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Human Listeners Are Able to Classify Dog (*Canis familiaris*) Barks Recorded in Different Situations

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The authors investigated whether human listeners could categorize played-back dog (*Canis familiaris*) barks recorded in various situations and associate them with emotional ratings. Prerecorded barks of a Hungarian herding dog breed (Mudi) provided the sample. Human listeners were asked to rate emotionality of the vocalization and to categorize the situations on the basis of alternative situations provided on a questionnaire. The authors found almost no effect of previous experience with the given dog breed or of owning a dog. Listeners were able to categorize bark situations high above chance level. Emotionality ratings for particular bark samples correlated with peak and fundamental frequency and interbark intervals. The authors did not find a significant effect of tonality (harmonic-to-noise ratio) on either the emotionality rating or situation categorization of the human listeners. Humans' ability to recognize meaning suggests that barks could serve as an effective means of communication between dog and human.

Wild and domesticated canids are well known for their rich repertoire of vocal signals (e.g., Lehner, 1978; Tembrock, 1976). Although most of the canine acoustic signals have been found to be connected to special social situations (Cohen & Fox, 1976), barking, which is the most characteristic vocalization of the dog, has been assumed to have no specific communicative role. Dog barking has been described as notoriously variable and used almost freely in various situations when dogs interact with each other (Cohen & Fox, 1976). As other wild canids bark only in their puppyhood and as adults bark only in specific contexts (e.g., during defending territory; Schassburger, 1993), some researchers have thought that excessive and repetitive barking in adult dogs is either a neotenic feature with no (or little) communicative function or that dog barking is a byproduct of relaxed selection during the domestication process (Cohen & Fox, 1976).

However, recently it has been hypothesized that dog barking could play a role in interspecific communication between dogs and humans (Feddersen-Petersen, 2000; Yin, 2002). Dogs form strong attachments to humans (Gácsi, Topál, Miklósi, Dóka, & Csányi, 2001; Topál, Miklósi, & Csányi, 1998), they are attracted by different human activities, and they are adept at understanding human communicative signals, both visual (e.g., Miklósi, Polgárdi, Topál, & Csányi, 2000; Soproni, Miklósi, Topál, & Csányi, 2002) and acoustic (Pongrácz, Miklósi, & Csányi, 2001). Dogs can learn to anticipate new, unusual patterns of human behavior (Kubinyi, Miklósi, Topál, & Csányi, 2003), and they can learn socially from human demonstrators (Kubinyi, Topál, Miklósi, & Csányi, 2003; McKinley & Young, 2003; Pongrácz, Miklósi, Kubinyi, et al., 2001; Pongrácz, Miklósi, Timár-Geng, & Csányi, 2003). Further, during domestication, humans have selected dogs according to specific working purposes (Coppinger & Coppinger, 2001) that could be the basis for abilities responsible for communication from the dogs toward humans.

There are two nonexclusive possibilities that can provide the foundation of interspecific communication. Species could rely on common rules of communication that determine the structure of the signal. The presence of such rules was assumed by Morton (1977), who showed that many mammalian and bird signals emitted in specific contexts can be characterized by distinctive acoustic features. Alternatively, the individuals of the different species could learn the meaning of the heterospecific signal. One such natural example for the latter is the realization of the recognition of another species' alarm call (e.g., Seyfarth & Cheney, 1990; Shriner, 1998), and in the laboratory other instances have also emerged; for example, mammals and birds can learn the referentiality of human pointing and verbal signals (dolphin: Herman et al., 1999; grey parrot: Pepperberg & McLaughlin, 1996). It is interesting to note that that there is much less evidence for the former process.

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In the present study, we investigated whether dog barks can play a role in dog–human communication. This assumption relies on at least two conditions: First, dog barks should be acoustically different (Yin, 2002; Yin & McCowan, 2004), and humans should react to dog barks as communicative signals—that is, they should be able to judge the emotional state of the sender and/or the situation in which the bark was emitted.

In the present study, we compared the acoustic structure of dog barks recorded in different behavioral situations and allowed humans to categorize these dog barks and describe their emotional content. Further, we looked at the role of experience by choosing humans with different experiences of dogs for the playback experiment.

Method

Subjects

We formed three experimental groups that were based on the listeners' knowledge about Mudis and on the listeners' general experiences of dogs. *Mudi owners* (n = 12; mean age = 40.17, range = 19–60 years; men:women = 6:6) either had a Mudi at the time of the experiment or possessed a Mudi earlier. They were mainly drawn from the members of the Hungarian Mudi Club or were the family members of the Mudi owners. *Other dog owners* (n = 12; mean age = 27.92, range = 19–52 years; men:women = 6:6) either had a dog at the time of the experiment or possessed a dog earlier, but they had never owned a Mudi. *Nonowners* (n = 12; mean age = 41.30, range = 31–69 years; men:women = 6:6) were those that had never had a dog.

Source of Sound Recordings

Barking vocalizations of a Hungarian sheepdog (*Canis familiaris*) breed, the Mudi, were used for this study (see Figure 1). This medium-sized breed is listed under the 238th Standard of the Fédération Cynologique International. This breed is used traditionally for herding flocks of sheep and cattle. It has also been used as a vigilant watchdog in the countryside. The working style of this breed requires extensive use of barking.

Bark recordings from 19 Mudis (10 males and 9 females; mean age = 3.80 years, range = 1.1–10.0 years) were collected for this study. All the dogs were kept as pets (by 15 owners) in family houses or apartments.

Recording Situations

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 s*chutzhund* 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 22), who acted as the stranger for all the dogs, appeared in the garden of the owner or at the front door of his or her apartment in the absence of the owner. The experimenter asked the owner by phone to stay in another room or at a greater distance during the time needed for the recording. The experimenter recorded the barking of the dog during his appearance and intrusion into the garden or apartment for about 2–3 min.

> Schutzhund: For dogs to perform in this situation, the trainer, who acted as the "bad guy," encouraged the dog to bark aggressively and to bite the bandage on the trainer's arm. During this situation, the owner held the dog on a long leash. The experimenter recorded the barks of the dogs during their training for 1–2 min.

Figure 1. Portrait of a Mudi. The Mudi is a midsized Hungarian sheepdog. It is an alert, intelligent, and obedient breed. Its herding style involves a lot of barking. Photo credit: Péter Pongrácz.

> Going for a walk: The owner was asked to behave as if he or she was preparing to go for a walk with the dog. For example, the owner took the leash of the dog in her or his hand and told the dog, "We are leaving now." The experimenter recorded the barks of the dogs during such situations.

> Alone: The owner tied the leash of the dog to a tree in a park and walked away, out of sight of the dog. The experimenter recorded the barks of the dog from a distance of 4–5 m in the absence of the owner for 3–4 min.

> 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. The barks elicited in this situation were recorded by the experimenter for 1–2 min.

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

We collected as many barks from a given dog and in as many situations as that dog produced barks. In total, 72 barks were used in this study, 12 from each situation originating from different individuals chosen randomly.

Recording and Preparing the Sound Material

Tape recordings were made with a tape recorder and a microphone. During recording of the barks, the experimenter stood in front of the dog and faced it while holding the microphone within 1–4 m of the dog.

The recorded material was transferred to a computer, where we cut out a 20-s-long sample from each bark recording for further analysis and for the playback experiment. We used very simple rules for cutting out the 20-s bark samples from the recordings: (a) The sample could not be the starting or ending section of the bark; (b) the sample needed to contain at least 10 individual barks; and (c) the first 20-s-long sample from the given bark recording was used, which fulfilled the first two criteria. These samples consisted of a various number of individual barks, depending on the interbark intervals. Barks were digitalized with a 16-bit quantization and a 22.05-kHz sampling rate by using a TerraTec DMX 6-fire 24/96 sound card. To equate the calls for loudness, barks were normalized by rescaling each waveform so that its highest amplitude peak was at −6 dB. Barks were analyzed with ACMS sound-analyzing software (contact Sándor Zsebõk at zsebok@ludens.elte.hu for more information). 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 by using a fast Fourier transform of 1,024 points and a frequency resolution of 22 Hz. The following parameters were collected or derived from the original samples:

Interbark interval: The average interval between the individual barks in a 20-s-long sample.

Average peak frequency: The average of the most intense (peak) frequency components of each individual bark in a 20-s-long sample sequence.

Average fundamental frequency: The frequency of the fundamental harmonic of the given bark. We confirmed visually all the individual fundamentals on narrow-band spectrograms after the software chose them automatically. We averaged the fundamental frequencies of the individual barks within the sample sequences.

Harmonic-to-noise ratio (HNR): This parameter served for the description of the "roughness" of the barking. The calculation of HNR was performed by the method described by Riede, Herzel, Hammerschmidt, Brunnberg, and Tembrock (2001), except that we used a 1,024-point fast Fourier transform. This provided us with twice greater dissolution for the analysis. The HNR compares the volume of harmonic tones of the sound with the volume of nonharmonic noise within the sound. The higher the HNR is, the clearer the sound is. The calculation of HNR was done as follows: We computed the power spectrum of a 50-ms segment from the middle of a bark. We estimated the noise level by calculating the moving average of the spectrum curve. Then we determined the maximum difference between the harmonic peaks and the noise level by using a Microsoft Excel macro.

Playback Experiments

Each human listener was provided with a unique set of 18 barks prepared in advance. No two listeners heard exactly the same 18 barks, and the order of the barks within the sets was also randomized. There were 12 listeners in each of the groups and 12 barks coming from different dogs in each of the six situations. Each listener was given 3 different barks from each situation, which resulted in the 18 barks per set. At first we randomized the order of the 12 out of 12 barks in every situation; then we assigned 3 out of 3 of them into the individual sets by using a method in which each bark could go into only 3 sets. After we randomized the barks within the individual situations again and again for the three groups of listeners, we prepared the sets of 18 barks; we could thus guarantee that every listener got a truly unique set of barks and that a given individual bark was scored by only three listeners within a given group.

The sound sets were copied onto a CD and could be played on a computer. Barks were presented to the participants via a multichannel, soft flat-panel PC speaker system. Each listener was exposed to one of the prepared sound sets, which were randomly chosen before the trial. The barks were played back one by one to the listeners, who were allowed to listen to every bark twice. The experimenter handled the player software. The listeners had to fill in the corresponding questionnaire sheet during the experiment. Two questionnaires were used as the experimenter presented two playback series to the subjects. These series were done one after the other, so the listeners handled only one questionnaire at the same time. After playing back a given bark sample twice, the experimenter stopped the device and gave listeners approximately 30 s to fill in the corresponding row on the questionnaire. The experimenter did not give suggestions or any specific help to the listeners but, if needed, played back the given bark sample once more. Listeners performed the playback tests alone or in smaller groups (up to three persons) with the experimenter. In Experiment 1, the listeners had to rate each bark sample for five different kinds of emotions. Following Experiment 1, the experimenter played the same sound set once more for the listeners, but now they had to guess the situation of every bark (Experiment 2). Listeners were not directly informed that they were given the same sound set, but if they asked, the experimenter told them that the same barks might be in both of the sets.

Questionnaire 1: Emotionality ratings. Listeners had to rate each bark sample on a 5-item scale for different content of emotionality: (a) aggressiveness, (b) fearfulness, (c) despair, (d) playfulness, and (e) happiness. Low values indicated the absence of that type of emotion, whereas higher values suggested a predominant presence of the emotion in question. For example, subjects could scale a given sample for the lack of aggressiveness (rated as 1 on the Aggressiveness Scale) but indicate high levels of playfulness (rated as 5 on the Playfulness Scale). Listeners had to rate each bark sample for the presence of each emotion by using the scale system.

Questionnaire 2: Categorization of situations. On the questionnaire, subjects categorized each sample into one of the six situations listed on their sheets. The listeners did not know that each situation could occur three times.

Data Analysis

At first we averaged the emotionality ranks given by the 3 subjects within every group who listened to the same bark sequence. Emotionality ratings were analyzed by a one-way analysis of variance (ANOVA) with Student Newman–Keuls post hoc tests or by a Friedman repeated measures test with Dunn's post hoc tests. We compared the acoustic parameters of the bark sequences in the different situations by using a one-way ANOVA with Student Newman–Keuls post hoc tests. Pearson correlation tests were used to analyze the possible relationship between the emotionality ratings and the acoustic parameters of the barks. The accuracy with which subjects categorized the bark situations was examined by one-sample t tests. We analyzed the effect of different situations on the categorizing of the bark samples by using an ANOVA with post hoc tests.

Results

Acoustic Comparison of Barks Recorded in Different Situations

First we wanted to know whether the bark sequences, originating from the six different situations, differed in the acoustic parameters (see Figures 2 and 3). One-way ANOVAs showed that with the exception of the tonality, the situation had a significant effect on the interbark interval, $F(5, 66) = 8.98$, $p < .001$; the average peak frequency, $F(5, 66) = 4.69$, $p < .001$; and the fundamental frequency of the bark, $F(5, 66) = 3.40$, $p < .01$. The Student Newman–Keuls post hoc tests showed that barks from the schutzhund situation had the shortest interbark intervals and that the barks from the alone and ball situations had the longest

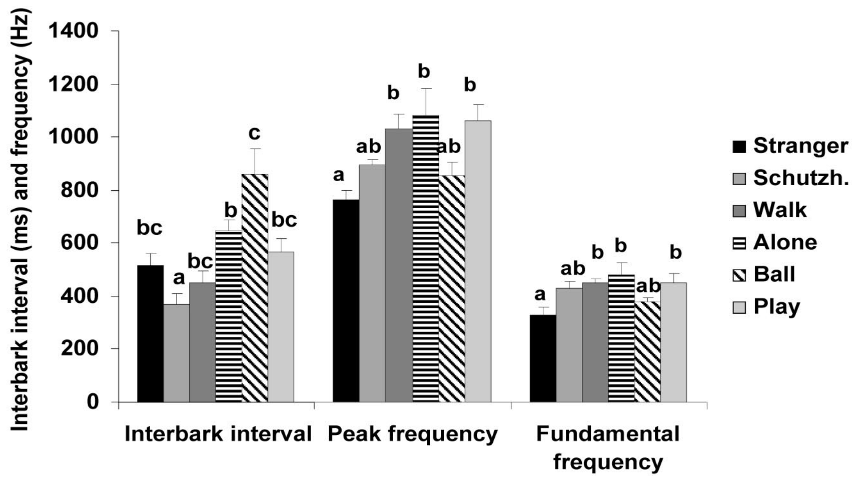

Figure 2. Acoustic parameters with significant differences between the bark situations. Different letters refer to significantly differing values of the given parameter (one-way analysis of variance with Student Neuman–Keuls post hoc test). Error bars represent standard errors of the mean. Schutzh. = schutzhund.

interbark intervals. The average peak frequency and fundamental frequency were the lowest in the stranger situation, which had significantly lower frequency values of both parameters than did the barks from the walk, play, and alone situations.

Emotionality Ratings

The overall comparison of the three groups' scores on the five emotionality scales (Friedman repeated measures test; see Table 1) showed significant differences in the case of the Despair and Playfulness scales. The only difference among the groups was that other dog owners gave significantly higher scores of despair than did the nonowners.

We analyzed how the listeners rated the emotionality of the barks from different situations in the different groups (see Table 2). In the Mudi owners group, Friedman ANOVAs showed that emotionality traits had a significant effect for most situations except for walk and ball barks. Mudi owners gave the highest scores of aggressiveness to barks recorded in the stranger and schutzhund situations (see Figure 4), they gave significantly higher despair and fearfulness than happiness scores to barks recorded in the alone situation, and they gave the highest scores of playfulness to the play barks in comparison to barks recorded in all the other situations, respectively. Additionally, they gave the lowest scores of happiness to the alone barks and the lowest scores of fear and despair to the play barks (Dunn's post hoc test). The results of the other dog owners group showed a similar general pattern (see Table 2). The listeners did not discriminate the walk, ball, and play situations on any of the emotionality scales. They gave the highest scores of aggressiveness to the barks recorded in the stranger and schutzhund situations (see Figure 4). Other dog owners gave high scores of despair and fearfulness and very low scores of happiness and playfulness to the alone barks. Listeners in the nonowners group found two situations difficult to judge by their emotionality: There were no significant differences in the case of either walk or ball barks (see Table 2). However, the categorizing habits of nonowners were very similar to the other two groups in the remaining situations. Nonowners gave high scores of aggressiveness to the stranger and schutzhund situations. Alone barks got high scores in fearfulness and despair while also being characterized by low scores of aggressiveness and happiness. Nonowners gave the highest scores of playfulness and happiness to the play barks, and this situation got the lowest scores on the Despair Scale.

Analyzing the groups separately, we found that humans associated different emotionality as a function of the bark situations (see Table 3). There was a significant effect of situations in all groups on all of the emotionality scales (Friedman repeated measures test with Dunn's post hoc tests). Listeners of all the groups gave significantly higher aggressiveness scores to the stranger and schutzhund situations than to any other emotions. Similarly, all listeners gave the significantly highest scores of fear and despair in the alone situation. In the Mudi owner and nonowner groups, the listeners gave the highest scores of happiness and playfulness to the play situation (see Figure 4).

Finally, we performed Pearson correlation tests to analyze the possible relationship between the emotionality ratings and the acoustic parameters of the barks. For this analysis, the groups were pooled because we found no fundamental differences between the ratings of the three groups. We used the mean score on each emotionality scale for any given bark. Similarly, we calculated the mean of the acoustic parameters for each bark (see Figure 3 for typical sonograms of different barks).

Aggressiveness ratings showed negative correlations with the interbark interval, fundamental frequency, and the average peak frequency of the barks. Ratings for despair correlated positively with the average peak frequency. Playfulness showed positive correlations with the interbark interval, average peak frequency, and fundamental frequency. Happiness correlated positively with the fundamental and average peak frequencies of the barks. There was no evidence of significant correlation in the case of fearfulness with any of the acoustic parameters (see Table 4).

It is interesting to note that we did not find relevant differences between the three groups of listeners in the scoring manners of the

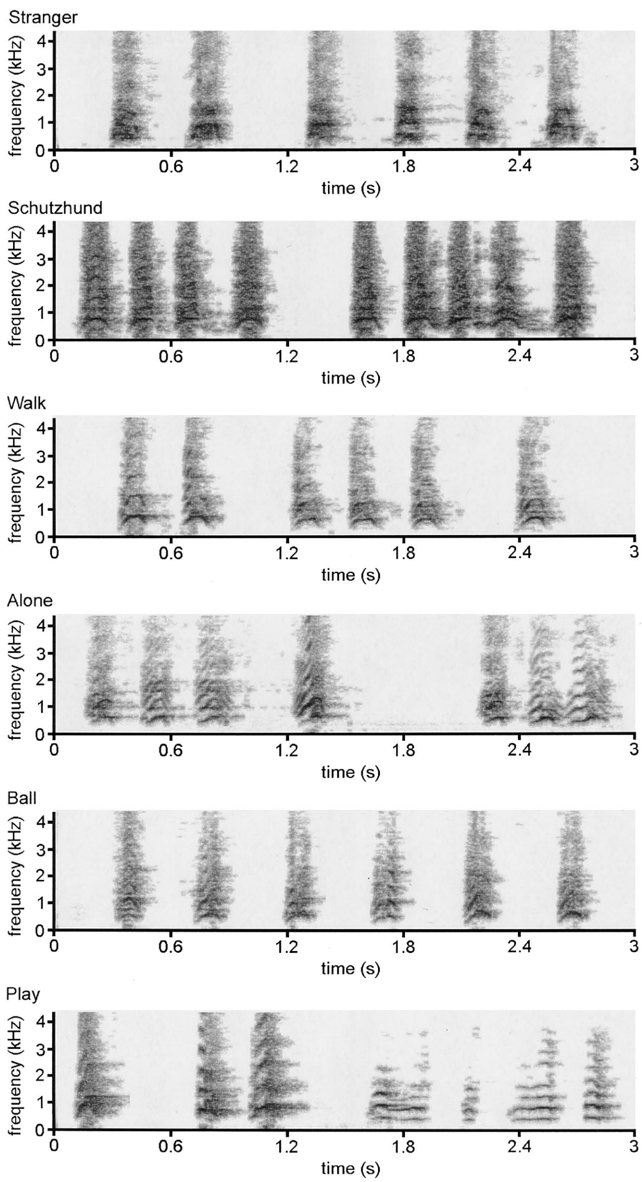

Figure 3. Sonograms recorded in different situations.

emotionality of barks. Group differences would have indicated that experience with dogs or, more possibly, experience with a particular breed can strongly influence the listener's opinion about the emotional content of a particular vocalization. Listeners found stranger and schutzhund situations to be mostly aggressive, barks recorded in the alone situation received high scores on the Despair Scale, and the majority of the listeners gave high scores of happiness and playfulness to the situations of walk and play. We should note that the listeners did the emotionality scoring first and had to categorize the barks later, so it is unlikely that the categorization of a bark influenced the emotionality scoring. We suppose that the emotionality scoring is more sensitive and free from the bias of earlier experiences in a broader extent than is guessing the exact context of a barking. Considering this, we found high agreement between the emotionality scorings of the different groups of subjects.

Table 1
Effect of Previous Experience With Dogs on the Scoring of Different Emotionality Scales (Friedman Repeated Measures Tests)

Scale	κ^2 (2)	p
Aggressiveness	0.58	.74
Fearfulness	2.73	.26
Despair	10.26	<.01
Playfulness	8.31	<.05
Happiness	5.76	.06

Note. Human listeners were divided into three groups: Mudi owners, other dog owners, and nonowners.

The walk and ball situations caused the most difficulty in scaling their emotionality. We assumed that the vocalizations emitted in the "begging for a ball" situation went through considerable shaping during previous interactions with the owner—that is, such barks could have a strongly learned component, which varies among individuals. A similar explanation could hold for the walk situation: Besides the high excitement of the dog, individual prewalking habits of a dog–owner pair could make a difference. Therefore, the manner of barks in this situation may suggest emotions varying among more scales because of the emotion of the individual dog's desire to go for the walk.

Additionally, we found that some emotional ratings correlated strongly with the acoustic features of the barks, which could provide the physical basis for the ability of humans to assign different emotional ratings to some types of barks. We found it interesting that the degree of fearfulness did not correlate with any of the acoustic parameters, but of course this emotion might be scored on the basis of compound or more complex acoustic features. The correlation analysis showed that a bark is likely described as being aggressive if it is characterized by low peak and fundamental frequencies and short interbark intervals. In contrast, high despair ratings are associated with the opposite acoustic parameters of high frequencies and longer interbark intervals. Playfulness and happiness correlated positively mainly with the frequency components, suggesting that a more high-pitched barking is considered more likely to relate to happy or playful emotions. We can conclude that the dimension of quickly versus slowly pulsating barks and high-pitched versus low-pitched fre-

Table 2
Effect of Emotionality Traits in the Different Barking Situations (Friedman Repeated Measures Test)

	Mudi owners		Other dog owners		Nonowners	
Situation	κ^2 (4)	p	κ^2 (4)	p	κ^2 (4)	p
Stranger	58.88	<.001	39.05	<.001	39.48	<.001
Schutzhund	43.79	<.001	69.99	<.001	46.03	<.001
Walk	7.60	.11	5.36	.025	5.14	.24
Alone	24.10	<.001	43.43	<.001	23.30	<.001
Ball	2.77	.60	3.70	.45	7.46	.11
Play	35.29	<.001	6.39	.17	30.92	<.001

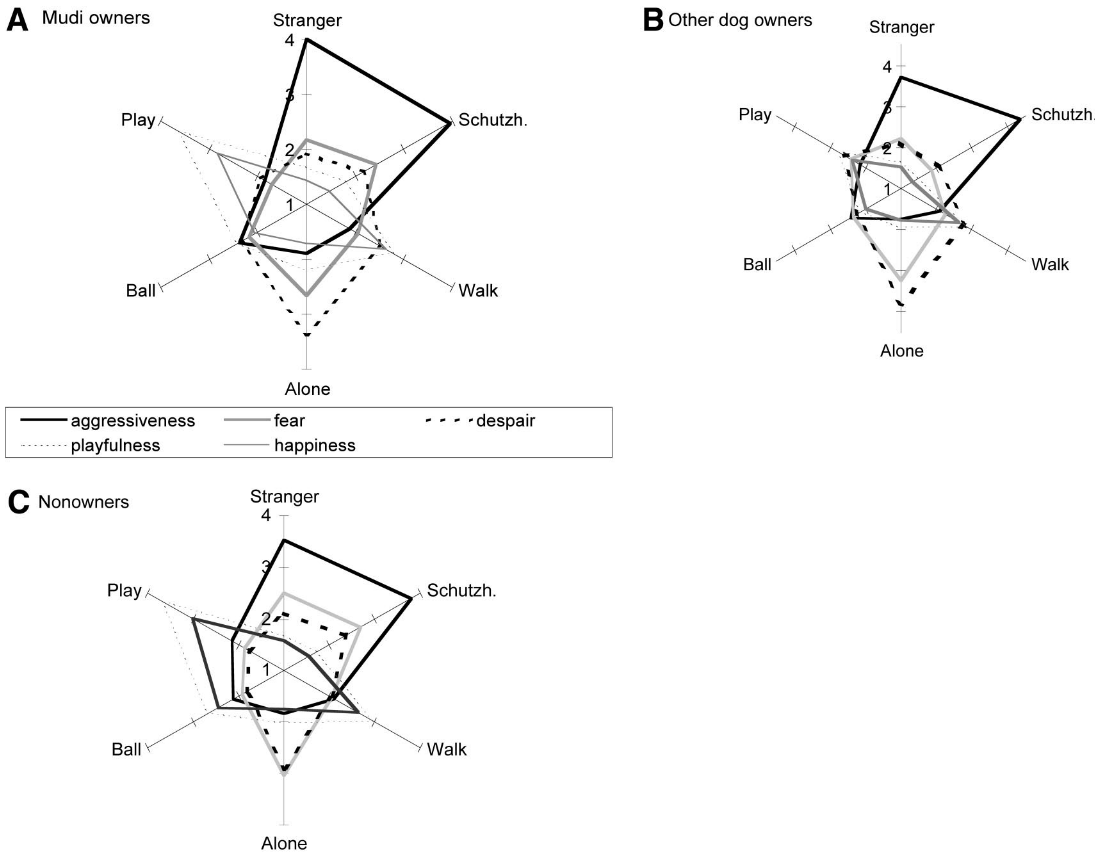

Figure 4. Radar histograms about the effect of situations on the emotionality ratings. The schutzhund (Schutzh.) and alone situations were characterized by high scores of aggressiveness, the alone situation was characterized by high scores of fear and despair, and the play situation was characterized by high scores of playfulness and happiness.

quency could be important for making happy versus sad distinctions, respectively.

Categorization of Situations

First we analyzed the accuracy of recognition of situations within the groups. We found that all groups performed significantly over the chance level (by chance humans could be correct on 3 out of 18 cases: 16.67%)—one-sample *t* tests: Mudi owners (40.74%), $t(11) = 8.22$, $p < .001$; other dog owners (39.35%), $t(11) = 4.08$, $p < .001$; nonowners (39.35%), $t(11) = 7.00$, $p < .001$ (see Figure 5). The comparison of groups with different experience with dogs showed that Mudi owners proved to be only slightly better at guessing the correct situations than listeners in the other two groups, and these differences were not significant: one-way ANOVA, $F(2, 33) = 0.06$, $p = .94$.

As the listeners in the different groups categorized the barks similarly, groups were pooled and we investigated whether the situation influenced the accuracy of categorization. We analyzed the percentage of correct answers with a one-way ANOVA and Student Neuman–Keuls post hoc tests. The type of situation had a significant effect, $F(5, 210) = 10.64$, $p < .001$ (see Figure 6). The listeners most accurately categorized the barking of dogs in the stranger, schutzhund, and alone situations. At the same time, they showed the poorest results in recognition of ball and walk barks. One could ask whether the acoustic features or merely the amount of individual barks in a given bark sample caused the differences between the accuracy of categorization of the different bark samples. As a sample was 20 s long and the average interbark intervals were different between some of the situations, it could happen that human listeners could better categorize those samples that originated from situations with shorter interbark intervals and therefore

Table 3
Effect of Barking Situations on How Human Listeners Rated Emotionality Scales (Friedman Repeated Measures Test)

Scale	Mudi owners		Other dog owners		Nonowners	
	κ^2 (5)	*p*	κ^2 (5)	*p*	κ^2 (5)	*p*
Aggressiveness	64.60	<.001	76.88	<.001	59.50	<.001
Fearfulness	19.39	<.01	20.72	<.001	24.93	<.001
Despair	19.79	<.01	30.87	<.001	25.17	<.001
Playfulness	35.85	<.001	23.83	<.001	44.16	<.001
Happiness	33.63	<.001	26.49	<.001	33.32	<.001

Table 4
Pearson Correlations Among Acoustic Parameters of Barks and Emotionality Scores Given by Listeners

	Interbark interval		Average peak frequency		Fundamental frequency		Tonality (HNR)	
Scale	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
Aggressiveness	−.31	<.01	−.35	<.01	−.23	.05	−.02	.87
Fearfulness	.28	.82	−.13	.27	−.12	.30	.02	.89
Despair	.07	.54	.26	<.05	.17	.15	.05	.65
Playfulness	.26	<.05	.42	<.001	.32	<.01	.08	.50
Happiness	.23	.06	.39	.001	.32	<.01	.09	.44

Note. The three groups of listeners were pooled for this analysis. HNR = harmonic-to-noise ratio.

contained more individual barks. Our results show that this is unlikely, however, as samples from the stranger, schutzhund, and alone situations were categorized most accurately by the listeners and, accordingly with Figure 2, the interbark intervals were the shortest in the schutzhund situation, medium length in the stranger, and long in the alone situations.

We calculated a so-called confusion matrix, too (see Table 5). We wanted to know if the listeners did not correctly categorize the given bark sample, which situations they used most for these misidentified items. Four situations were quite well identified: stranger, schutzhund, alone, and play. From these, stranger and alone had no preferred alternative, as the wrong answers were distributed quite equally among the other situations. On the other hand, schutzhund was quite often misinterpreted as stranger, and play was mistakenly categorized most often as ball.

Discussion

Our results from the two experiments showed that (a) independent from their previous experiences with dogs, human listeners scored the emotional content of barks in similar manner and accuracy; and (b) the emotional ratings were in accordance with expectations knowing how the specific situations could affect the emotions of dogs (i.e., vocalizations of dogs attacking a stranger in the garden or performing schutzhund training were given high scores of aggressiveness, or the vocalizations of dogs left alone and tied to a tree were given high scores of despair). Further, we found evidence that (c) the emotional content as judged by humans correlates with particular acoustic parameters of a given bark, but (d) we did not find a major difference in the accuracy of categorization between the performance of the listeners on the basis of their previous experiences with dogs; (e) human listeners categorized more accurately those situations for which they found the emotional content less ambiguous (stranger, schutzhund, alone, and play), but (f) listeners could categorize over the chance level the majority of the barking situations on the basis of listening only to the vocalizations.

Until now there were only a few investigations that compared dog barks emitted in different situations (Bleicher, 1963; Riede & Fitch, 1999). Recently, Yin (2002) found that barks from three situations (*to strange noise, dog is left alone in a room,* and *play*) differed in some acoustic parameters and hypothesized that this could provide a basis for interspecific communication; similarly, Feddersen-Petersen (2000) suggested that dogs might communicate with humans mainly by barking. Our experiments were con-

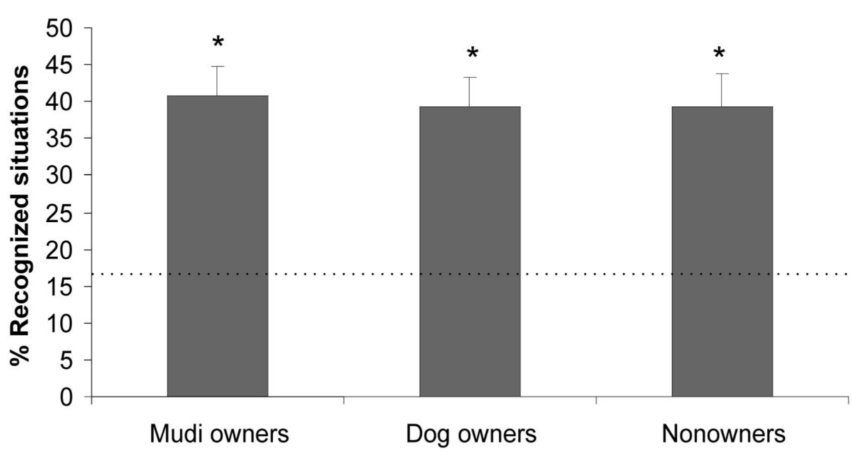

Figure 5. Overall percentages of situations categorized correctly. All three groups of listeners performed over the chance level (16.67%; one-sample *t* test). There was no significant difference between the groups (one-way analysis of variance). Errors bars represent standard errors of the mean. *$p < .001$.

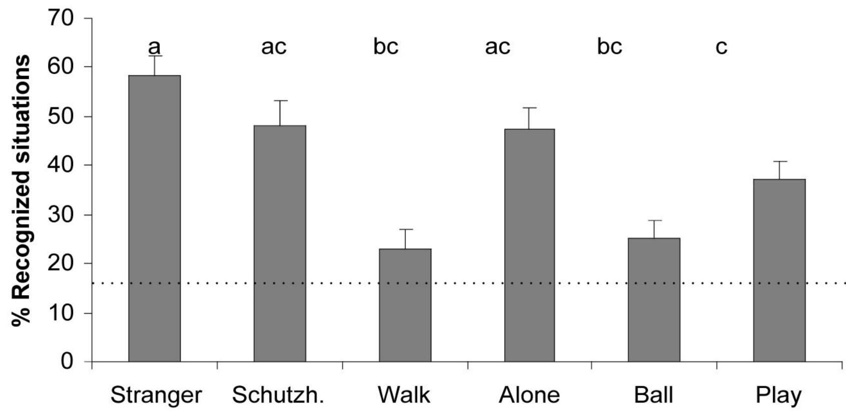

Figure 6. Percentages of correctly categorized situations in the pooled groups of human listeners. The different letters refer to significantly differing situations (one-way analysis of variance with Student Neuman–Keuls post hoc test). Error bars represent standard errors of the mean. Schutzh. = schutzhund.

ducted on a relatively large human sample, and we used barks from more dogs and from more situations than had been collected before. Our results showed that human listeners are able to categorize these situations on the basis of auditory cues only. As our subjects were not given visual cues of the situations, we can conclude that the acoustic structure of barks provides features that make them recognizable for human listeners. This suggests that some dog barks may present means for interspecific communication. This finding differs from the results by Nicastro and Owren (2003), who found that human listeners were less skilled in classifying cat meows and that their abilities were in strong correlation with their experience and affinity to cats.

It is interesting to note that in our case, there was no significant difference between humans who had many opportunities for learning about dogs and those who have never had a dog at home. Therefore, humans might share some learned knowledge about dog vocalization and behavior, and/or dog barks may have a strong emotional content because acoustic features affect homologous inborn human abilities. According to the latter, it is worth referring to Morton’s (1977) theory of how the acoustic parameters of the mammalian and avian vocal signals express the aggressiveness or subordinance of the signaler. Morton concluded that atonal, low-pitched signals bear aggressive meaning, whereas tonal and high-pitched signals express subordinance or the lack of aggressiveness. Most important, these results were based on several nonrelated species; therefore, Morton assumed that these rules could be universal, at least among mammals and birds. Our results partly support Morton’s theory as we found that high fundamental and peak frequencies of the dogs’ barks were characteristic to the nonaggressive situations (walk, play, and alone), whereas low fundamental and peak frequencies were found in the stranger and schutzhund situations, which were characterized by the humans as the most aggressive ones as well. It is interesting that tonality had no significant effect on how our subjects categorized the barks or on what kind of emotions they attributed to them (but see Yin & McCowan, 2004).

It is interesting that humans judged bark sequences of shorter interbark interval to be more aggressive. This has some parallels with the findings of McConnell and Baylis (1985), who found that shepherds’ high-pitched, quickly pulsating whistles have an activating, encouraging effect on dogs, because in both cases the pulsing of the sound is associated with some urgency on the part of the listener.

We found that most of the dog barks bear a very strong emotional content for human listeners. This suggests that basic emotions and the ability to recognize them is an ancient capability shared by animals and humans. The fact that humans found the barks to express basic emotions could be a sign that this form of

Table 5
“Confusion Matrix” of Correct and Incorrect Identifications of Bark Situations

	Answers (%)					
Situation	Stranger	Schutzhund	Walk	Alone	Ball	Play
Stranger	58.33[a]	12.96	7.41	9.26	5.56	6.48
Schutzhund	30.56	48.15[a]	3.70	4.63	3.70	9.26
Walk	11.11	4.63	23.15[a]	18.52	20.37	22.22
Alone	12.96	4.63	10.19	47.22[a]	14.81	10.19
Ball	16.67	6.48	11.11	25.93	25.00[a]	14.81
Play	4.63	12.96	12.96	9.26	23.15	37.04[a]

Note. The answers from the three groups were pooled.
[a] Indicates percentage of correct answers.

vocalization has communicative relevance for humans. Natural and artificial selection could have favored the emergence of such understandable vocalizations in dogs. Macedonia and Evans (1993) suggested that pressure for predator-specific avoidance behavior resulted in functionally referential alarm calls in some of the mammalian species, whereas in those mammal prey species for which predator avoidance always requires the same behavior, alarm calls remain nonreferential. Considering this, we may expect context-specific barks in such situations that it is important for humans to react accurately after hearing the given bark (e.g., when the dog expresses aggression or despair). Contrary to this hypothesis, the highly emotional situations, where we collected our vocal samples, as well as the listeners' ratings indicate that dog barking is mainly an emotionally driven communicative process, which makes referentiality less likely (Hauser, 1996, 2000). We think that there are at least two key conditions that changed dog barking to an effective communicative signal between dog and human: First, domestication processes have resulted in dogs that are more dependent on humans, making them more human oriented (Miklósi et al., 2003; Miklósi, Topál, & Csányi, 2004). Second, humans have selected for dogs that bark reliably and in accordance to certain behavioral and emotional situations.

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