

Can humans discriminate between dogs on the base of the acoustic parameters of barks?

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Abstract

In this study we tested the often suggested claim that people are able to recognize their dogs by their barks. Earlier studies in other species indicated that reliable discrimination between individuals cannot be made by listening to chaotically noisy vocalizations. As barking is typically such a chaotic noisy vocalization, we have hypothesized that reliable discrimination between individuals is not possible by listening to barks. In this study, playback experiments were conducted to explore (1) how accurately humans discriminate between dogs by hearing only their barks, (2) the impact of the eliciting context of calls on these discrimination performances, and (3) how much such discrimination depends on acoustic parameters (tonality and frequency of barks, and the intervals between the individual barks). Our findings were consistent with the previous studies: human performances did not pass the empirical threshold of reliable discrimination in most cases. But a significant effect of tonality was found: discrimination between individuals was more successful when listeners were listening to low harmonic-to-noise ratio (HNR) barks. The contexts in which barks were recorded affected significantly the listeners' performances: if the dog barked at a stranger, listeners were able to discriminate the vocalizations better than if they were listening to sounds recorded when the dog was separated from its owner. It is rendered probable that the bark might be a more efficient communication system between humans and dogs for communicating the motivational state of an animal than for discrimination among strange individuals.

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1. Introduction

An acoustic signal may simultaneously provide information about the caller's species, sex, age, motivational state, dominance status, group membership, and identity (e.g. Gerhardt, 1992a,b; Hauser, 1996). The discrimination of individuals on the base of their vocal signals is a common phenomenon in animal communication. This discrimination is based on individually different acoustic characteristics of the vocal signals. Several studies have demonstrated that in various species there are characteristic differences between the vocalizations of the individuals: (tree frogs: Bee et al., 2001, birds: Lambrechts and Dhondt, 1995, timber wolf: Goldman et al., 1995, and domestic dog: Yin, 2002; Yin and McCowan, 2004). Other studies explored by conducting playback experiences whether conspecifics were able to discriminate between individuals by hearing their vocal-

izations: birds (banded wren: Molles and Vehrencamp, 2001, spotted antbird: Bard et al., 2002, and Adélie penguin: Jouventin and Aubin, 2002), amphibians (tree frogs: Gerhardt, 1992a) and mammals (e.g. Japanese macaques: Ceugniet and Izumi, 2004, tamarin: Miller and Hauser, 2004, spider monkey: Teixidor and Byrne, 1999, African elephant: McComb et al., 2001, spotted hyena: Holekamp et al., 1999, and Arctic fox: Frommolt et al., 1997, 2003).

A wide spectrum of acoustic parameters have been reported to be individually distinctive: e.g. F_0 (fundamental frequency), formant frequencies (e.g. non-human primates, Owren and Rendall, 1997), the temporal characteristics of the call (collared dove, Slabbekoorn and ten Cate, 1999), or the tonality and the 'non-linear phenomena' (reviewed by Fitch et al., 2002, rhesus monkey, Owren and Rendall, 2003). Many authors hypothesized that the anatomical individual variability of the supralaryngeal vocal tract could be the primary source of cues used for individual recognition (e.g. Fitch and Hauser, 1995).

Owren and Rendall (2003) and Fitch et al. (2002) suggest that the rhesus monkey's 'coo' vocalizations (which are basically

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tonal sounds) are more useful for individual discrimination than ‘screams’ (atonal ones). They argue that tonal coo sounds generated by stable vocal fold vibrations are more individual than the unstable vocal fold vibrations that generate screams. On the spectra of tonal sounds the formant frequencies are more distinctive. These acoustic features are produced by vocal tract filtering and therefore they provide more reliable information about body size and identity of the caller. Based on these findings one could hypothesize that the distinguishing elements of dog barks would also be dependent on spectral characteristics, mainly on tonality.

However, barks are mostly noisy sounds with more or less harmonic components. The ratio of power of the harmonic and the noisy components vary among barks emitted in different contexts. This noise is produced by irregular oscillation of vocal folds (the sound source) and by turbulence of airflow in the vocal tract (Riede and Fitch, 1999; Riede et al., 2005; Tokuda et al., 2002). For that reason the study of bark acoustics needs to be based on non-linear dynamics. This chaotic feature of barks has several implications. Some barks have harmonic components with deterministic chaos. Therefore, it seems to be more accurate to categorize barks with their measured ‘harmonics-to-noise ratio’ (and not “tonal” and “atonal”). Chaotic sounds provide less evidence of vocal tract (formant) filtering than harmonically structured sounds (Rendall et al., 1998). In sum according to other studies (e.g. Owren and Rendall, 2003) pure tonal (less noisy) sounds provide more cues for vocal tract filtration (and therefore individual discrimination) compared to atonal, more noisy sounds (like dog barks).

In the last decades only a few studies have focused on the acoustic communication of dogs (e.g. Cohen and Fox, 1976; Tembrock, 1976; Bleicher, 1963; Feddersen-Petersen, 2000; Yin, 2002; Yin and McCowan, 2004; Pongrácz et al., 2005). The main reason for this is many researchers considered the dogs vocal behavior to have been so altered during domestication that their bark lacks (or has lost in comparison to wolves, see Schassburger, 1993) a specific communication function (Yin, 2002; Yin and McCowan, 2004). But in the last few years some studies have demonstrated that: (1) dog bark is characterized by context specific (and probably motivational state specific) acoustic parameters (Yin, 2002; Yin and McCowan, 2004) and (2) humans are able to categorize the barks into contexts and describe the emotional content (Pongrácz et al., 2005). From our earlier investigations we know that bark can be considered as a relevant form of dog–human communication. Our results showed that particular acoustic parameters (tonality, dominant peak frequency and interbark intervals) play a crucial role in human understanding of the situation where the bark was recorded, and these parameters also make possible the evaluation of the emotional state of the barking dog for the humans. Furthermore, we found that humans with different levels of experience with dogs showed similar trends in categorization and described the possible inner state of the given barking dog (Pongrácz et al., 2005).

Human listeners described the less noisy (high HNR) barks which had higher frequency and longer intervals between the individual barks as ‘fearful’, and the more noisy (low HNR)

barks with lower frequencies and shorter interbark intervals as ‘aggressive’ (Pongrácz et al., *in press*). These findings showed that some features of the barks correspond to the motivational-structural rules described by Morton (1977) on the basis of bird and mammalian vocalizations, but within a same type of vocalization. (Morton originally described the rules for different call types.) This phenomenon is unique among animal vocalizations, hence in other species different types of calls are emitted in different contexts. But in barks one type of vocalization can be modulated to communicate different inner states, or “emotions”.

Another important question if humans could be able to discriminate between individual dogs after hearing their barks. As dog bark is a mostly atonal type of sound, it is questionable that it could make a reliable individual discrimination possible. Our first goal in this study therefore is that we want to see if tonality, dominant peak frequency, and interbark intervals have an effect on humans’ performances in the discrimination between individual dogs. Secondly, if we find that the same parameters are important for individual discrimination and also for evaluating the dogs’ emotions and the situation in which they bark, it can raise the question of the interference between the two kinds of information for human listeners. This possibility would make new considerations necessary regarding our earlier findings on the categorization of situations and emotions via listening dog barks.

2. General methods

2.1. Subjects

We formed three experimental groups depending on the listener’s experiences with dogs. (1) Mudi owners: either currently owned a Mudi or had owned a Mudi previously. (2) Dog owners: were present or previous owners of a dog other than a Mudi. (3) Non-owners: never owned a dog. In our opinion ‘Mudi owners’ and ‘owner of other breeds’ should be differentiated since the played-back material was recorded from Mudis. Mudi owners have more opportunity for listening to Mudi barks, and if Mudi’s barks have some unique features compared to barks of other breeds, their performances should have been more accurate than those of owners of other breeds of dogs. All the subjects were Hungarian adult people.

2.2. Experiment procedures

Participants were tested alone or in small groups of up to three. They were seated behind one another in a seminar room at the university, far enough (at least in distance of 2 m) from each other in order to prevent them from seeing each other. Bark sequences were presented to the listeners via a Philips MMS 305/A 3.500 multi-channel soft flat panel PC speaker system. Before a test session, the participants were provided with information about their task. They were told in advance that in the test they would hear dog barks in pairs and their task would be to decide whether the two samples were recorded from the same or different individuals. The listeners were asked to give

their answers by checking the appropriate box on a questionnaire sheet. During the test they were not given any specific help. If the listener asked, the given bark sample was played back once more.

2.3. Stimuli

2.3.1. Source and collection of sound recordings

Barks from the Mudi breed (a Hungarian sheepdog listed at the 238th Standard of the Fédération Cynologique Internationale (FCI)) were used for this study. We collected bark recordings in six different behavioral contexts, most of which could be arranged at the homes of the owners, with the exceptions of the ‘Fight’ situation, which was staged at dog training schools, and the ‘Alone’ situation, which was staged on a street or in a park. The six situations are as follows:

‘Stranger’: The experimenter (male, age 23 years) was the stranger for all the dogs, and appeared in the garden of the owner or at the front door of his/her apartment in the absence of the owner. The experimenter recorded the barking of the dog during his appearance and intrusion into the garden or apartment for 2–3 min.

‘Fight’ or ‘Schutzhund’: For dogs to perform in this situation, the trainer encourages the dog to bark aggressively and to bite the glove on the trainer’s arm. Meanwhile the owner kept the dog on leash.

‘Walk’: The owner was asked to behave as if he/she was preparing to go for a walk with the dog. For example, the owner took the leash of the dog in her/his hand and told the dog “We are leaving now”.

‘Alone’: The owner tied the dog to a tree with a leash in a park and walked away, out of sight of the dog.

‘Ball’: The owner held a ball (or some favorite toy of the dog) at a height of approximately 1.5 m in front of the dog.

‘Play’: The owner was asked to play with the dog a usual game, such as tug-of-war, chasing or wrestling. The experimenter recorded the barks emitted during this interaction.

(In Experiment 2 only barks recorded in ‘Stranger’, ‘Alone’, and ‘Ball’ contexts were used as stimuli.)

2.3.2. Recording and preparing the sound material

Recordings were made with a Sony TCD-100 DAT Tape Recorder and a Sony ECM-MS907 microphone on Sony PDP-65C DAT tapes. During recording of the barks, the experimenter

held the microphone within 4–5 m of distance from the dog. The experimenter tried to stand in front of the dog if it was possible. The recorded material was digitalized with a 16-bit quantization and a 22.05 kHz sampling rate, using a TerraTec DMX 6fire 24/96 sound card. To equate the calls for loudness, barks were normalized by rescaling each wave form so its highest amplitude peak was at –6 dB.

Stimuli were constructed by pairing sound samples recorded from the same or different individuals. The method of pairing is described below. The samples began and ended with a 500 ms silence. The sound pairs in a sample were inserted in one Wave format file, so intervals between them were controlled. Playback sets included ‘Same’ and ‘Different’ trials in equal numbers.

2.4. Statistical analyses

To measure the listeners’ ability to discriminate stimuli, their responses were converted to d' values, according to the Signal Detection Theory (Macmillan and Creelman, 1991). Responses of all the listeners were categorized as ‘hits’ (correct response for the ‘same’ stimuli), ‘misses’ (incorrect response for the ‘same’ stimuli), ‘correct rejections’ (correct response for the ‘different’ stimuli), and ‘false alarms’ (incorrect response for the ‘different’ stimuli) separately. The d' values index the discrimination sensitivity by comparing the statistical distributions of the ‘hits’ and ‘false alarms’ to the observed proportion of these values.

If the stimulus sets are balanced (the numbers of ‘same’ and ‘different’ trials are equal), chance performance produces an expected d' value of 0. The higher d' values suggest a more efficient judgement on the part of the human listener. (For further description, see Macmillan and Creelman, 1991.)

One-sample t -tests were used to compare the performances of the listeners with the chance performance level ($d' = 0$). For further comparisons, multi-way repeated measured ANOVAs were used. The statistical analyses were made using SPSS 9.0 for Windows software.

3. Experiment 1

In this experiment we explored the possibility that humans are able to make same/different distinctions on the basis of listening to a single bark of a dog. Earlier it has been found that human listeners could make such a distinction by listening to ‘coo’ and ‘scream’ calls of rhesus monkeys (Owren and Rendall, 2003) and the efficiency of the participants depended on the tonality of the calls which provided the basis for their discrimination. Here, we hypothesized that the tonality of barks might have an effect on discrimination ability.

3.1. Method

3.1.1. Subjects

Mudi owners ($N = 20$, mean age = 39.77 years, with a range from 17 to 66 years, male/female = 4/16). Dog owners ($N = 20$, mean age = 31.12 years, with a range from 16 to 52 years, male/female = 6/14). Non-owners ($N = 20$, mean age = 33.00 years, with a range from 19 to 67 years, male/female = 9/11).

3.1.2. Stimuli

Barks of 16 adult dogs (male/female = 9/7; mean age: 4.34 years) were used in this experiment as stimuli with the only selection criteria being that the sounds used fit within the ranges of the acoustic parameters (the dominant peak frequency and tonality) listed below. The recordings were made in the six contexts described above. The acoustic parameters of the barks were measured with ACMS sound analyzing software written by Sándor Zsebök. The program took 100 sequential frequency and amplitude measurements of the dominant frequency (the frequency band in which the most energy is concentrated) in a frequency-time spectrum for each individual bark, using an FFT size of 1024 points, and frequency resolution of 22 Hz. The following parameters were used for the selection of the playback material: (1) dominant peak frequency (frequency): the mean of the frequency measures done at 100 points in time and (2) harmonic-to-noise ratio (HNR): this parameter serves for the description of the tonality, “harshness” of the barking. The calculation of HNR was performed by the method described by Riede et al. (2001), with the difference that we used a 1024-point fast Fourier transform (FFT). The HNR compares the amplitude of harmonic tones of the sound to the amplitude of non-harmonic noise within the sound. The higher the HNR, the more pure tone-like the sound. The calculation of HNR was done as follows. We computed the power spectrum of a segment of 50 ms from the middle of a bark. Then we estimated the noise level by calculating the moving average of the spectrum curve. Next we determined the maximum difference between the harmonic peaks and the noise level by using a Microsoft Excel macro.

For both of the two parameters we defined ranges of ‘high’ and ‘low’ values in advance. The ranges were as follows: (1) dominant peak frequency: ‘low’ range: 500–800 Hz, ‘high’ range: 1200–1500 Hz (barks in which dominant peak frequency was between 800 and 1200 Hz were excluded) and (2) HNR: ‘low’ range: 20–28, ‘high’ range: 28.1–36.

Using these frequency and tonality criteria, we randomly selected 20 individual barks from each dog from a pool containing 8129 barks. In the played back material we had got barks from 16 dogs. From eight dogs we had got high dominant peak frequency barks, and we had got low dominant peak frequency barks from the other eight individuals. From each dogs we selected 10 “more noisy” barks (low HNR) and 10 “less noisy” barks (high HNR). So in the end we had 20 barks from each individual, half of the barks were less noisy and the other half were more noisy, but the dominant peak frequencies of all barks from a given individual were in the same range.

Playback pairs were composed of two barks which were chosen randomly in a counterbalanced form outlined below. The bark pairs were inserted in one single file with an interval of 500 ms between them. The paired barks belonged to the same frequency range (low or high). The total number of samples played back to a listener was $N = 96$. ‘Same’ and ‘Different’ trials were presented in equal proportions. One-third of both the ‘Same’ and ‘Different’ trials were constructed of two ‘high HNR’ barks, the second third contained a ‘high HNR’ and a ‘low HNR’ one, and the last third of the samples was constructed of two ‘low HNR’ barks. Among the trials, equal numbers of sounds, recorded from

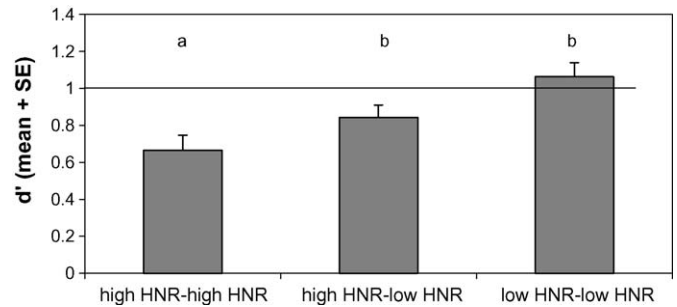


Fig. 1. The effect of tonality of call on the listeners' performances in Experiment 1. Listeners' efficiencies were poorer if listening to bark pairs containing two high HNR barks compared to one high HNR–one low HNR or two low HNR barks. The horizontal line indicates the threshold of reliable discrimination.

all 16 dogs, of the three tonality types (high HNR–high HNR), (high HNR–low HNR), and (low HNR–low HNR) were used. No barks were used twice for a trial session.

3.2. Statistical analyses

The comparisons were based on multi-way repeated measures ANOVAs with Student Newman–Keuls post hoc, in which the listeners' experiences with dogs (Mudi owner, Dog owner, and Non-owner) and the tonality and frequency of barks were used as factors.

3.3. Results and discussion

The listeners' sexes had no significant effect on their answering efficiencies (t -test: $t(58) = 0.42$, $P = 0.63$) so sexes were merged for further analyses. The effect of tonality was significant ($F(2,56) = 11.14$, $P < 0.001$, Fig. 1). The participants discriminated the caller identity more efficiently when listening to the two low HNR or one high HNR–one low HNR barks, than when listening to the two high HNR ones, but there was no significant difference in performance between the two low HNR and one high HNR–one low HNR conditions. The dominant peak frequency (pitch) of the barks did not have a significant effect on the participants' performance ($F(2,57) = 0.05$, $P = 0.81$), but there was a significant interaction between the effects of frequency and tonality ($F(2,56) = 23.10$, $P < 0.001$, Fig. 2). Listeners performed better with sounds in which dominant peak frequency is low when listening to two high HNR barks, but better with

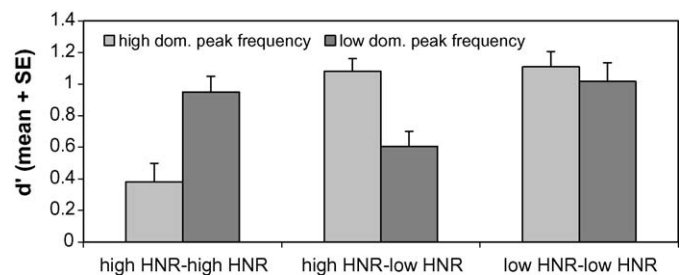


Fig. 2. The collective effect of tonality and dominant peak frequency of the call on the listeners' performances. The horizontal line indicates the threshold of reliable discrimination.

high dominant peak frequency sounds when listening to one low HNR and one high HNR bark, and performed equally well on low and high dominant peak frequency sounds when listening to two low HNR barks. The participants' experiences with dogs also had a significant effect on their performances ($F(2,57)=7.98$, $P<0.001$): the 'Dog owners' achieved higher d' values than the 'Mudi owners' and the 'Non-owners', but there was no significant difference between the latter two groups. Neither of the two-way interactions, between frequency and the listeners' experiences ($F(2,57)=0.19$, $P=0.82$ ns) and tonality and the listeners' experiences ($F(4,114)=2.18$, $P=0.07$ ns), was significant.

In the literature d' values of 1.0–1.5 have been suggested as empirical thresholds at which reliable discrimination occurs (Macmillan and Creelman, 1991; Owren and Rendall, 2003), so we compared discrimination performances to empirical threshold of 1.0. We found that listeners did not pass this threshold, regardless of the stimulus type they were listening to (low HNR–low HNR: mean = 1.06, $t(59)=0.67$, $P=0.50$; high HNR–low HNR: mean = 0.84, $t(59)=2.52$, $P<0.05$; and high HNR–high HNR: mean = 0.67, $t(59)=3.65$, $P<0.001$). None of the three participant groups had a d' value significantly higher than value of 1.0 (Mudi owners: mean = 0.59, $t(20)=3.13$, $P<0.01$; Dog owners: mean = 1.077, $t(20)=1.10$, $P=0.29$; and Non-owners: mean = 0.76, $t(20)=3.53$, $P<0.01$).

4. Experiment 2

Considering the relatively low d' values achieved by the listeners in Experiment 1, it is probable that a single bark does not contain enough cues about caller identity for humans to provide a basis for reliable discrimination. But it could be that bark sequences, which contain more barks, do contain sufficient cues for discrimination between individuals. The bark sequences contain not only more barks, but additionally, barks are separated by silent intervals of varying duration, which could provide further information on the identity of the caller. To explore the possible effect of the repetition of barks and the variable interbark intervals, we conducted another playback experiment, using five-bark sequences as stimuli. Additionally, we selected sound samples recorded in three different contexts. As a sub-experiment of this experiment we played back to the owners their own dogs' and another dogs' corresponding barks to find out whether ownership enhances discrimination ability.

4.1. Method

4.1.1. Subjects

Mudi owners ($N=20$, mean age = 43.41 years, with a range from 26 to 72 years, male/female = 7/13). Dog owners ($N=20$, mean age = 24.50 years, with a range from 19 to 39 years, male/female = 6/14). Non-owners ($N=20$, mean age = 25.43 years, with a range from 19 to 52 years, male/female = 6/14).

4.1.2. Stimuli

Bark sequences of five individual barks recorded in 'Stranger', 'Alone', and 'Ball' contexts, were used as stimuli

for this experiment. We randomly chose bark samples from the 10 dogs recorded in all three situations, so we had two samples from 10 different individuals in the 'Stranger', 'Alone', and 'Ball' contexts as well ('Stranger': male/female = 6/4, mean age = 3.56 years; 'Alone': male/female = 4/6, age = 4.86 years; and 'Ball': male/female = 6/4, age = 4.22 years). The samples from a given dog, in the same context, were recorded on different days.

For all the bark sequences we produced a version where the interbark intervals were normalized to the value of 300 ms. Both the original version of the bark sequences (where the actual intervals were present) and the normalized version, were played back for the listeners to explore the possible effect of the intervals.

The total number of samples played back for a listener was 24. For all 20 participants in the group, unique sound pairs were randomized, so no listener in a group was tested with the same stimuli. The two sounds paired were always recorded in the same context. Between the paired two bark sequences, a whistle sound was inserted as a signal for the end of the first bark sample. One single Wave file contained the two bark sequences and the whistle sound between them. The same number of 'Same' and 'Different' trials were presented. One-third of each of the 'Same' and 'Different' trials was from the context 'Stranger', the second third was from 'Alone', and the last third of the samples was from 'Ball'. A given listener was tested with both the original version (with the actual intervals) and the normalized version of a given sample. So, all of the participants were exposed to four bark samples recorded in all three situations in the 'Same' trials and they also listened to the same number in the 'Different' trials. No barks were used twice for a trial session. In the end, among the 480 trials (24 trials \times 20 listeners) all barks were presented in a balanced number.

For a sub-experiment, eight Mudi owners were used as listeners (six females, two males, age: 43.87 years). Twelve samples were played back to them. The samples were similar to those used in Experiment 2, but all of them were recorded in "Stranger" context. In half of the samples one or both of the five-bark sequences were recorded from the given owner's dog.

4.1.3. Statistical analyses

The comparisons that were based on multi-way repeated measures ANOVAs, were the listeners' experiences with dogs (Mudi owner, Dog owner, and Non-owner), the context of barks, and the existence of the actual interbark intervals which were used as factors.

4.2. Results and discussion

The listeners' sexes had no significant effect on their answering efficiencies (t -test: $t(58)=-0.79$, $P=0.43$) so sexes were merged for further analyses. The context of the bark sequences used as stimuli in this experiment had a significant effect on the participants' performances ($F(2,56)=4.14$, $P<0.05$; Fig. 3): the d' values derived from the discrimination ability for barks recorded in 'Stranger' context were higher than for 'Alone'

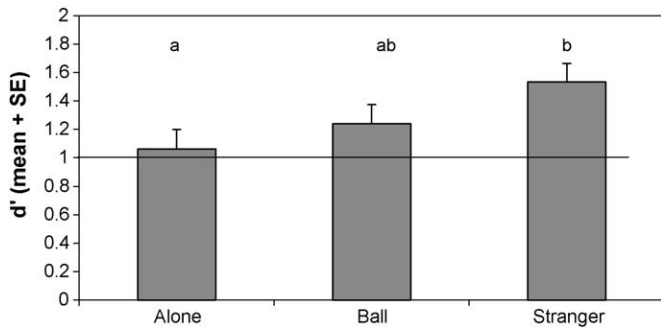


Fig. 3. The effect of context of the call on the listeners' performances in Experiment 2. Listeners' efficiencies were higher if listening to "Stranger" bark compared to "Alone" barks. The horizontal line indicates the threshold of reliable discrimination.

barks. Discrimination for 'Ball' barks did not differ significantly from the other two contexts. Performances of listeners did pass the empirical threshold of $d' = 1.0$ when they were listening to barks recorded in 'Stranger' context: mean = 1.53, $t(59) = 4.37$, $P < 0.001$; but did not pass the threshold when listening to 'Alone' (mean = 1.06, $t(59) = 0.17$, $P = 0.87$) or 'Ball' situations (mean = 1.24, $t(59) = 1.35$, $P = 0.18$). The presence or absence of the actual interbark intervals had no significant effect on the discrimination ability ($F(1,57) = 0.75$, $P = 0.39$).

The d' values calculated for the Mudi owners, the Dog owners and the Non-owners did not differ significantly ($F(2,57) = 0.13$, $P = 0.88$). None of the interactions between the factors had a significant effect (context-listener's experience: $F(4,114) = 0.95$, $P = 0.98$; intervals-listener's experience: $F(2,57) = 0.32$, $P = 0.74$; and context-interval: $F(2,56) = 0.84$, $P = 0.44$). However, in all three groups of participants, the discrimination performances were above the d' -level of 1.0 but they did not differ significantly from the empirical threshold (Mudi owners: mean = 1.34, $t(59) = 1.51$, $P = 0.18$; Dog owners: mean = 1.21, $t(59) = 1.07$, $P = 0.30$; and Non-owners: mean = 1.27, $t(59) = 1.18$, $P = 0.25$).

The average d' values in Experiment 2 were higher than in Experiment 1, however, because of the differences between the two experiments, in our opinion, statistical comparison of performances is not possible. Nevertheless, findings suggest that sequences of five barks conveys probably more information for humans to perform a reliable discrimination, but the mean d' values measured with this stimuli are still relatively low.

To explore if owners' performance would be better if they listened to barks recorded from their own dogs, we conducted another playback experiment. In half of the stimuli played back to them, one or both of the bark sequences were recorded from their own dogs. There was no significant difference between their performance when they were listening to their own dogs or strange individuals (paired t -test: $t(7) = 0.61$, $P = 0.56$). Listeners did pass the empirical threshold of $d' = 1.0$ when listening to strange individuals (mean = 2.67, one-sample t -test: $t(7) = 2.78$, $P < 0.05$) and did not pass it when listening to their own dogs (mean = 2.21, $t(7) = 2.04$, $P = 0.08$) but their performances were almost significantly above the threshold in this latter case.

5. General discussion

The results of the experiments show that (1) humans could not perform a reliable discrimination (except when listening to sounds of a dog barking at a stranger person), and only achieved modest rates of accuracy (65–70% when chance level was at 50%). (2) The tonality of the bark has a significant effect on the discrimination ability since the lower was the in the HNR bark, the higher discrimination values the participants achieved. (3) The performances of listeners did not differ if their task was to discriminate between bark sequences where the actual interbark intervals were present or absent. (4) Their performances did not differ when they were exposed to high or low dominant peak frequency sounds. (5) The listeners' discrimination performances were more efficient if the given bark played back was recorded in the context where the dog barked at a stranger, than when it was tied to a tree and left alone.

An effect of tonality has been found on the discrimination ability. Owren and Rendall (2003) found that human listeners had a more efficient performance if they had to discriminate between the tonal coo calls as they found a positive effect of tonality on discrimination ability of the sound. Several studies demonstrated (e.g. Rendall et al., 1998) that harmonically structured tonal sounds provide more information on the caller's identity than noisy calls. The tonal sounds show more evidence of formant filtering than noisy sounds and vocal tract filtering effects are reliable markers of individual identity.

Dog barks are mainly noisy sounds (e.g. Tembrock, 1976; Riede et al., 2005) as a result of irregular vocal fold vibrations. The relatively modest accuracy of listeners could be a result of this acoustic feature of barks. This finding is consistent with other studies' results (Owren and Rendall, 2003; Rendall et al., 1998). On the other hand, in contrast to others' results discussed above, we found that listeners were able to discriminate between individuals more efficiently if they were exposed to low HNR barks and less efficiently when listening to high HNR barks.

According to Fitch et al. (2002), some instability in vibrations of vocal folds can increase individual distinctiveness of calls by making formant effects more evident. This could be an adaptive function of chaotic dynamics of vocal folds. But this hypothesis was made for basically harmonic sounds where noise is secondary and not for barks generated by chaotic vibrations. As Fig. 4 shows on the spectra of barks, it is difficult to determine where the formants are. Another effect may be that a degree of noisiness in the barks of different individuals is variable, meaning that some individuals have almost no noisiness in their barks and others have more or very chaotic sounds.

We found that the context of the bark significantly affects the discriminability of sounds: listeners discriminated more successfully the barks recorded in the 'Stranger' situation than the 'Alone' barks. One possible reason of this finding could be that in different contexts the dogs have different levels of arousal. The relatively small changes in arousal level could produce a change in sub-glottal air pressure and vocal fold vibrations, and therefore, by a non-linear dynamic system,

could result in qualitatively different sound. Another effect of arousal could be that an individual having a high arousal level could produce more variable barks and acoustic features of calls could become more evident. Since most people hear barks more commonly when they find themselves in a ‘Stranger’ situation they may have more opportunity to come to know the individual characteristics of barks elicited in this situation. Also barks in the ‘Stranger’ situation may be more stereotyped within an individual, thus they make more efficient identification possible.

In Experiment 1 we found that Mudi owners’ performances were significantly lower than Dog owners’. But in Experiment 2 the groups of listeners did not differ significantly. In an extension of Experiment 2, owners of dogs whose barks were played back to them did not perform more accurately when listening to their own dogs’ barks. These findings suggest that previous experi-

ences with Mudis does not affect the discrimination ability of humans.

Among Dog owners it is a common belief that they can discriminate between dogs on the basis of their barks. Our results confute it. The base of this belief could be that when people hear dog barks, they sense several other cues which helps them with discrimination between individuals. When a dog vocalizes it emits other types of sounds (e.g. whines, grunts, and growls) which can also be individually distinctive. Another possibility that people can discriminate between individuals only if they are familiar with both of the individuals. If this is true it can be hypothesized that humans could discriminate between multiple dogs living in their household. Perhaps an explanation for Mudi owners’ modest performances could be that when they think they can recognize individuals by their vocalizations, in

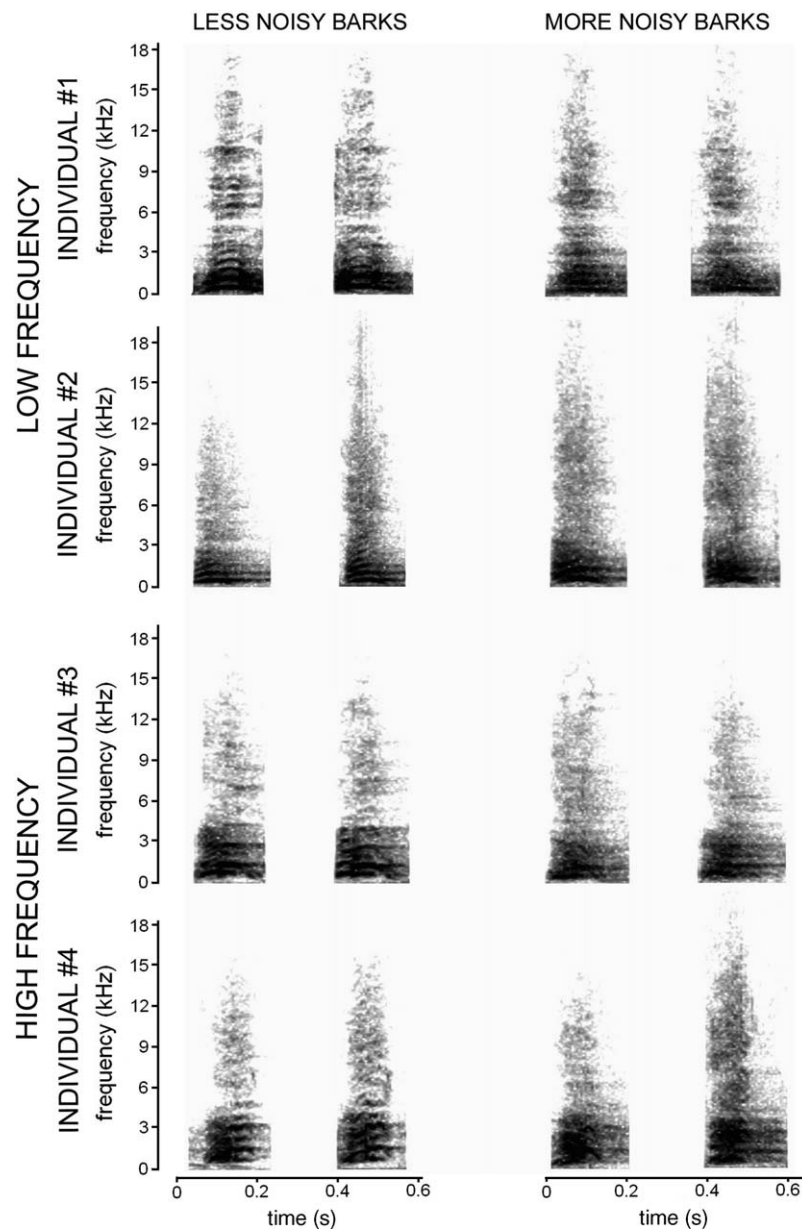


Fig. 4. Example spectra of barks used as stimuli in Experiment 1.

reality what they identify is breed-specific differences in dog bark.

In sum, we have found that the modest mean accuracy rates the listeners achieved, when they were exposed to only pairs of single barks, did not exceed the empirical threshold of reliable discrimination. Nevertheless, there was some improvement when listeners had to discriminate five-bark sequences (some of these did exceed the threshold). Some acoustic parameters, like the tonality in interaction with the frequency and the contexts of barks, have a significant effect on the discrimination performances of humans. Since we found in one of our previous papers that humans were able to categorize barks into contexts and describe the possible motivational states of the barking individuals, as a final conclusion, it is rendered probable that the bark might be a more efficient communication system between humans and dogs for broadcasting information on the motivational state of an animal, than for discrimination between strange individuals.

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