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

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

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22 *Declarations of interest: none*

23

Abstract

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

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

50 Keywords: dog, unsolvable task, vocalization, whine, bark
51

52

53 **1. Introduction**

54 Dogs communicate to their human partners about an inaccessible target mainly by using
55 gaze alternation between the human and the target and by positioning themselves close to the
56 target. Extensive research using the unsolvable task paradigm has determined that these gaze
57 and positioning modalities fit the criteria of functional referential and intentional communication
58 (Gaunet, 2008; Gaunet and Deputte, 2011; Gaunet and El Massioui, 2014; Savalli et al., 2014,
59 2016; Miklósi et al., 2000; Townsend et al., 2016). In addition, these signals convey attention-
60 getting and deictic information. The abovementioned authors have also shown that dogs
61 communicate using sonorous mouths licks, touch the owner, whine and bark. To date, however,
62 no attention has been focused on the potential differences in vocal coding of the target according
63 to the direction of dogs' gaze nor on the acoustic compositions of these vocalizations.

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

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

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

83 Dog vocalizations have also been found to vary according to context, especially social
84 context. For instance, barks differ according to whether the dog is playing, in isolation or in the
85 presence of a stranger (Cohen and Fox, 1976; Pongrácz et al., 2005; Yin and McCowan, 2004).
86 Dogs reliably produce different growl variants depending on the external social event,
87 particularly during threatening situations compared to when playing with a human (Faragó et al.,
88 2010a). Using playbacks, variations in growls have been shown to be meaningful to receivers.
89 Dogs spent less time in contact with a food item after being played back food-guarding growl
90 variants than either play or ‘threatening stranger’ growls. Because dogs were just as likely to
91 approach the food source while hearing ‘threatening stranger’ growls as play growls, the authors
92 argue that the dogs were not responding purely to the emotional information in the call; instead,
93 the calls provided specific information to receivers regarding the ongoing social context (Faragó
94 et al., 2010a).

95 Dog barks also have a considerable effect on humans' inner state, following Morton's
96 (1977) motivation–structural (MS) rules: low-pitched barks with short inter-bark intervals were
97 rated as aggressive, while high-pitched barks with long intervals were considered playful and
98 happy (Pongrácz et al., 2006). Meaning attribution to vocalizations has been shown to some
99 extent (Pongrácz et al., 2005, 2006): humans can determine if a situation involves aggression,
100 fear or isolation from dog vocalizations, whether or not they are dog owners.

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

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

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

113 Still, there is not yet a full and exhaustive repertoire of dogs' vocalizations according to
114 context or intra- or inter-species interactions (Cohen and Fox, 1976; Feddersen-Petersen, 2000;
115 Tembrock, 1976). On the basis of spectrographic evidence, Cohen and Fox (1976) identified
116 twelve basic vocal sound types of the canid species (mews, grunts, whines/whimpers, yelps,
117 yips, howls, coos, growls, coughs, barks, clicks, tooth snaps). Feddersen-Petersen (2000)
118 described ten classes of vocalizations in dogs and wolves, grouped into three categories of
119 sounds: harmonic/tonal (whines, yelps, screams, whimpers), intermediate (moans, growls,
120 barks) and noisy (woofs, snarls, yaps); see also Faragó et al. (2014). Finally, Tembrock (1976)
121 described the temporal structure and the frequency composition of ten classes of vocalizations
122 in various canids. The major factors of variability are breed and context. There is a full
123 consensus that, in a social context, dogs pant (Faragó et al., 2014), mouth-lick (Faragó et al.,
124 2014; Gaunet and El Massioui, 2014; Savalli et al., 2014, 2016), bark, growl, whine and
125 sometimes howl (see Taylor et al., 2014 and Faragó et al., 2014).

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

128 dogs, among others including harmonic-to-noise ratio, between vocalization intervals, intensity
129 or tonality (e.g. Pongrácz et al., 2006, Riede and Fitch, 1999). Since only F0 and duration are
130 robust in regarding recording conditions, we will focus on these characteristics in the present
131 study in the case of barks and whines. Barks have been characterized as short, plosive, and
132 possibly noisy, produced in sequence or isolated, and with variable pitch across breeds,
133 individuals and contexts (Taylor et al., 2014). Their spectral shape looks like a ‘Christmas tree’
134 formation due to a progressive increasing followed by a lowering of energy in higher
135 frequencies (Feddersen-Petersen, 2000; Scott, 1976). A bark unit can be described as follows:
136 Feddersen-Petersen (2000): F0: 120-1640 Hz, duration: 69-1000 ms, for 6 breeds; Cohen and
137 Fox (1976): F0: maximum of 2000 Hz, duration: < 500 ms; duration varies between 100 and
138 500 ms as compiled by Lord et al. (2009); Faragó et al. (2014) reported bark durations between
139 0.2 and 0.6 sec. Whines have been characterized as tonal, high pitched, noiseless vocalizations.
140 The nuances of whines were described by Feddersen-Petersen (2000) for six breeds: 400-8800
141 Hz, duration: 38-2025 ms. Yelps, screams and whimpers have also been described (Cohen and
142 Fox, 1976: F0: 400-3500 Hz, no description for duration).

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

153 vocalizations a dog produces when gazing at the target compared to vocalizations when gazing
154 at their owner, as a mean to study if vocalizations at the target and at the owner differ. In food
155 (or toy) requesting tasks, dogs have been shown to display different behaviors towards the
156 owner as compared to the target. Using videos and sounds collected with a unidirectional
157 microphone placed in the center of a room (Savalli et al., 2014, 2016), the present study is the
158 first to use an unsolvable task to explore qualitative and quantitative descriptions of the two
159 main canid vocalizations: barks and whines and their related vocalizations (but see Pongrácz et
160 al., 2017 in the case of a separation context). Slocombe and Zuberbühler (2006) showed that
161 chimpanzees may include the exact nature of the food may be included in the signal
162 (referentiality) in chimpanzees, and King and Janik (2015) demonstrated that in the case of
163 dolphins, specific social signals were significantly correlated with food call production, and
164 that these calls rarely occurred in the absence of food. Given the analogies and convergence on
165 referential communication behaviors of monkeys, apes and dogs, we expected dogs to
166 discriminate the target and the social agent when vocalizing toward them, both in terms of
167 types of vocalizations (and their number) and acoustic characteristics. Although Savalli et al.
168 (2014; 2016) found that gaze at the food and at the owner fitted all the operational criteria for
169 functionally referential and intentional communication (previously found in a study with
170 chimpanzees, Leavens et al., 2005), this was not the case for the number and duration of
171 vocalizations, likely because there were too few occurrences. Accordingly, due to the lack of
172 an exhaustive and dedicated study testing referentiality and intentionality of vocalizations
173 directed at the target and receiver in the pet dogs, these vocalizations are thought of as
174 reflecting the inner state of the dogs, as an attention-getting signal.

175

176 **2. Methods**

177 ***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.

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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

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

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

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

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

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

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

273

274 **4. Results**

275 **4.1. Vocalization description and categorization**

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

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

285

286 INSERT TABLE 2 ABOUT HERE

287

288 Table 2 shows that most vocalization occurrences consisted in barks, then in whines
289 (67.72% and 32.27%, respectively). They were mostly directed at the owner (67.7%), then at
290 the target (32.3%). Table 2 also reveals that the main vocalizations (see the four cells in
291 italics, i.e. all whines and typical barks) were not produced by all dogs, but only by four to six
292 different dogs out of the eleven dogs, in each of the four cases.

293 The GEE model (estimated parameters presented in Figure 2) for the number of
294 vocalizations according to the type (whines or barks) and their direction (target or owner)
295 indicated a possible interaction between types of vocalizations (2) and gaze directions (2)
296 (Wald = 3.50, df = 1, p = 0.0615). As a matter of fact, there was no difference between
297 numbers of barks and of whines when directed at the owner (Wald = 0.64, df = 1, p = 0.4237);
298 however, there were significantly more barks than whines directed at the target (Wald = 4.65,
299 df = 1, p = 0.0310). No difference was found between the number of barks directed at the
300 owner compared to the target (Wald = 0.39, df = 1, p = 0.5314). However, the number of
301 whines directed at the owner was significantly greater than those directed at the target (Wald
302 = 6.27, df = 1, p = 0.0123).

303

304 INSERT FIGURE 2 ABOUT HERE

305

306 In the case where the dogs were gazing at the target, it was not possible to compare the
307 distribution of the four types of whines and the number of vocalizations using the GEE model
308 due to the small number of occurrences recorded. In the case where the dogs were gazing at
309 the owner, yelps could not be included in the analysis, but the GEE model used to compare
310 the three other distributions indicated that there was no difference between them (Wald =
311 1.28, $df = 2$, $p = 0.5266$). In contrast, there were considerably more typical barks directed in
312 each direction than the four other types of barks (at the target: Wald = 604.31, $df = 4$, $p <$
313 0.0001 ; at the owner: Wald = 14.17, $df = 4$, $p = 0.0068$, respectively).

314

315 ***4.2. Typical whine and whine-related vocalizations***

316 ***4.2.1. Overall description***

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

322

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

325

326

INSERT FIGURE 3 ABOUT HERE

327

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

330

331 INSERT FIGURE 4 ABOUT HERE

332

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

335

336 INSERT FIGURE 5 ABOUT HERE

337

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

340

341 INSERT FIGURE 6 ABOUT HERE

342

343 4.2.2. Distribution of dogs according to the four types of whines

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

352

353 4.2.3. Direction of whines and concomitant acoustic parameters (F0 and duration)

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

357

358 4.2.4. Number of bouts in a row of whines towards the target and the owner

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

363

364 **4.3. Typical barks and bark-related vocalizations**

365 4.3.1. Overall description

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

372

373 4.3.2. Typical barks

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

379

380

INSERT FIGURE 7 ABOUT HERE

381

382 Based on the observation of typical spectrograms of barks', a clear stable central and
383 tonal segment could be preceded by a noisy segment (the onset) and sometimes followed by a
384 short segment (the offset) of the bark. In order to analyze and compare all the barks and take
385 into account potential onsets or offsets, we considered three sub-units in typical barks; cf. Fig.
386 8.

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

394

395

INSERT FIGURE 8 ABOUT HERE

396

397 *4.3.2.1. Distribution of the composition of the typical bark*

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

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

406

407 *4.3.2.2. Direction of the typical bark and concomitant acoustic parameters (F0 and duration)*

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

413

414 INSERT TABLE 3 ABOUT HERE

415

416 *4.3.2.3. Number of bouts in a row for typical barks towards the target and the owner*

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

422

423 *4.3.3. Other barks*

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

429

430

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

436

437

INSERT FIGURE 9 ABOUT HERE

438

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

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

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

447

448

INSERT FIGURE 10 ABOUT HERE

449

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

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

457

458 INSERT FIGURE 11 ABOUT HERE

459

460 ‘*Cooing Bark*’ (Fig. 12). This cooed vocalization showed a low frequency (270Hz to 470 Hz)
461 band energy concentration slightly modulated around 10%. This sound lasted from 230ms to
462 715ms, and the five items found were emitted alone (i.e. not in a row). The cooed effect
463 resembles a perceptual vibrato.

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

470

471 INSERT FIGURE 12 ABOUT HERE

472

473 **Discussion**

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

479 Firstly, and interestingly, only 21.6 % of the fifty-one dogs recorded in Savalli et al.
480 (2014; 2016) vocalized. Breed was investigated (Scott, 1976; Feddersen-Petersen 2000) but
481 not revealed to be a factor. A plausible explanation then is that many of the non-vocalizing
482 dogs had previously learned from their owners not to vocalize in situations involving food
483 requests (Duranton and Gaunet, 2016; Henschel et al., 2020). We also found that the number
484 of vocalizations varied considerably between the 11 dogs (1-50 for the total of 189 found).
485 The vocalizing dogs in contrast, may have produced a vocalization at one point when in the
486 presence of their owner and food. And this vocalization may have been rewarded by food.
487 Accordingly, vocalizations can be of various forms, in accordance with the various types we
488 found. Only four to six different dogs produced all the whines and the typical barks, and the
489 various types of whines and barks and units of the barks were not produced by all dogs; see
490 Tables 2, 3 and 6. This variability in vocal productions between dogs may reasonably be
491 based on an effect of the dogs' previous experience with their owners (Duranton and Gaunet,
492 2016; Henschel et al. 2020), in accordance with Scott's (1976) observation that "barks differ
493 in quality and quantity,".

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

500 Most of the 189 vocalizations (67.72%) consisted in typical and related barks, and the
501 other third in whines and whine-related vocalizations. Interestingly, the majority of
502 vocalizations (67.7%) were directed at the owner. The tendency of an interaction between the
503 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

529 (Cohen and Fox 1976; Tembrock, 1976) to 8800 Hz (Feddersen-Petersen, 2000;
530 Schassburger, 1993), and F0 is known to depend on dog size and breed (Riede and Fitch,
531 1999), elements that are variable in our experiment. Possible differences with the literature
532 could also be due to context. Whining is reported in contexts involving greetings, frustration,
533 active submission, and attention-seeking (Yeon, 2007), whereas our recordings likely
534 involved attention-seeking to get food (Gaunet and El Massioui, 2014; Savalli et al., 2014,
535 2016). We thus propose that the range of F0 we found may be linked to the socio-physical
536 recording contexts that often differ between studies. Our range is likely to be specific to an
537 attention-getting communicative activity, though variability may occur according to sizes and
538 breeds of dogs. In contrast, the durations of whine-related vocalizations are not systematically
539 reported in the literature. Still, the durations we found were in the lower range of the durations
540 previously reported (Feddersen-Petersen, 2000; Cohen and Fox, 1976; Faragó et al., 2014).

541 Regarding the production of barks, we found the typical Christmas-tree production
542 (Faragó et al., 2014; Feddersen and Petersen, 2000) to be the most common compared to the
543 four other related barks we found. While whine and whine-related vocalizations were
544 produced by eight dogs, only four dogs barked; we believe this is likely due to the request
545 from owners for their dogs not to bark at food in general. Again, in contrast with whining,
546 typical barks were directed equally towards the owner and the target. The acoustic
547 characteristics of the typical barks found matched those recorded in the literature, especially
548 in non-aggressive contexts (i.e. higher peak, mean, and range of F0, Feddersen-Petersen,
549 2000; Yin, 2002). The presence of three segments in the typical bark may reveal a specific
550 vocal coding. The in-depth analysis of the acoustic characteristics we performed revealed a
551 statistical tendency for the b segment of the typical bark to have higher F0 and lower duration
552 during gazes at the target than during gazes at the owner. Adding more dogs and more
553 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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610

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727 **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.

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	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 <i>by 4 different dogs (5,2,1,1)</i>	1	6	0	2	52	35 <i>by 4 different dogs (21,9,1,2)</i>	4	6	3	4	61	32.3
Number of vocalizations during Gaze Owner	52 <i>by 6 different dogs (18,16,11,3,3,1)</i>	11	7	19	15	76	52 <i>by 4 different dogs (12,2,5,30)</i>	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	

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 vocalizations for both directions of gaze (with the number of occurrences per dog).

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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)	

741

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)	

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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)	

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

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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).

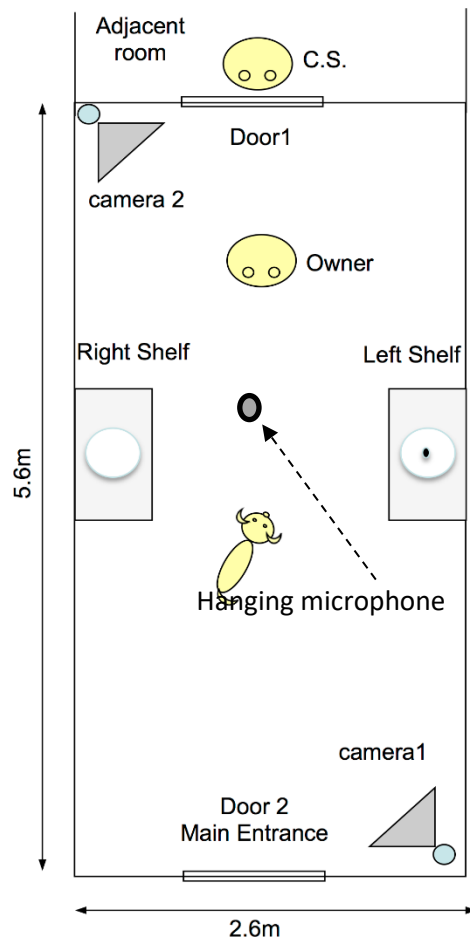
774 Fig. 12. Cooing Bark from Netuno. Duration = 286ms - Top: oscillogram (arbitrary unit),
775 Bottom: spectrogram (Hz).

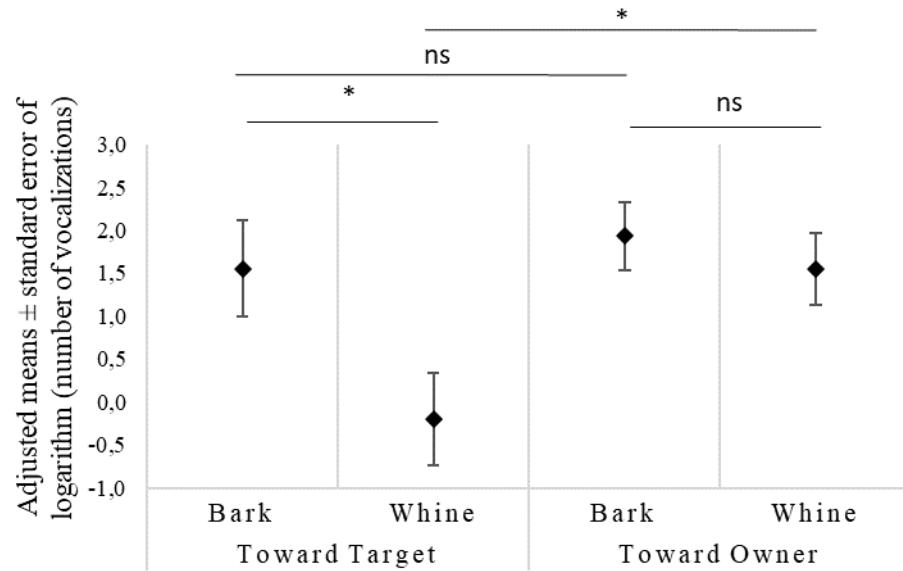
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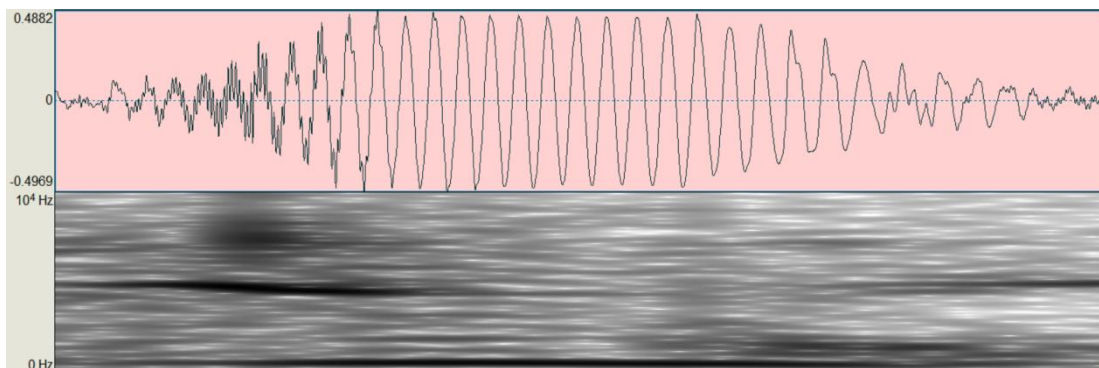
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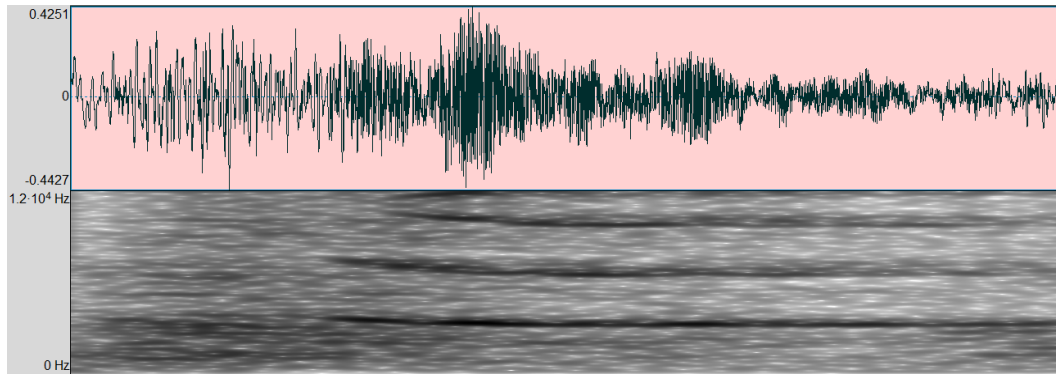
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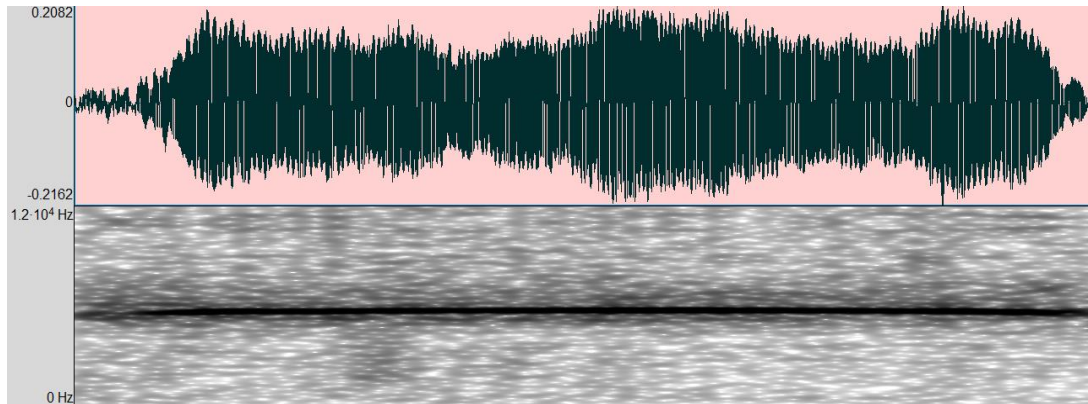
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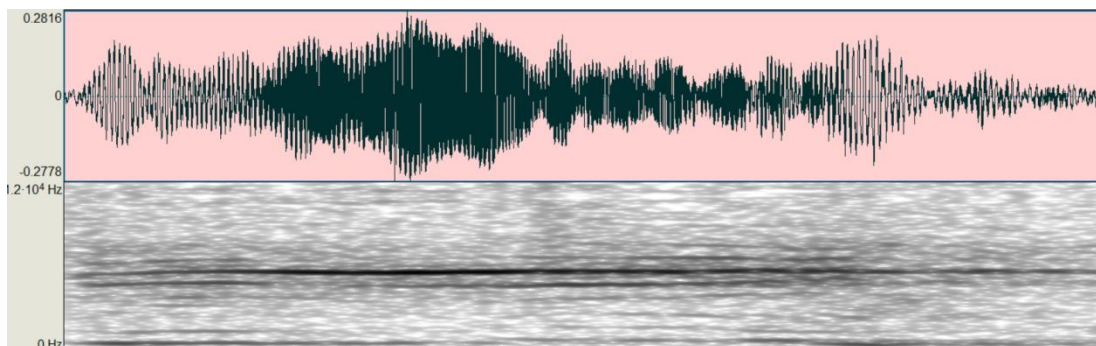
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802
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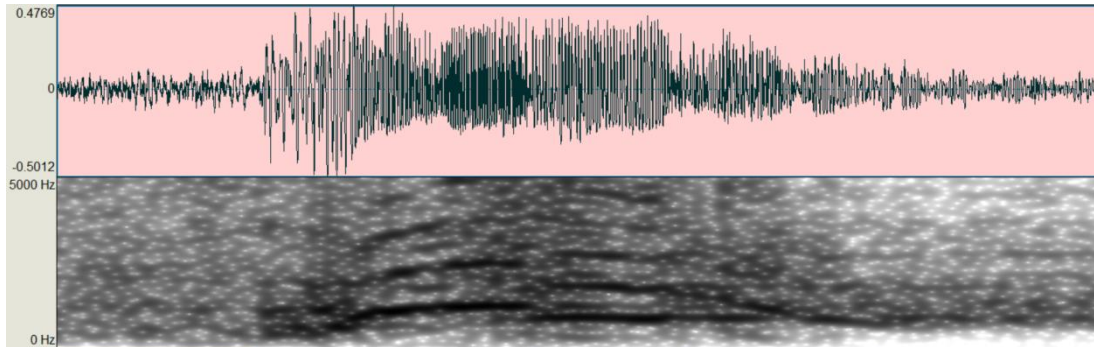
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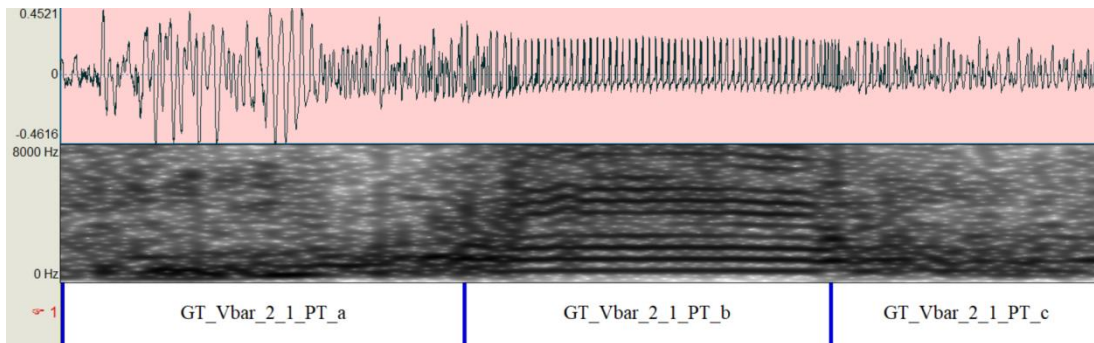
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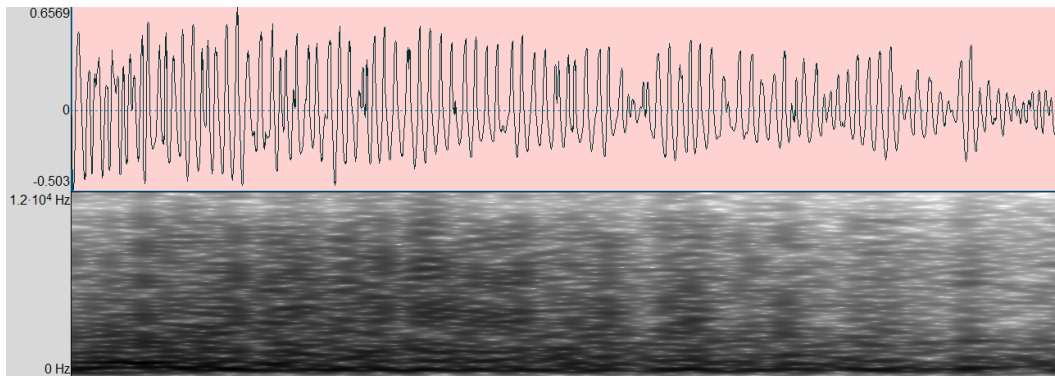
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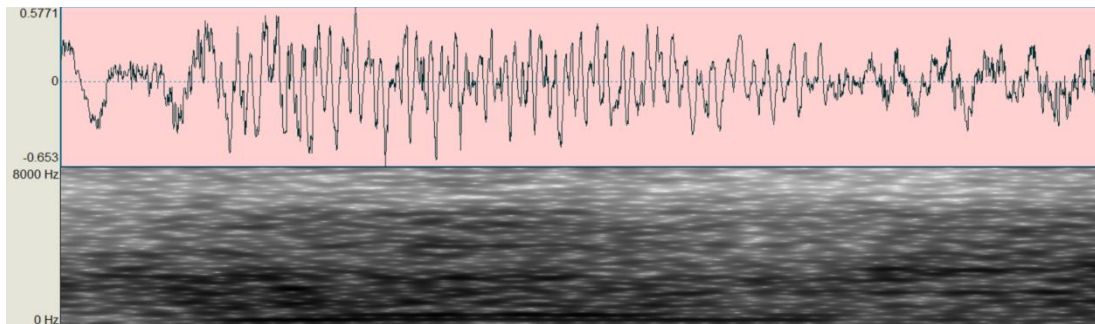
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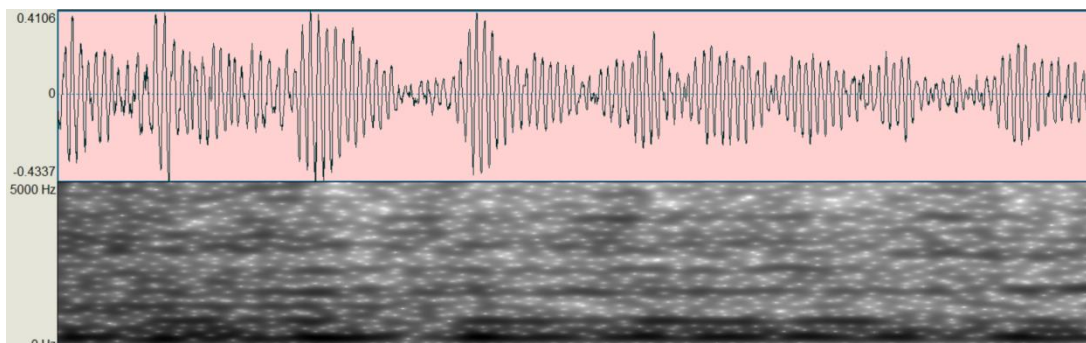
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838 Fig. 10. Push Bark from Barto. Duration = 186ms - Top: oscillogram (arbitrary unit), Bottom:
839 spectrogram (Hz).

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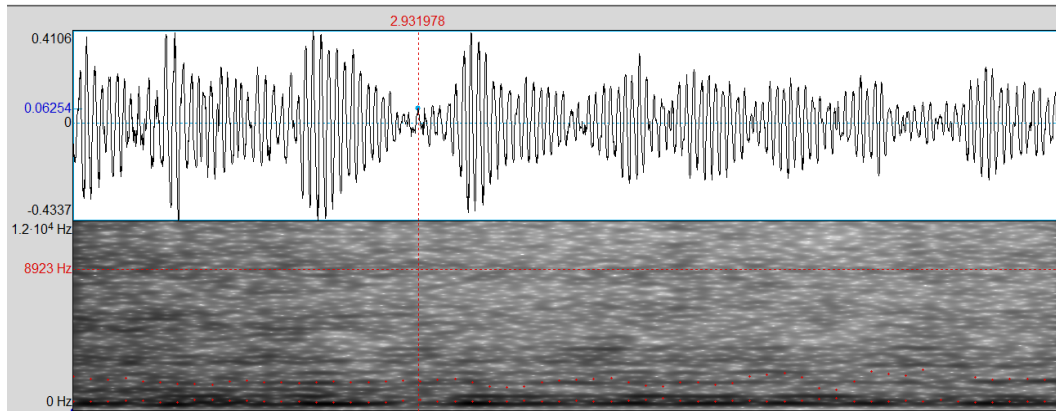


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844 Fig. 11. Cooing Flat Bark from Netuno. Duration = 285ms- Top: oscillogram (arbitrary unit),
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