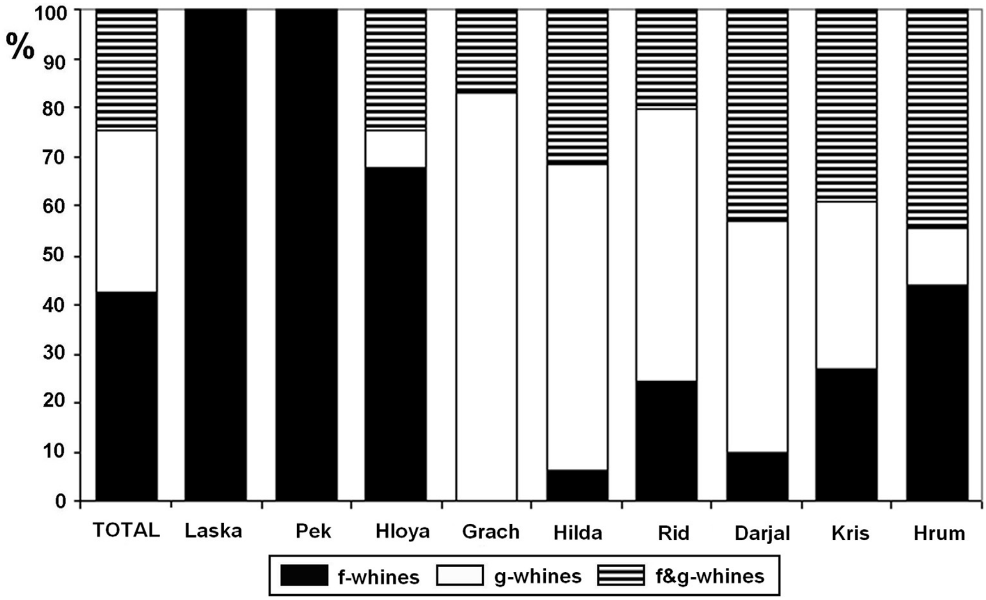

Figure 2: The occurrence of whines only with low (f-whines), only with high (g-whines) and with both the fundamental frequencies (f&g-whines) totally for all nine dogs and separately for each individual, included to this study.