An exploratory study on dogs' vocalizations towards their owner and food in an unsolvable task

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Short title: an exploratory study on vocalizations by dogs when asking for food

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Abstract

Despite ongoing research, many aspects of dogs' vocal communication are not yet fully understood, including how they convey information about items. The aim of the present exploratory study was to determine whether dogs vocalize differently toward their owner and food in an unsolvable task where food is inaccessible and to characterize the acoustic composition of canine vocalizations.

In Savalli et al. (2014; 2016), food was placed in an inaccessible location with the dog present. Next, with the owner present, the communicative modalities of the dogs were recorded, including their vocalizations. Only 21.6 % of the fifty-one dogs vocalized (11 dogs out of 51; 189 vocalizations); 32.27% of the vocalizations were whines and whine-related, and 67.72% were barks and bark-related. Vocalizations may thus be a secondary modality of communication or, more likely, most of the dogs had previously learned from their owners not to vocalize in food-request situations by lack of reinforcement. We characterized four types of whines and five types of barks, respectively making up 1/3 and 2/3 of the vocalizations recorded. No other type of vocalization was found. We found firstly that the majority of the vocalizations (67.7%) were directed at the owner. Secondly, whines were rarely directed at food. Thirdly, though fundamental frequency (F0) and duration did not statistically differ for each type of vocalization, whether directed at the target or at the owner, we found a tendency of specific sub-unit of a bark to have a higher F0 and lower duration when dogs gazed at the target compared when the gazed at the owner. This type of vocalizations was thus not used similarly according to the target viewed, indicating that dogs employ different types of vocal coding to call for attention. Given the small number of dogs who vocalized in this study, future studies will involve a larger group of dogs who will be tested outdoors with an inaccessible toy to enable more vocalizations. This exploratory study opens perspectives in understanding needs expressed by dogs.

Keywords: dog, unsolvable task, vocalization, whine, bark

1. Introduction

Dogs communicate to their human partners about an inaccessible target mainly by using gaze alternation between the human and the target and by positioning themselves close to the target. Extensive research using the unsolvable task paradigm has determined that these gaze and positioning modalities fit the criteria of functional referential and intentional communication (Gaunet, 2008; Gaunet and Deputte, 2011; Gaunet and El Massioui, 2014; Savalli et al., 2014, 2016; Miklósi et al., 2000; Townsend et al., 2016). In addition, these signals convey attention-getting and deictic information. The abovementioned authors have also shown that dogs communicate using sonorous mouths licks, touch the owner, whine and bark. To date, however, no attention has been focused on the potential differences in vocal coding of the target according to the direction of dogs' gaze nor on the acoustic compositions of these vocalizations.

Initially discovered in vervet monkeys which produce three distinct alarm call variants according to the predator encountered (Seyfarth et al., 1980ab), vocal signals meeting the criteria of functional reference (see Savalli et al., 2014 for the criteria) have since been described for social, food, and alarm calls for a range of primate taxa (Clay et al., 2012; ; Fischer and Price, 2017; Seyfarth et al., 1980ab; Seyfarth and Cheney, 1986; Slocombe and Zuberbühler, 2006; Wheeler, 2010; Zuberbühler, 2003). Functionally referential vocalizations contain contextual features defining the ‘‘referent’’ and elicit specific responses in perceivers even in the absence of the supposed referent (Wheeler and Fischer, 2012). Studies on chimpanzees and bonobos have also revealed that calls vary according to the food presented and trigger different reactions: information related to appetence/motivation, if not the exact nature of the food (referentiality) is included in the signal (Clay and Zuberbühler, 2011; Slocombe and Zuberbühler 2005, 2006).

In canids, domestication has had an effect on communicative mechanisms involving people in interactions. As a point of fact, Gogoleva et al. (2011) showed that aggressive and

unselected foxes selectively produced vocal activity for the duration of the presence of an unfamiliar human at their cage, while foxes of tame strain displayed bursts of vocal activity for the first minute after the appearance of an unfamiliar human, which faded quickly. Affiliative behaviors were also displayed, similar to domestic dogs, indicating a positive emotional state arising from interactions with people, acting to attract human attention.

Dog vocalizations have also been found to vary according to context, especially social context. For instance, barks differ according to whether the dog is playing, in isolation or in the presence of a stranger (Cohen and Fox, 1976; Pongrácz et al., 2005; Yin and McCowan, 2004). Dogs reliably produce different growl variants depending on the external social event, particularly during threatening situations compared to when playing with a human (Faragó et al., 2010a). Using playbacks, variations in growls have been shown to be meaningful to receivers. Dogs spent less time in contact with a food item after being played back food-guarding growl variants than either play or 'threatening stranger' growls. Because dogs were just as likely to approach the food source while hearing 'threatening stranger' growls as play growls, the authors argue that the dogs were not responding purely to the emotional information in the call; instead, the calls provided specific information to receivers regarding the ongoing social context (Faragó et al., 2010a).

Dog barks also have a considerable effect on humans' inner state, following Morton's (1977) motivation–structural (MS) rules: low-pitched barks with short inter-bark intervals were rated as aggressive, while high-pitched barks with long intervals were considered playful and happy (Pongrácz et al., 2006). Meaning attribution to vocalizations has been shown to some extent (Pongrácz et al., 2005, 2006): humans can determine if a situation involves aggression, fear or isolation from dog vocalizations, whether or not they are dog owners.

There also appear to be breed-typical differences in the production of barks. In a study on nine different breeds of dogs, Feddersen-Petersen (2000) found a high level of variability in

their vocalizations: each breed produced between two and twelve subtypes of barking based on spectrographic features and behavioral correlates. Categories of function or emotion included ongoing social play, play soliciting, exploration, caregiving, social contact and "greeting,", loneliness, and agonistic behaviors. Furthermore, Molnár et al. (2008, 2009) categorized individual dogs based on their barks, but no study has demonstrated individual recognition based on auditory information (Taylor et al., 2010). Additionally, these authors and Faragó et al. (2010b) showed that dogs perceive size-related information in growls.

The vocal repertoire of dogs thus conveys a range of socially relevant information about the context and the signaler, including its breed and body size, motivational state and almost certainly some measure of individual identity (Taylor et al., 2010).

Still, there is not yet a full and exhaustive repertoire of dogs' vocalizations according to context or intra- or inter-species interactions (Cohen and Fox, 1976; Feddersen-Petersen, 2000; Tembrock, 1976). On the basis of spectrographic evidence, Cohen and Fox (1976) identified twelve basic vocal sound types of the canid species (mews, grunts, whines/whimpers, yelps, yips, howls, coos, growls, coughs, barks, clicks, tooth snaps). Feddersen-Petersen (2000) described ten classes of vocalizations in dogs and wolves, grouped into three categories of sounds: harmonic/tonal (whines, yelps, screams, whimpers), intermediate (moans, growls, barks) and noisy (woofs, snarls, yaps); see also Faragó et al. (2014). Finally, Tembrock (1976) described the temporal structure and the frequency composition of ten classes of vocalizations in various canids. The major factors of variability are breed and context. There is a full consensus that, in a social context, dogs pant (Faragó et al., 2014), mouth-lick (Faragó et al., 2014; Gaunet and El Massioui, 2014; Savalli et al., 2014, 2016), bark, growl, whine and sometimes howl (see Taylor et al., 2014 and Faragó et al., 2014).

As is the case in human communication, fundamental frequency (F0) and duration are two of the most meaningful characteristics in bioacoustic investigations of vocal communication in

dogs, among others including harmonic-to-noise ratio, between vocalization intervals, intensity or tonality (e.g. Pongrácz et al., 2006, Riede and Fitch, 1999). Since only F0 and duration are robust in regarding recording conditions, we will focus on these characteristics in the present study in the case of barks and whines. Barks have been characterized as short, plosive, and possibly noisy, produced in sequence or isolated, and with variable pitch across breeds, individuals and contexts (Taylor et al., 2014). Their spectral shape looks like a 'Christmas tree' formation due to a progressive increasing followed by a lowering of energy in higher frequencies (Feddersen-Petersen, 2000; Scott, 1976). A bark unit can be described as follows: Feddersen-Petersen (2000): F0: 120-1640 Hz, duration: 69-1000 ms, for 6 breeds; Cohen and Fox (1976): F0: maximum of 2000 Hz, duration: < 500 ms; duration varies between 100 and 500 ms as compiled by Lord et al. (2009); Faragó et al. (2014) reported bark durations between 0.2 and 0.6 sec. Whines have been characterized as tonal, high pitched, noiseless vocalizations. The nuances of whines were described by Feddersen-Petersen (2000) for six breeds: 400-8800 Hz, duration: 38-2025 ms. Yelps, screams and whimpers have also been described (Cohen and Fox, 1976: F0: 400-3500 Hz, no description for duration).

Yeon (2007) demonstrated that barks are produced during contexts involving alerts/warnings, territorial defense/rivalry/defense, individual identity, social facilitation, play solicitation, greetings, or calls for attention; whines are produced during greetings, active submission, or frustration or attention-seeking contexts. The present study addressed the following question: is there a difference between dogs' vocalizations toward the target and their vocalization toward the owner when the target is a desirable food inaccessible to the dog? In the absence of existing research, the present study uses existing material produced by Savalli et al. (2014; 2016). One of the present aims is to quantify vocalizations produced in a food request context in terms of percentages of dogs and numbers of vocalizations per type of vocalizations found. We also examine differences in the acoustic characteristics of the

vocalizations a dog produces when gazing at the target compared to vocalizations when gazing at their owner, as a mean to study if vocalizations at the target and at the owner differ. In food (or toy) requesting tasks, dogs have been shown to display different behaviors towards the owner as compared to the target. Using videos and sounds collected with a unidirectional microphone placed in the center of a room (Savalli et al., 2014, 2016), the present study is the first to use an unsolvable task to explore qualitative and quantitative descriptions of the two main canid vocalizations: barks and whines and their related vocalizations (but see Pongrácz et al., 2017 in the case of a separation context). Slocombe and Zuberbühler (2006) showed that chimpanzees may include the exact nature of the food may be included in the signal (referentiality) in chimpanzees, and King and Janik (2015) demonstrated that in the case of dolphins, specific social signals were significantly correlated with food call production, and that these calls rarely occurred in the absence of food. Given the analogies and convergence on referential communication behaviors of monkeys, apes and dogs, we expected dogs to discriminate the target and the social agent when vocalizing toward them, both in terms of types of vocalizations (and their number) and acoustic characteristics. Although Savalli et al. (2014; 2016) found that gaze at the food and at the owner fitted all the operational criteria for functionally referential and intentional communication (previously found in a study with chimpanzees, Leavens et al., 2005), this was not the case for the number and duration of vocalizations, likely because there were too few occurrences. Accordingly, due to the lack of an exhaustive and dedicated study testing referentiality and intentionality of vocalizations directed at the target and receiver in the pet dogs, these vocalizations are thought of as reflecting the inner state of the dogs, as an attention-getting signal.

2. Methods

2.1. Data collection and participants

178 Vocalizations were collected by Savalli et al. (2014, 2016) in an unsolvable task: after
179 habituation to the room, a helper took a pet dog to an experimental room with food, put the
180 food on one of two shelves (randomly chosen) that were inaccessible to the dog, and left the
181 room. The owner entered the room and remained quietly standing, equidistant from the two
182 shelves, for 30 seconds during which the owner visually followed the dog with his/her gaze;
183 see Savalli et al. (2014, 2016) for all details on the procedure. This condition, called
184 "Food+Owner", was used three times in the 2014 study; see the video in Savalli et al. (2014).
185 The identical condition in Savalli et al. (2016) was called "Visual following." For the aim of
186 this study, just these four identical conditions were taken into account. In total, 51 pet dogs
187 living in households were tested by Savalli et al. (2014, 2016). Behaviors analysed in these
188 two previous studies were the visual communicative behaviors (e.g. gaze alternation, gaze
189 direction). No dog had been training to vocalize on command. Their multimodal behaviors
190 (including vocalizations but without dissociating the types of vocalizations, i.e. barks, whines,
191 etc.) were also recorded by two video cameras and a unidirectional microphone placed in the
192 center of the room and attached to a crossbar connecting the two sides of the room (Rode
193 NT55A); see Figure 1. Their durations and numbers were extracted using Actogram Kronos
194 software (Octarés Edition, http://www.actogram.com/index.htm) by Savalli et al. (2014,
195 2016). As a byproduct of the Savalli et al. (2014, 2016) studies, the present study kept and
196 analyzed vocalizations produced when the dog's head/nose was oriented toward the food and
197 towards the owner's head and face. These additional data were recorded to address the present
198 aim to compare vocalizations towards the food and towards the owner.
199 A total of 189 vocalizations produced by eleven dogs were collected and categorized. A
200 small number of vocalizations were removed from the data set (total = 5, among these 3 barks
201 and 2 whines) because of background noise or ambiguity over the direction of the dog's head;
202 see Table 1 for characteristics of the dogs included in the analysis.

INSERT FIGURE 1 ABOUT HERE

INSERT TABLE 1 ABOUT HERE

2.2. Ethics Statement

This study was approved by the Committee for Ethical Research in Animals of the Institute of Psychology of the University of São Paulo (N° 004.2012). Owners consented to their dogs' participation.

2.3. Extraction of acoustical boots and categorization

For each dog, the soundtrack (16 bits – 44.1kHz) was extracted from the video, and then analyzed with Praat software, version 4.4.32 (Boersma and Weenik, 1996).

The videos were re-used to determine the periods of interest for acoustic analysis with Praat: vocalizations produced while gazing at the target and at the owner. Next, vocalization boundaries were precisely defined using both the oscillogram and the spectrogram. An auditory perceptual evaluation of the vocalization coupled with a visual inspection of oscillograms and spectrograms was used to further subdivide vocalizations into units when necessary. The envelope was taken into account for the visual inspection of the oscillogram, whereas frequency composition and voiced/unvoiced mode were used for the spectrogram. The name and category of each vocalization as well as its segmentation (overall boundaries and subunits) were agreed upon by three judges (two of the authors and Stéphanie Mana).

Several acoustic parameters were extracted using Praat. Duration and F0 (fundamental frequency) were calculated for voiced segments.

3. Qualitative and quantitative analysis

We first provide the percentage of dogs who vocalized out of the 51 dogs recorded, and we indicate the mean and standard deviation of the number of vocalizations. We then provide the extracted list of vocalizations and their description from the corpus collected, i.e. the vocal repertoire in terms of typical whines/barks and whine/bark-related vocalizations. We collected the occurrences (189) of these two types of vocalizations when they were directed at the target or at the owner. The comparison between the number of vocalizations according to the type (i.e. typical whines or barks, and whine- or bark-related vocalizations) and their direction (target or owner), as well as the interaction between these two factors were carried out using a GEE (Generalized Estimating Equation) with the number of vocalizations as a counting variable and the logarithm as a link function. The Wald statistic was used for tests. The within-dogs' dependence was incorporated by using an exchangeable structure, assuming that correlations among measures taken from the same dog were the same. Additionally, we analyzed the distribution of the vocalizations for the four types of whines and the five types of barks also identified using GEE models with the same specification for the two directions of gazes separately.

In the next section, we provide an *Overall description* of the acoustic characteristics of each type of whine. We then provide information about the *Distribution of dogs according to the four types of whines (GEE)*. The acoustic parameters (F0 and Duration) according to the direction are then presented. The effect of the direction of the dog's gaze (Owner or Target) on the frequency F0 and duration of whines was analyzed with linear mixed models (LMM) considering the dog's identity as a random effect (within-subject effect). The mixed model was compared to the independent model (excluding random effect) based on the evaluation of Akaike Information Criteria. For all models, except for the duration of the bark sub-unit a, the lowest Akaike Information Criterion (AIC) was obtained when the random effect of the dog was incorporated. Residuals were visually analyzed and considered acceptable for all models.

Finally, we describe the number of bouts in a row (from 1 to 7) of whines towards the target and the owner.

In the last section, we first provide an *Overall description* of the acoustic characteristics of barks. Next, we focus on the *typical bark*, first with a description of its acoustic characteristics (subdivided into units).

We then describe the *Distribution of the composition of a typical bark* (i.e. which dogs used the various units and their number of vocalizations), with a GEE model. The acoustic parameters (F0 and Duration) of the sub-units according to the direction of the typical bark (owner vs. target) are then presented. The effect of the direction of gaze (Owner or Target) on F0s and durations of the bark sub-units were analyzed with linear mixed models (LMM) considering the dog's identity as a random factor (within-subject factor), as mentioned above. Additionally, the number of bouts in a row (from 1 to 4) of the typical bark towards the target and the owner are presented, which we fed into a GEE model. Finally, we describe the other types of barks in terms of distribution of occurrences across dogs and across types of barks, as well as their acoustic forms.

A second naïve observer independently coded 46% of the sample, i.e. frequency of typical barks when gazing at the owner and at the target. The exact same occurrences were found. Additionally, we calculated the Kendall's concordance coefficient for durations of these barks that were respectively 0.83 and 0.81, indicating a good agreement between raters.

4. Results

4.1. *Vocalization description and categorization*

The proportion of dogs that vocalized was 21.6% (i.e. 11 out of 51 dogs). Additionally, the number of vocalizations varied considerably between dogs, from one to 51 occurrences (mean = 17.2, sd = 16.2), with a total of being 189.

Using spectrogram and auditory analyses, we identified two types of vocalizations directed at the target and at the owner: whines composed of typical whines and whine-related vocalizations (3 types), and barks composed of typical barks and bark-related vocalizations (4 types). Table 2 presents the distribution of vocalizations according to the types of vocalizations found and the direction of the dog's gaze (target or owner) for 189 occurrences produced by 11 dogs.

INSERT TABLE 2 ABOUT HERE

Table 2 shows that most vocalization occurrences consisted in barks, then in whines (67.72% and 32.27%, respectively). They were mostly directed at the owner (67.7%), then at the target (32.3%). Table 2 also reveals that the main vocalizations (see the four cells in italics, i.e. all whines and typical barks) were not produced by all dogs, but only by four to six different dogs out of the eleven dogs, in each of the four cases.

The GEE model (estimated parameters presented in Figure 2) for the number of vocalizations according to the type (whines or barks) and their direction (target or owner) indicated a possible interaction between types of vocalizations (2) and gaze directions (2) (Wald = 3.50, df = 1, p = 0.0615). As a matter of fact, there was no difference between numbers of barks and of whines when directed at the owner (Wald = 0.64, df = 1, p = 0.4237); however, there were significantly more barks than whines directed at the target (Wald = 4.65, df = 1, p = 0.0310). No difference was found between the number of barks directed at the owner compared to the target (Wald = 0.39, df = 1, p = 0.5314). However, the number of whines directed at the owner was significantly greater than those directed at the target (Wald = 6.27, df = 1, p = 0.0123).

INSERT FIGURE 2 ABOUT HERE

In the case where the dogs were gazing at the target, it was not possible to compare the distribution of the four types of whines and the number of vocalizations using the GEE model due to the small number of occurrences recorded. In the case where the dogs were gazing at the owner, yelps could not be included in the analysis, but the GEE model used to compare the three other distributions indicated that there was no difference between them (Wald = 1.28, df = 2, p = 0.5266). In contrast, there were considerably more typical barks directed in each direction than the four other types of barks (at the target: Wald = 604.31, df = 4, p < 0.0001; at the owner: Wald = 14.17, df = 4, p = 0.0068, respectively).

4.2. Typical whine and whine-related vocalizations

4.2.1. Overall description

Our recordings of whine vocalizations matched all the types of whines described by Tembrock (1976) and Feddersen-Pettersen (2000). The vocalizations that we recorded were high frequency, tonal, narrow-banded and noiseless, along with the whines in Figures 3, 4, 5 and 6 below. Their intensity was largely stable and their harmonic composition sometimes visible (cf. the four types over time).

Typical Whines. These whines were high frequency / high pitched, with the energy of harmonics that varied over time; cf. Fig. 3.

INSERT FIGURE 3 ABOUT HERE

Screams. This vocalization was high frequency, tonal, narrow-banded, and noiseless, along with a clear harmonic composition; cf. Fig. 4.

INSERT FIGURE 4 ABOUT HERE

Whimpers. This vocalization was high frequency, tonal, nearly monofrequency and noiseless (i.e. strong and stable pitch) with no harmonic composition visible; cf. Fig. 5.

INSERT FIGURE 5 ABOUT HERE

Yelps. This vocalization was high frequency and tonal, with a clear dominant frequency, and was noiseless with little harmonic composition; cf. Fig. 6.

INSERT FIGURE 6 ABOUT HERE

4.2.2. Distribution of dogs according to the four types of whines

Eight of the eleven dogs who vocalized produced whine vocalizations. Each type of whine was produced by a similar number of dogs (i.e. three or four). Additionally, only four dogs produced two or three types of whines and whines-related vocalizations (Cachoro: yelps and whimpers; Phoebe: whines, screams and yelps; Mel: whines and whimpers; Mancha: whimpers and screams). The four other dogs produced only one type of whine-related vocalization. Finally, the GEE model indicated that there was no difference in the number of dogs that produced the four types of whines (Wald = 1.75, df = 3, p = 0.6269). See Table 1 in the supplementary material.

4.2.3. Direction of whines and concomitant acoustic parameters (F0 and duration)

The results obtained from the linear mixed models revealed that the F0 and durations of whines addressed to the owner and the target did not differ; see Table 2 in the supplementary material.

4.2.4. Number of bouts in a row of whines towards the target and the owner

The number of bouts for all whines when the vocalization was produced toward the owner (see Table 3 in the supplementary material.) tended to be produced alone or in a sequence of two bouts rather than in a sequence of three or more; however, it was not possible to run the GEE model to validate or invalidate this observation.

4.3. Typical barks and bark-related vocalizations

4.3.1. Overall description

Barks, or what we call 'typical barks' are usually described in the literature as presenting a Christmas-tree shape, i.e. a rising part with an increasing pitch (and harmonics) over time, then a more or less symmetric decreasing pitch (and harmonics) of a more or less similar duration, including a stable part, cf. Faragó et al., 2014 and Fig. 1a in the supplementary material, see the second bark for a stable part; Feddersen-Petersen, 2000 and Fig. 1b in the supplementary material, mostly described in Scott, 1976).

4.3.2. Typical barks

In our case, out of 87 barks, we recorded only five barks that did not include the stable part of the Christmas tree (see Fig. 7 for an item representative of a Christmas-tree-like bark); all five were produced by a single dog. Scott (1976) noted that "barks differ in quality and quantity"; our recordings regarding quality are in agreement with his observation, and see Table 2 for variations in quantity.

INSERT FIGURE 7 ABOUT HERE

Based on the observation of typical spectrograms of barks', a clear stable central and tonal segment could be preceded by a noisy segment (the onset) and sometimes followed by a short segment (the offset) of the bark. In order to analyze and compare all the barks and take into account potential onsets or offsets, we considered three sub-units in typical barks; cf. Fig. 8.

- Sub-unit "a": the start of the vocalization. This sub-unit is a transition to the sub-unit "b" and corresponds to the left part of the Christmas tree. In general, no pitch was detected at the beginning of sub-unit "a"; it appeared and rose quickly. This segment was quite noisy.
- Sub-unit "b": this was the stable part of the vocalization. The harmonic structure was clearly visible and stable, and no modulation (intensity, frequency) was observed.
- Sub-unit "c": this sub-unit, when it existed in our corpus, signaled the end of the call; it corresponded to the right-hand part of the Christmas tree.

INSERT FIGURE 8 ABOUT HERE

4.3.2.1. Distribution of the composition of the typical bark

Only four of the eleven dogs that vocalized produced typical barks that could be composed differently with their a, b or c parts, presenting different configurations; see the supplementary material. Each type of bark configuration was produced by a similar number of dogs (one or four); all four dogs produced the configuration a, ab and abc, while ac, bc or b configurations were each produced by one dog (Nana or Mila). Finally, a very small percentage of barks (4.65%) present the Christmas-tree pattern per se (ac) and most of the

barks (45.36 %) present ab sub-units; however, it was not possible to run a GEE model to validate or invalidate the observation due to instability of estimation.

4.3.2.2. Direction of the typical bark and concomitant acoustic parameters (F0 and duration)

Table 3 shows the adjusted mean and standard errors for F0 and durations obtained from linear mixed models for the sub-units a, b, and c of barks toward the owner and the target. The results revealed that barks addressed toward the owner and the target did not differ. We found a tendency for sub-unit b to have a higher F0 and lower duration when dogs gazed at the owner compared to the target; however, it was not significant at a level of 5%.

INSERT TABLE 3 ABOUT HERE

4.3.2.3. Number of bouts in a row for typical barks towards the target and the owner

To extract the number of bouts within a production for barks composed of the 3 sub-units, we considered all barks regardless of the number of sub-units (ac, a, ab, abc, bc, or b). We found mainly single bouts when the vocalization was produced toward the owner or the target (see Table 5 in supplementary material); however, it was not possible to run a GEE model to validate or invalidate the observation.

4.3.3. Other barks

Four novel types of barks were found in our data, representing a small percentage of the total vocalizations (22.64%, cf. Table 2). These four types of barks had not been found in the previously quoted literature. Given the small number of occurrences, we will describe them briefly and only qualitatively. Table 6 in the supplementary material shows that the distribution of these barks varies considerably between dogs.

'Dull Bark' (Fig. 9). This vocalization had a muffled sound. The characteristics of dull barks were stable in time and could not be decomposed into sub-units. The durations ranged from 76 to 280ms. For this weakly tonal and strongly noisy (small harmonic to noise ratio) vocalization, the detection of the first two formants was easy and reliable. F0, F1 and F2 stability over time showed very little variation, in congruence with a monosegmentation.

INSERT FIGURE 9 ABOUT HERE

'Push Bark' (Fig. 10). This vocalization resembled a breathy cough; it was partially tonal and always very noisy. Durations lasted from 99 to 222ms. To our knowledge, this type of vocalization has not been previously described in the literature.

Of the eight vocalizations of this type, most (five) were composed of two segments:

- Sub-unit "a": this part of the vocalization was noisy with no pitch detected, and was the sub-unit more closely resembling a cough.
- Sub-unit "b": this segment was voiced, and still contained a lot of noise. The pitch ranged from 90Hz to 583Hz. This segment presented a higher degree of breathiness than a bark.

INSERT FIGURE 10 ABOUT HERE

'Cooing Flat Bark' (Fig. 11). This bark was an atonal vocalization lasting from 101 to 439 ms and sounded like an exhaled breath. The frequency composition was stable along the vocalization with no perceptible modulation. This vocalization was the noisiest of the repertoire.

The spectrogram clearly shows two formants. The first formant (F1), around 1100Hz, signed the jaw aperture; the second formant (F2), around 2200Hz, indicated the tongue position, i.e. antero-posterior.

INSERT FIGURE 11 ABOUT HERE

'Cooing Bark' (Fig. 12). This cooed vocalization showed a low frequency (270Hz to 470 Hz) band energy concentration slightly modulated around 10%. This sound lasted from 230ms to 715ms, and the five items found were emitted alone (i.e. not in a row). The cooed effect resembles a perceptual vibrato.

This vocalization was similar to ones found by Feddersen-Petersen (2000, called 'vibrato growling'), and by Tembrock (1976, see Figure 6, 'Snarl'), in a smooth/soft version. Both authors characterized this vocalization as wide-banded, composed of extended sounds, a long ascension time, changes in amplitude with a tendency to form cycles, the appearance of more bands, and a primary frequency with an increase in intensity, with vibrato involved in both pitch and intensity.

INSERT FIGURE 12 ABOUT HERE

Discussion

The aim of the present exploratory study was to quantify vocalizations produced in an unsolvable task where food was inaccessible in terms of percentage of dogs and of vocalizations per type of vocalizations found. We also sought to determine whether dogs vocalize differently toward their owner and food in terms of repartition and the acoustic composition of canine vocalizations. The results indicate that this is indeed the case.

Firstly, and interestingly, only 21.6 % of the fifty-one dogs recorded in Savalli et al. (2014; 2016) vocalized. Breed was investigated (Scott, 1976; Feddersen-Petersen 2000) but not revealed to be a factor. A plausible explanation then is that many of the non-vocalizing dogs had previously learned from their owners not to vocalize in situations involving food requests (Duranton and Gaunet, 2016; Henschel et al., 2020). We also found that the number of vocalizations varied considerably between the 11 dogs (1-50 for the total of 189 found). The vocalizing dogs in contrast, may have produced a vocalization at one point when in the presence of their owner and food. And this vocalization may have been rewarded by food. Accordingly, vocalizations can be of various forms, in accordance with the various types we found. Only four to six different dogs produced all the whines and the typical barks, and the various types of whines and barks and units of the barks were not produced by all dogs; see Tables 2, 3 and 6. This variability in vocal productions between dogs may reasonably be based on an effect of the dogs' previous experience with their owners (Duranton and Gaunet, 2016; Henschel et al. 2020), in accordance with Scott's (1976) observation that "barks differ in quality and quantity,".

What did canine vocalizations look like in the present study? Only whine and whine-related and bark and bark-related vocalizations were found (Cohen and Fox, 1976; Farrago et al., 2014; Feddersen-Petersen, 2000; Taylor, 2014; Tembrock, 1976). In the first category, we identified four types of vocalizations already described in the literature. We described five types in the second category, including four new types of barks; we postulate an effect of context.

Most of the 189 vocalizations (67.72%) consisted in typical and related barks, and the other third in whines and whine-related vocalizations. Interestingly, the majority of vocalizations (67.7%) were directed at the owner. The tendency of an interaction between the direction of the vocalization and types of vocalizations, with significantly fewer whines

504 directed at the target, suggest firstly that vocalizations tended to be mostly used to attract the
505 owner's attention to the dog itself rather than to designate the target per se, and thus were
506 essentially a social (King and Janik, 2015), attention-seeking signal (Gaunet and El Massioui,
507 2014; Savalli et al., 2014, 2016; Henschel et al. 2020). Secondly, while the present protocol
508 does not make it to assume a referential property of barks (see the end of the Introduction),
509 these results suggest a different inner state for attention-getting when they bark,
510 comparatively to when they whine. Importantly, the interaction clearly indicates that dogs
511 treat their owner and the food differently by way of their vocal productions. Furthermore, the
512 distribution of the four types of whines appeared to be similar when dogs were gazing at their
513 owner or at the target, indicating flexible use of the different types of whines. In contrast,
514 there were more typical barks than related barks when dogs were gazing at their owner or at
515 the target, indicating that typical barks are the main bark pattern.

516 Statistical analyses did not show that the means of F0 and of durations statistically
517 differed for each type of vocalization according to the direction of the dogs' gaze toward the
518 target and the owner. There was however a tendency for bark b to have higher F0 and lower
519 duration when gaze was directed at the owner compared to the target. In addition, the number
520 of items was too small to be able to compare the distribution of the different lengths of bouts
521 when whine-related vocalizations were produced toward the target or the owner; however,
522 barks appeared to be produced mostly alone.

523 The whine per se and whine-related vocalizations we found matched those reported in the
524 literature based on acoustic characteristics (Feddersen-Petersen, 2000; Tembrock, 1976).
525 They were high frequency, tonal, narrow-banded and noiseless vocalizations, with harmonic
526 composition sometimes visible, corresponding to calls used for short range communication
527 (Taylor et al., 2014). The present ranges of F0 for gazes at the target and at the owner
528 corresponded to those reported in the literature. F0 has been reported to vary from 400 Hz

(Cohen and Fox 1976; Tembrock, 1976) to 8800 Hz (Feddersen-Petersen, 2000; Schassburger, 1993), and F0 is known to depend on dog size and breed (Riede and Fitch, 1999), elements that are variable in our experiment. Possible differences with the literature could also be due to context. Whining is reported in contexts involving greetings, frustration, active submission, and attention-seeking (Yeon, 2007), whereas our recordings likely involved attention-seeking to get food (Gaunet and El Massioui, 2014; Savalli et al., 2014, 2016). We thus propose that the range of F0 we found may be linked to the socio-physical recording contexts that often differ between studies. Our range is likely to be specific to an attention-getting communicative activity, though variability may occur according to sizes and breeds of dogs. In contrast, the durations of whine-related vocalizations are not systematically reported in the literature. Still, the durations we found were in the lower range of the durations previously reported (Federsen-Petersen, 2000; Cohen and Fox, 1976; Faragó et al., 2014).

Regarding the production of barks, we found the typical Christmas-tree production (Faragó et al., 2014; Feddersen and Petersen, 2000) to be the most common compared to the four other related barks we found. While whine and whine-related vocalizations were produced by eight dogs, only four dogs barked; we believe this is likely due to the request from owners for their dogs not to bark at food in general. Again, in contrast with whining, typical barks were directed equally towards the owner and the target. The acoustic characteristics of the typical barks found matched those recorded in the literature, especially in non-aggressive contexts (i.e. higher peak, mean, and range of F0, Feddersen-Petersen, 2000; Yin, 2002). The presence of three segments in the typical bark may reveal a specific vocal coding. The in-depth analysis of the acoustic characteristics we performed revealed a statistical tendency for the b segment of the typical bark to have higher F0 and lower duration during gazes at the target than during gazes at the owner. Adding more dogs and more occurrences of barks to the study could reveal more marked differences.

554 None of the four related barks (dull, push, cooing flat and cooing barks) is described in
555 the literature. Interestingly, the latter resembled a variant of the typical bark with a poor
556 harmonic structure and a high noise level. We hypothesize that these barks were generated
557 and maintained by positive reinforcement within each specific human-dog pair in earlier
558 interactions, as has been shown for other communicative behaviors (Gaunet, 2008; Gaunet
559 and Deputte, 2011; Gaunet and El Massioui, 2014; Savalli et al., 2014, 2016; Miklósi et al.,
560 2000; Townsend et al., 2016).

561 Barks have been found to be produced in various contexts and thus seem a priori to be
562 non-specific: they are used for long distances and proximal interactions, in various contexts
563 such as aggressive signaling, the defense of self and territory, drawing attention, separation
564 and submissive behaviors, and playful and positive situations (Cohen and Fox, 1976; Faragó
565 et al., 2014; Taylor et al., 2014). Barks and whines thus convey different attention-getting
566 inner-state content, with effects of breed, size and individual experience potentially at play.

567 Given the convergence of communicative behaviors between dogs, monkeys and apes,
568 and that vocalization in dogs is said to have developed to enable dogs to communicate with
569 humans (Gogoleva et al., 2011; Larranaga et al., 2015; Pongrácz et al., 2006), the present
570 results indicate specific vocal coding in dogs' vocalizations worth examining in a more
571 systematic manner. Note that only 11 vocalizations occurred while the dogs were not gazing
572 either at the target or at the owner, confirming the importance of vocalizations associated with
573 gaze direction at a social agent or a desirable target.

574 To conclude, does the present study suggest that dogs' vocalized signals should be
575 conceived as reflecting different attention-getting signals? In other words, was there a
576 difference between dogs' vocalizations toward the target or toward the owner? The
577 differential distribution of whines and barks according to gaze direction and the tendency for
578 the stable segment of the typical bark to differ according to the owner vs. the food suggest

579 that this is the case. So, although we found a limited differentiation of vocal characteristics
580 per se according to the direction of gaze (owner vs. food) in an unsolvable task, this is likely
581 due to a limited control of the position of articulators that introduce variations in formant
582 positions, and to the anatomy of dogs and in particular the length of the vocal tract (see Taylor
583 et al., 2014). In this exploratory study, we provide a path to expand research on the content of
584 vocalizations, since some argue that the vocal communication of the canid species developed
585 with humans during domestication (Gogoleva et al., 2011; Larranaga et al., 2015; Pongrácz et
586 al., 2006). Though we started with a large number of dogs (51), only 11 vocalized, resulting in
587 a total of 189 vocalization occurrences, a fact which should be taken into account in future
588 studies which should include an even larger number of dogs to form a larger corpus of
589 vocalizations. Future studies should also focus on only one breed, and take place outdoors and
590 with a toy; these two last experimental characteristics would enable a greater proportion of
591 dogs to vocalize. Adding these characteristics to the paradigm by Savalli et al. (2014) will
592 make it possible to study referentiality and intentionality in the acoustical content of dogs'
593 vocalization, and possibly show evidence of more than an affective state within the
594 vocalizations. In other words, if acoustical characteristics of vocalizations differ when
595 directed at an owner or at food, and the criteria for referential and intentional communication
596 are fulfilled, we may hypothesize proto-semanticity in dog vocalizations. Finally, temporal
597 characteristics (cf. Yin, 2002 for barks and Taylor et al., 2009 for growls) might provide a
598 guide to motivational state because these characteristics are influenced by changes in the rate
599 of respiration and/or muscular tension in the vocal folds (Hauser, 2000; Bachorowski and
600 Owren, 2008). A study of intercalls should thus be another avenue to pursue to find evidence
601 of specific vocal coding in dogs' vocalizations, since the variability of a signal may reflect the
602 function of the signal (Scott, 1976).

603 The present study opens perspectives in terms of understanding needs expressed by dogs.
604

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Tables

Dogs	Breed	Sex	Age (in years)	Weight (Kg)	Number of Vocalizations
Mancha	Mongrel+Border	F	8.8	33	16
Cacchoro	Mongrel	M	3	29	13
Netuno	American Staffordshire terrier	M	5.5	40	43

Bartolomeu	Labrador	M	6	35	23
Flavio	Mongrel	M	3	29	1
Kiara	Golden retriever	F	3	36	1
Nana	Schnauser	F	5	20	13
Phoebe	Mongrel	M	12	32	8
Eros	Labrador	M	9	36	15
Mel	Mongrel	F	8	32	5
Mila	Golden retriever	M	7	40	51

728 Table 1. Characteristics of the dogs.
729

730

731

	Whines: Typical whines & whine-related vocalizations					Barks: Typical barks and bark-related vocalizations						Total number of vocalizations	% of vocalizations
	Typical whines & whine-related	Typical whines	Yelp	Whimper	Scream	Typical barks and bark-related	Typical barks	Dull bark	Push bark	Cooing flat bark	Cooing bark		
Number of vocalizations during Gaze Target	9 *by 4 different dogs (5,2,1,1)*	1	6	0	2	52	35 *by 4 different dogs (21,9,1,2)*	4	6	3	4	61	32.3
Number of vocalizations during Gaze Owner	52 *by 6 different dogs (18,16,11,3,3,1)*	11	7	19	15	76	52 *by 4 different dogs (12,2,5,30)*	19	1	3	1	128	67.7
Total number of vocalizations	61	12	13	19	17	128	87	23	7	6	5	189	100
% of vocalizations	32.27	6.34	6.87	10.05	8.99	67.72	46.03	12.16	3.70	3.17	2.64	100	

732 Table 2. Numbers of vocalizations by category and direction of gaze. In italics, the number of different dogs that presented whines, whine-related and typical bark
733 vocalizations for both directions of gaze (with the number of occurrences per dog).

Sub-unit a	F0 (Hz)		Duration (ms)	
	Gaze Owner	Gaze Target	Gaze Owner	Gaze Target
Mean (SE)	533.73 (90.96)	461.93 (93.72)	63.11 (5.19)	69.34 (5.19)
Min – Max	285 – 1022	203 – 854	24 – 207	33 – 135
Number of entries	24	14	32	32
Inferential statistics for means	$X^2 = 1.53$, df = 33, p = 0.2163 (LMM)		$X^2 = 0.72$, df = 62, p = 0.3956 (Independent model)	

Sub-unit b	F0 (Hz)		Duration (ms)	
	Gaze Owner	Gaze Target	Gaze Owner	Gaze Target
Mean (SE)	443.62 (100.49)	501.30 (101.52)	82.77 (18.55)	71.23 (18.74)
Min – Max	213 – 1077	279 – 989	13.8 – 170	30 – 152
Number of entries	47	30	47	31
Inferential statistics for means	$X^2 = 3.34$, df = 72, p = 0.0676 (LMM)		$X^2 = 3.68$, df =73, p = 0.0546 (LMM)	

Sub-unit c	F0 (Hz)		Duration (ms)	
	Gaze Owner	Gaze Target	Gaze Owner	Gaze Target
Mean (SE)	586.20 (157.84)	684.67 (197.15)	65.69 (12.06)	62.89 (11.82)
Min – Max	288 – 1129	323 – 1245	19.3 – 78.4	21 – 115
Number of entries	21	3	27	11
Inferential statistics for means	$X^2 = 0.32$, df = 20, p = 0.5726 (LMM)		$X^2 = 0.07$, df = 33, p = 0.7917 (LMM)	

Table 3. Adjusted Means, Standard Error and inferential statistics from Linear Mixed Models (dog as random effect) for F0 and durations of the three types of units (a, b and c), for barks produced when gazing at the owner and at the target.

748

749 **Figure captions**

750

751 Fig. 1. Experimental layout (schema from Savalli et al., 2014), with the position of the
752 unidirectional microphone that registered vocalizations of dogs.
753 Fig. 2. Adjusted means and standard error of the logarithm of the number of vocalizations
754 estimated by the GEE model.
755 Fig. 3. Whine-related vocalizations (typical whines) from Mila. Duration = 57.5ms - Top:
756 oscillogram (arbitrary unit), Bottom: spectrogram (Hz).
757 Fig. 4. Whine-related vocalizations (screams) from Netuno. Duration =146ms - Top: oscillogram
758 (arbitrary unit), Bottom: spectrogram (Hz).
759 Fig. 5. Whine-related vocalizations (whimpers) from Cachorro. Duration =205ms - Top:
760 oscillogram (arbitrary unit), Bottom: spectrogram (Hz).
761 Fig. 6. Whine-related vocalizations (yelps) from Cachorro. Duration =284ms - Top: oscillogram
762 (arbitrary unit), Bottom: spectrogram (Hz).
763 Fig. 7. The Christmas-tree-like bark of Nana. Duration = 353ms - Top: oscillogram (arbitrary
764 unit), Bottom: spectrogram (Hz).
765 Fig. 8. Detailed description of the 3 sub-units of the barks. Duration=236ms - Top: oscillogram
766 (arbitrary unit), Middle: spectrogram (Hz), Bottom: annotation line that shows « a » (left
767 part), « b » (middle part) and « c » (right part) sub-unit boundaries.
768 Fig. 9. Dull Bark from Eros. Duration = 164ms - Top: oscillogram (arbitrary unit), Bottom:
769 spectrogram (Hz).
770 Fig. 10. Push Bark from Barto. Duration = 186ms - Top: oscillogram (arbitrary unit), Bottom:
771 spectrogram (Hz).
772 Fig. 11. Cooing Flat Bark from Netuno. Duration = 285ms- Top: oscillogram (arbitrary unit),
773 Bottom: spectrogram (Hz).
774 Fig. 12. Cooing Bark from Netuno. Duration = 286ms - Top: oscillogram (arbitrary unit),
775 Bottom: spectrogram (Hz).
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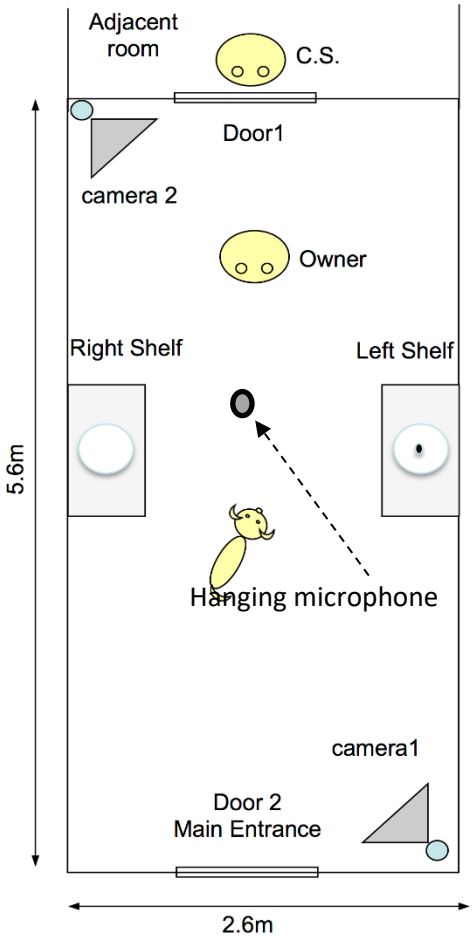
778

779 Fig. 1. Experimental layout (schema from Savalli et al., 2014), with the position of the

780 unidirectional microphone that registered vocalizations of dogs.

781



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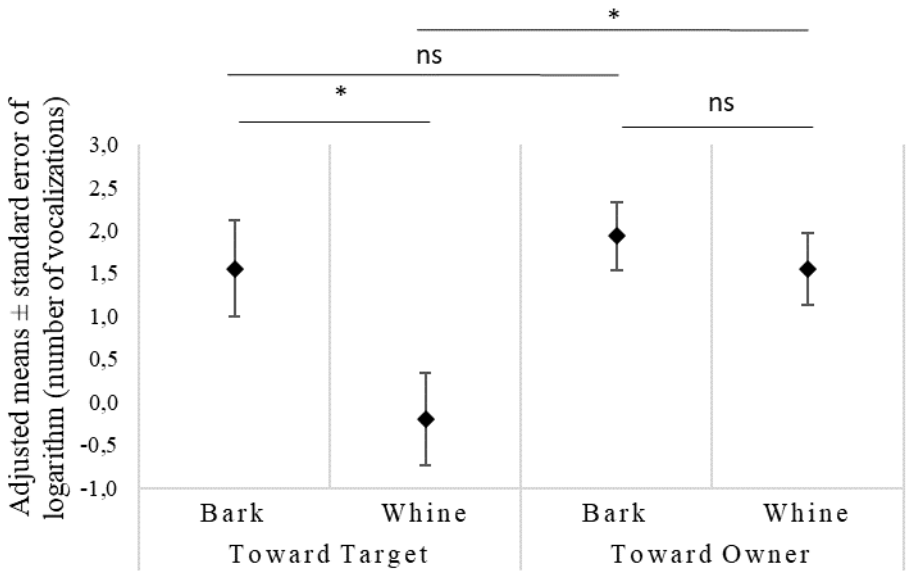

Fig. 2. Adjusted means and standard error of the logarithm of the number of vocalizations estimated by the GEE model.

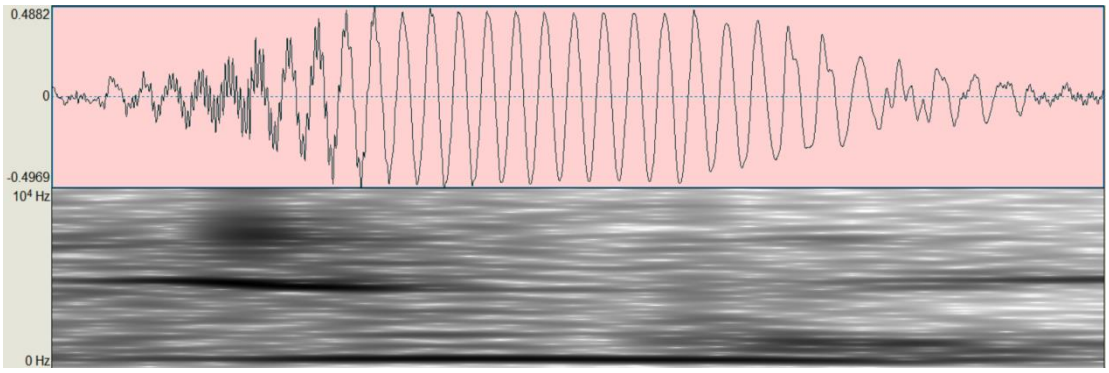

Fig. 3. Whine-related vocalizations (typical whines) from Mila. Duration = 57.5ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

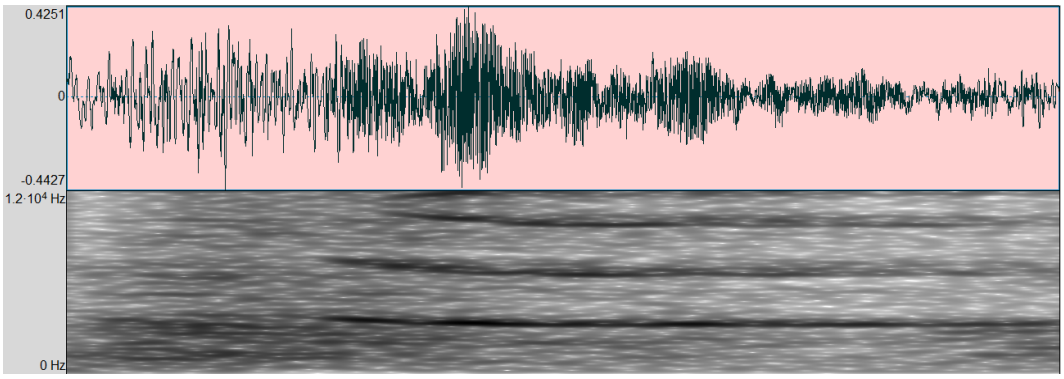

Fig. 4. Whine-related vocalizations (screams) from Netuno. Duration =146ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

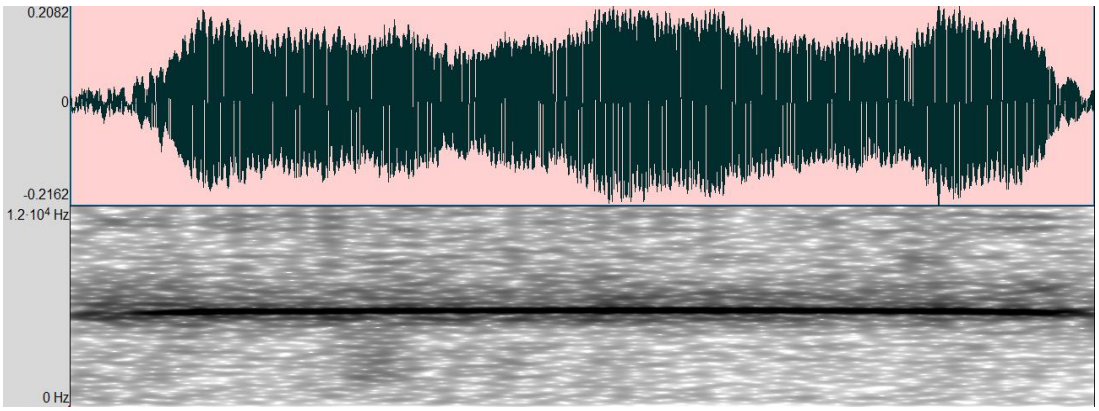

Fig. 5. Whine-related vocalizations (whimpers) from Cachorro. Duration =205ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

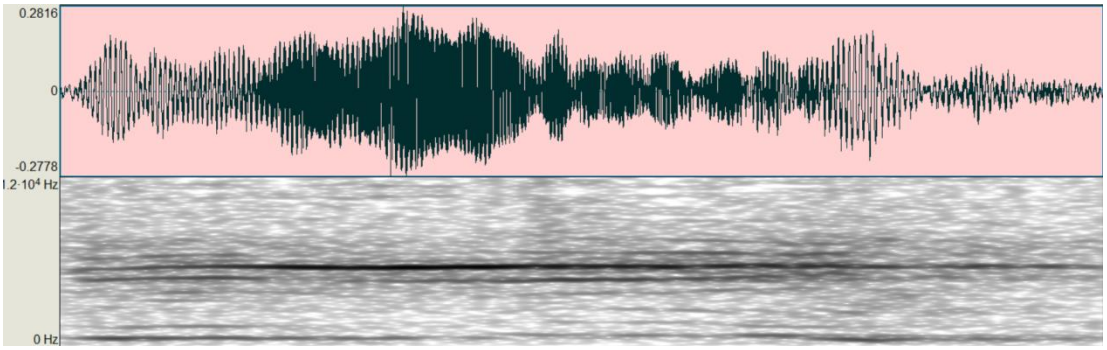

Fig. 6. Whine-related vocalizations (yelps) from Cachorro. Duration =284ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

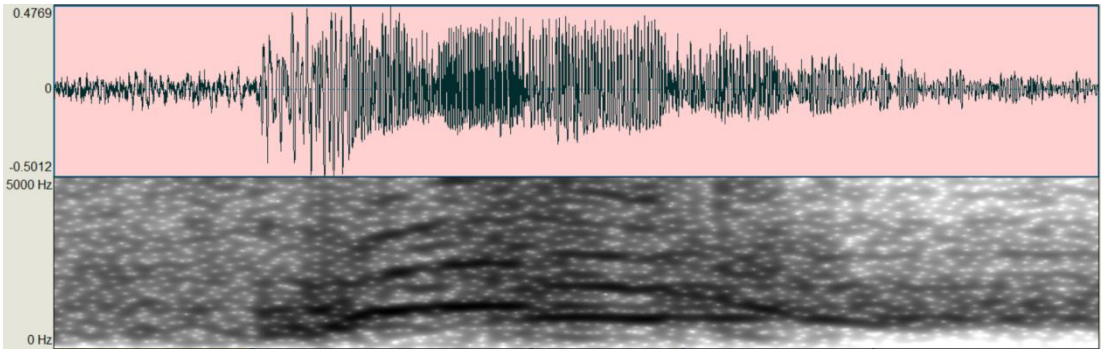

Fig. 7. The Christmas-tree-like bark of Nana. Duration = 353ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

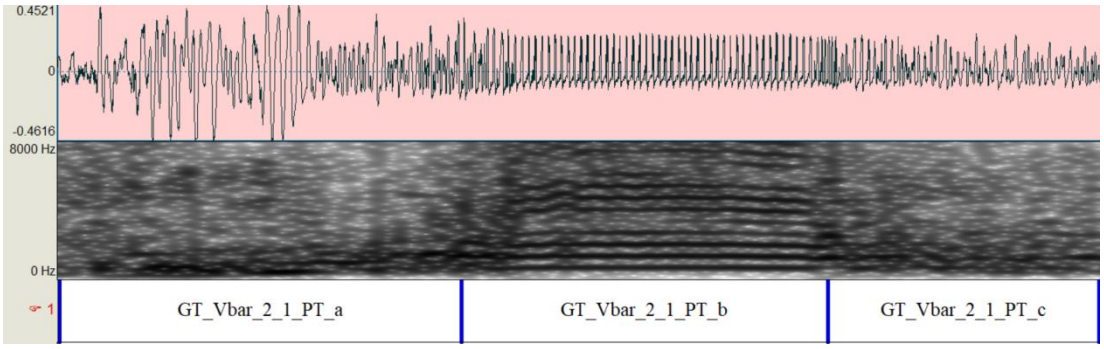

Fig. 8. Detailed description of the 3 sub-units of the barks. Duration=236ms - Top: oscillogram (arbitrary unit), Middle: spectrogram (Hz), Bottom: annotation line that shows « a » (left part), « b » (middle part) and « c » (right part) sub-unit boundaries.

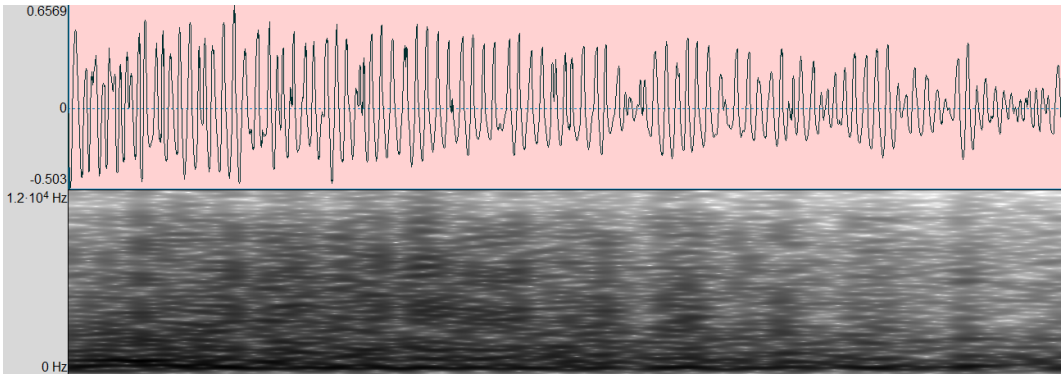

Fig. 9. Dull Bark from Eros. Duration = 164ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

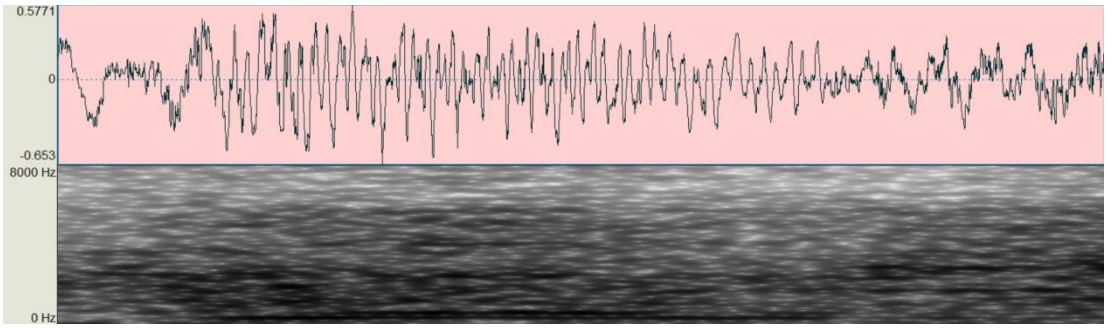

Fig. 10. Push Bark from Barto. Duration = 186ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

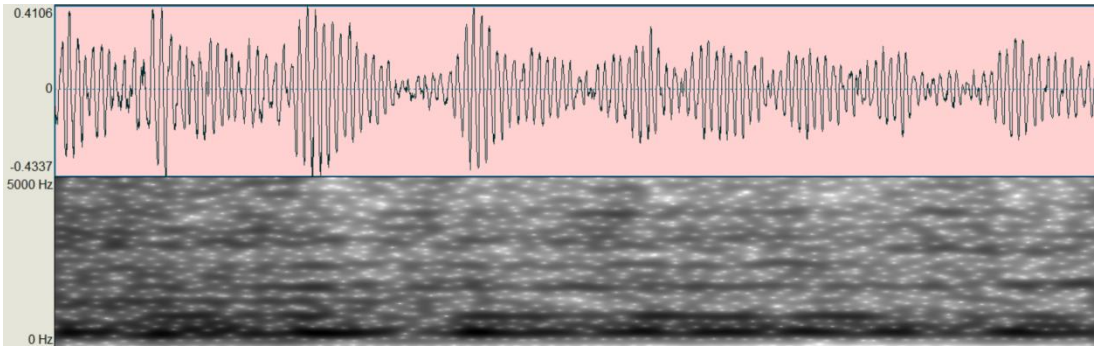

Fig. 11. Cooing Flat Bark from Netuno. Duration = 285ms- Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).

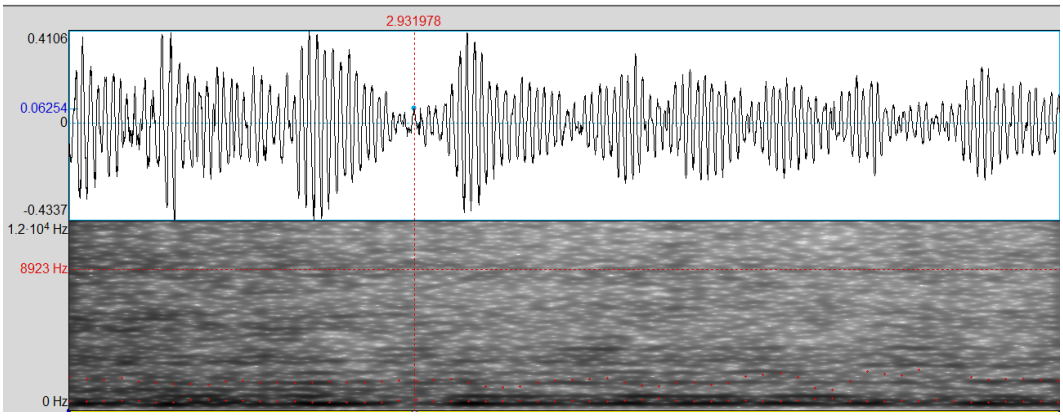

Fig. 12. Cooing Bark from Netuno. Duration = 286ms - Top: oscillogram (arbitrary unit), Bottom: spectrogram (Hz).