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Acoustic parameters of dog barks carry emotional information for humans

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Abstract

In an earlier study, we found that humans were able to categorize dog barks correctly, which were recorded in various situations. The acoustic parameters, like tonality, pitch and inter-bark time intervals, seemed to have a strong effect on how human listeners described the emotionality of these dog vocalisations. In this study, we investigated if the effect of the acoustic parameters of the dog bark is the same on the human listeners as we would expect it from studies in other mammalian species (for example, low, hoarse sounds indicating aggression; high pitched, tonal sounds indicating subordinance/fear). People with different experience with dogs were asked to describe the emotional content of several artificially assembled bark sequences on the basis of five emotional states (aggressiveness, fear, despair, playfulness, happiness). The selection of the barks was based on low, medium and high values of tonality and peak frequency. For assembling artificial bark sequences, we used short, middle or long inter-bark intervals. We found that humans with different levels of experience with dogs described the emotional content of the bark sequences quite similarly, and the extent of previous experience with the given breed (Mudi), or with dogs in general, did not cause characteristic differences in the emotionality scores. The scoring of the emotional content of the bark sequences was in accordance with the so-called Morton's structural–acoustic rules. Thus, low pitched barks were described as aggressive, and tonal and high pitched barks were scored as either fearful or desperate, but always without aggressiveness. In general, tonality of the bark sequence had much less effect than the pitch of the sounds. We found also that the inter-bark intervals had a strong effect on the emotionality of dog barks for the human listeners: bark sequences with short inter-bark intervals were scored as aggressive, but bark sequences with longer inter-bark intervals were scored with low

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values of aggression. High pitched bark sequences with long inter-bark intervals were considered happy and playful, independently from their tonality. These findings show that dog barks function as predicted by the structural–motivational rules developed for acoustic signals in other species, suggesting that dog barks may present a functional system for communication at least in the dog–human relationship. In sum it seems that many types of different emotions can be expressed with the variation of at least three acoustic parameters.

Keywords: Dogs' bark; Human; Communication; Acoustic parameters

1. Introduction

Based on a comprehensive comparison of bird and mammalian vocalisations, Morton (1977) hypothesized that low pitched (and atonal) vocalisations signal aggressive intentions, in contrast to high pitched (and tonal) vocalisations signalling friendly/ submissive intention. His basic argument was that, according to the general physical laws, larger bodies emit sounds characterized by lower frequencies (and these are also noisier/ atonal), thus receivers can predict the size of the sender. This relationship could have formed the basis of an evolutionary ritualisation process whereby low pitched vocalisations tended to signal aggression because larger animals are more likely to win contests. Similar argument can be made for high pitched vocalisations, assuming that those are usually associated with small bodied and young individuals of a species. Again, as a result of ritualisation, high pitched vocalisations became predictors of submission or friendly intent.

Compared to the other vocalisations (like growling, howling, whining, etc.) of wild Canids, dog barks are highly variable and are used in various situations (Cohen and Fox, 1976). These led many researchers to assume that barks have no direct communicative function and are a hypertrophied ‘‘by-product’’ of domestication. Such assumptions were strengthened by the finding that foxes selected for tame behaviour also displayed elevated levels of barking (Belyaev, 1979). Coppinger and Feinstein (1991) considered the excessive barking of dogs as a result of the so-called ‘‘heterochronical’’ development of the dog during the domestication. It means that the dog, being a somewhat ‘‘neotenized’’ wolf from many aspect, retained the barkiness of the wolf pups for their adulthood, too. The mentioned theory of Coppinger and Feinstein also argues therefore for the original meaninglessness of dog barking.

Earlier it has been found that dogs emit acoustically different barks in different situations suggesting that motivational changes in the dog are reflected in barking vocalisations (Feddersen-Petersen, 2000; Yin, 2002). More importantly, in an extensive playback study, where we used numerous bark samples recorded from specimens of a Hungarian sheepdog breed, the Mudi, we found that human listeners can categorize dog barks accurately regarding to the original recording situation, and also the possible emotionality of the barking animal (Pongrácz et al., 2005). Human listeners had to choose one of six possible situations (stranger appears, dog attacks human, left alone, before walking, asking for ball and playing with humans) after they listened to a bark sample. Similarly, they had to rate the possible emotional state of every bark sample on the basis of five emotional scales (aggression, fear, despair, happiness and playfulness). An acoustic analysis showed that barks recorded in different situations have distinctive acoustic patterns, regarding to their harmonic-to-noise ratio, fundamental and peak frequencies and inter-bark intervals. We have found close correspondence in most cases between the categories and emotional states indicated by human listeners picked, which also corresponded with some of the above mentioned acoustic parameters, e.g. low pitched barks were more likely described as ‘‘aggressive’’ and categorized as being emitted in either in the ‘‘stranger in the garden’’ or ‘‘dog attacks human’’ situations (for details see Pongrácz et al., 2005).

In this study, we investigate if the acoustic parameters of dog bark do follow the rules put forward by Morton (1977). As dogs and humans are both mammalian species, our main question was whether human understanding of different barking vocalisations of dogs was based on the common mammalian heritage following Morton's structural–motivational rules. This question is even more interesting if we consider that dog human communication via acoustic signals can be a new case of spontaneous interspecific communication. Although humans obviously can teach a big variety of animal species to obey conditioned signals, there are only a few cases when animals, living in their natural environment signal voluntarily to humans. Perhaps the most well-known example for this is how honeyguide birds (*Indicator indicator*) help African tribal people to find beehives in the forset (Isack and Reyer, 1989). Dog–human communication would be a comparable case as dogs are considered as animals living in their ‘‘natural environment’’ at the human families. Our hypotheses were that (1) the human understanding of dog bark's emotions is based mainly on Morton's structural–motivational rules; (2) humans categorize the emotional states of the dog bark mostly independent from the acoustic parameters which Morton predicted as main factors for channelling the signallers' emotions. According to these predictions, the acoustic parameters, which were found earlier to be relevant in differentiating bark situations and emotions, were used for further elaborated investigations here. It is important to point out that in contrast to our earlier study (Pongrácz et al., 2005), here we test whether humans are able to associate specific emotional states to a series of barkings if the vocalisation is artificially assembled from different individual barks chosen only on the basis of their acoustic parameters and independent from the recording situation. To rule out the role of the effect of possible individual differences and the influence of the recording situation, all bark samples collected were used from a pool in which individual barks were chosen solely on the basis of their acoustic characteristics. Accordingly, we selected the individual barks only on the basis of their pitch (low, medium and high) and harmonic to noise ratio (HNR) (low, medium and high). These barks were joined together into sequences where the inter-bark interval (pulsing) was also manipulated (short, medium and long). This collection of 27 bark sequences (3 pitch $\times$ 3 HNR $\times$ 3 pulsing) was presented to three different groups of human volunteers, who differed in the amount and type of previous experiences with dogs (Mudi owner, other dog breed owner, no dog owner) for judgement of the emotional state of the dog.

2. Materials and methods

2.1. Human listeners

We formed three experimental groups depending on the listener's experience with dogs. (1) "Owner of a Mudi at time of the study or in past", or shortly *Mudi owners* ($n = 30$, mean age = 38.4 years, with a range from 16 to 69 years, male/female = 7/23). (2) "Owner of a dog breed other than Mudi at time of the study or in past", or shortly *dog owners* ($n = 30$, mean age = 21.9 years, with a range from 19 to 28 years, male/female = 12/18). (3) "Never owned a dog", or shortly *non-owners* ($n = 30$, mean age = 25.6 years, with a range from 18 to 51 years, male/female = 15/15).

2.2. Procedures

2.2.1. Source and collection of sound recordings

Barks of the Mudi breed (a Hungarian herding dog listed under the 238th Standard of the Fédération Cynologique International (FCI)) were used for this study. 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, as well as being a watchdog, is characterized by the extensive use of barking. Bark recordings from 15 Mudis (6 males and 9 females, average age: 4.3 years; range: 1–9 years) were collected for this study. All the dogs were kept as pets (by 10 owners) in family houses or apartments. Bark recordings were collected in six different behavioural contexts, most of which could be arranged at the homes of the owners, with the exceptions of the 'dog attacks human' situation, which was staged at dog training schools, and the 'alone' situation, which was staged on a street or in a park. All the barks were recorded by one of the authors, Cs. M. (age: 22 years, male), who was the "experimenter" during the recordings. Because our previous study (Pongrácz et al., 2005) showed that humans attribute strong emotional aspects to almost all of these bark types, we decided to use the same situations again as the source of individual barks for assembling the "artificial" bark samples in the present study. By using only acoustic, but not referential (i.e. situations) criteria for selecting the individual barks, we ensured that our listeners' answers would depend on the bark samples' acoustic characteristics only. The six situations are as follows.

2.2.1.1. Stranger. The experimenter was the stranger for all the dogs, would arrive at the garden of the owner or at the front door of his/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 2–3 min.

2.2.1.2. Dog attacks human. This situation refers here to the so-called 'Schutzhund' training (this German term is used worldwide by dog trainers and applied dog literature). For dogs to perform in this situation, the trainer who acts as the "bad guy" encourages the dog to bark aggressively and bite the glove on the trainer's arm. The experimenter recorded the barks of the dogs during their training for 1–2 min.

2.2.1.3. 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''. The experimenter recorded the barks of the dogs during such situations for 1–2 min.

2.2.1.4. 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.

2.2.1.5. 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 experimenter recorded the barks elicited in this situation for 1–2 min.

2.2.1.6. 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 play. He collected as many barks from a given dog, and in as many situations as that dog produced barks. Later, we pooled all barks and used this sound collection (with slightly more than 4000 individual barks) for choosing randomly the required amount of barks for the determined ranges of particular acoustic parameters. From these barks, we assembled artificial bark strings for the playback experiment.

2.2.2. 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 1–4 m of distance from the dog. The experimenter stood in front of the dog. The recorded material was transferred to a computer, where it 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 waveform so its highest amplitude peak was at 6 dB. Bark sequences were analyzed with ACMS sound analyzing software written by Sándor Zsebõk (zsebok@ludens.elte.hu). 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 preparing the playback material.

2.2.2.1. Mean dominant frequency. We characterized each individual bark by calculating the mean of the frequency measures done at 100 points in time.

2.2.2.2. Harmonic-to-noise ratio. This parameter serves as the description of the ''roughness'' of the barking (Fig. 1). The calculation of HNR was performed by the method described by Riede and Fitch (1999), with the difference that we used a 1024-point fast Fourier transformation (FFT). This provided us with twice greater resolution for the analysis. The HNR compares the volume of harmonic tones of the sound to the volume of non-harmonic noise within the sound. The higher is the HNR, the more clear (harmonic) is

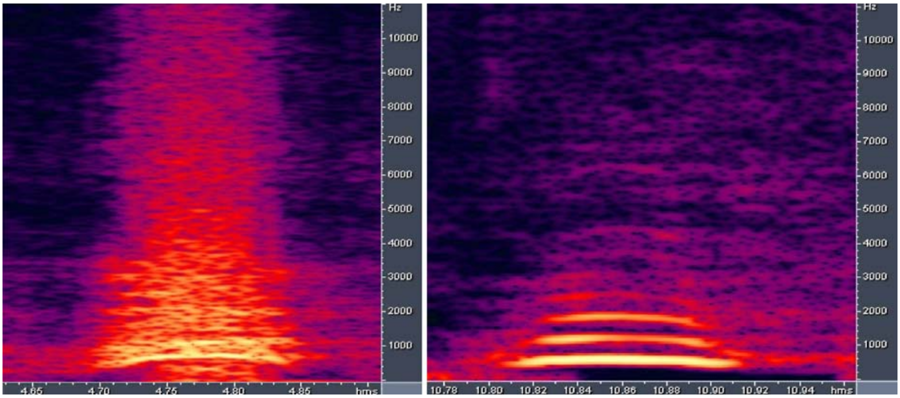

Fig. 1. Illustration of single barks used to assemble the bark sequences. These two barks differ markedly in the harmonic to noise ratio (HNR), where HNR is larger in the bark on the right. The bark on the left comes from the situation ‘stranger’, while the bark on the right comes from the situation ‘alone’.

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.

2.2.2.3. Inter-bark interval. The average interval of time from the end of the individual barks to the beginning of the next bark in the artificially made bark samples.

2.2.3. Assembling of the artificial bark sequences

First, we measured the natural range of average sound frequency and HNR of the individual barks in our collection and determined the range of the inter-bark intervals on the basis of the original bark recordings. Then, we determined three non-overlapping subcategories for each parameter, we considered them as ‘‘low’’ (or ‘‘short’’), ‘‘middle’’ and ‘‘high’’ (or ‘‘long’’). The natural ranges and the chosen subcategories are shown in Table 1. After this we searched for individual barks from the pooled bark population which were put into one of the nine subcategories, determined by the possible combinations of the mean frequency (3) and the HNR (3). For each subcategory, we picked randomly 10 individual barks. We set the intensity of each bark to 6 dB. From these barks we formed artificial bark sequences by adding inter-bark intervals between them, corresponding to the three inter-bark interval subcategories. To avoid the highly unnatural sound resulting from the totally equal inter-bark intervals within a subcategory, we gave a slight variance to the intervals. It was a randomly sorted variation of 5 ms, which would lengthen or shorten the inter-bark intervals within a given sample. In total, we made 27 different artificial bark sequences, with an approximate duration of 15 s. The total duration of the sequences varied slightly because we varied the inter-bark interval (short, medium and long) that was inserted among the 10 barks. A particular individual bark was present in a given bark sequence only once, because we did not use computerized bark-multiplication. As the

Table 1

	Min–max	Mean	S.D.	*n*
Average sound frequency (Hz)				
Total sample	497–1512	923.58	210.51	4000
Low	500–700	626.12	71.65	189
Medium	850–1050	941.60	57.08	540
High	1200–1400	1267.58	50.43	93
Harmonic to noise ratio (HNR)				
Total sample	19.57–41.99	27.30	5.31	4000
Low	20–23	21.42	1.20	310
Medium	28–31	29.40	0.82	242
High	36–39	37.34	0.88	52
Inter-bark interval (s)				
Total sample	0.05–1.70	0.41	0.46	4000
Low	0.05–0.15	0.08	0.05	506
Medium	0.25–0.35	0.30	0.03	168
High	0.45–0.55	0.50	0.03	77

In the first column, we show the ranges of sound frequency, HNR and inter-bark intervals in the collected bark samples (Total sample), and also the ranges of the selected barks in the ‘‘Low’’ (‘‘Short’’), ‘‘Medium’’ and ‘‘High’’ (‘‘Long’’) categories. Following columns provide the means and standard deviations of the barks.

barks were chosen randomly, it was very likely that a given bark sequence consisted of barks originating from different individuals. This way we could avoid the possible side effects of the ‘‘individuality’’ of a particular dog (i.e. if the bark sequence would been assembled from the barks of the same dog); at the same time we could use real sound samples instead of artificially generated barks.

2.2.4. Playback experiments

We formed four sound sets consisting of the same 27 bark sequences and within these four, the order of the barks was randomized. The sound sets were copied onto a CD and could be played on a computer. Bark sequences were presented to the participants via a Philips MMS 305/A 3.500 multi-channel soft flat panel PC speaker system. Each listener was exposed to one of the prepared sound sets chosen randomly before the trial. The bark sequences were played back one by one to the listeners, who were allowed to listen to every bark sequence twice. The experimenter handled the player. The listeners had to fill in a questionnaire sheet during the experiment. After playing back a given bark sequence twice, the experimenter stopped the device, and gave approximately 30 s for the listeners 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 once more the given bark sample. Listeners performed the playback tests alone or in small groups (up to four people) with the experimenter. None of our listeners knew that artificial bark sequences were used. Some of the listeners asked about the unusually quiet inter-bark intervals, in those cases we answered that sometimes we had to filter disturbing background noises from the environment where the recording was made. For the ‘‘emotional ratings’’ the listeners had to rate each bark sequence for five different kinds of emotional states.

2.2.5. Emotional ratings

Listeners had to rate each bark sequence on a five-item scale for different content of emotional state: (1) aggressiveness, (2) fearfulness, (3) despair, (4) playfulness and (5) happiness. Low values indicated the absence of that type of "emotion", while higher values suggested a predominant presence of the "emotion" in question. For example, listeners could scale a given bark sequence for the lack of aggression (rate 1 on the aggressiveness scale) but indicate high levels of playfulness (rate 5 on the playfulness scale). Listeners had to rate each bark sample for each emotional state separately.

2.3. Data analysis

The units of the statistical analysis were the group averages of the individual listeners' emotional ratings on each bark sequence. A four-way mixed ANOVA was performed, with three independent variables of pitch (low, medium, high); tonality (low, medium, high); inter-bark interval (short, medium, long); the fourth variable was the experience with dogs, as a within-subject repeated factor (Mudi owners, dog owners, non-dog owners). The five emotion scales served as dependent variables (aggression, fear, despair, playfulness and happiness). In case of significant effects, Duncan post hoc tests were performed.

3. Results

Table 2 shows the results of all the Duncan post hoc tests, which were performed if the four-way mixed ANOVA showed a significant effect. We got the following results for the aggression scores: while the tonality of the barks ($F(2,20) = 1.51$; $p = 0.25$) and the experience with dogs ($F(1,20) = 0.89$; $p = 0.36$) had no significant effect, the other two independent factors had significant effect on the aggression scores of the listeners: pitch ($F(2,20) = 34.37$; $p < 0.001$); inter-bark interval ($F(2,20) = 46.75$; $p < 0.001$). High pitched barks were considered being less aggressive than the ones with medium and low sound frequencies, and barks with short inter-bark interval got the highest scores of aggression.

Table 2

	Pitch			HNR			Inter-bark interval			Experience		
	Low	Med.	High	Low	Med.	High	Short	Med.	Long	Mudi	Other dog	No dog
Aggressiveness	3.00a	2.80a	1.97b	2.61	2.67	2.45	3.27a	2.35b	2.11b	2.51	2.66	2.57
Fear	2.08a	2.22a	2.50a	2.19	2.25	2.37	2.29	2.19	2.32	2.20a	2.19ab	2.42b
Despair	1.98a	2.15a	2.71b	2.15a	2.25a	2.44b	2.15a	2.25a	2.45b	2.34	2.22	2.29
Playfulness	2.08a	2.04a	2.47b	2.19	2.23	2.16	1.97a	2.34b	2.26b	2.24ab	2.27a	2.06b
Happiness	1.88ab	1.85a	2.28b	2.00	2.05	1.97	1.86	2.13	2.04	2.04	2.04	1.94

Results of the Duncan post hoc tests, performed in the cases where the four-way mixed ANOVA proved to be significant. The emotional states are in the far left column, and the independent variables are in the top row. The average score values are in the individual cells. Where the post hoc test proved to be significant between the values within a given independent variable's three levels, significantly different values are marked with different letters (a and b).

The pitch of the barks ($F(2,20) = 11.63$; $p < 0.001$) and experience ($F(1,20) = 8.99$; $p < 0.01$) had significant effect on the emotional state 'fear'. The tonality ($F(2,20) = 2.25$; $p = 0.13$) and inter-bark interval ($F(2,20) = 1.10$; $p = 0.35$) had no significant effects, however. Listeners in the 'non-owner' group gave higher points of fear, than did the 'Mudi owners'. Listeners gave the significantly highest scores of fear to the high pitched bark sequences.

Only the experience ($F(1,20) = 0.51$; $p = 0.48$) had no significant effect on the emotional state 'despair', while the pitch ($F(2,20) = 41.00$; $p < 0.001$), the tonality ($F(2,20) = 6.26$; $p < 0.01$) and inter-bark intervals ($F(2,20) = 6.73$; $p < 0.01$) had significant effects. High pitched barks were given the highest despair scores, as well as the ones with high HNR values. The long inter-bark intervals elicited the highest despair points.

From among the four independent factors, only the tonality ($F(2,20) = 0.20$; $p = 0.82$) did not have significant effect on the emotional state 'playfulness'. In the case of experience ($F(1,20) = 8.69$; $p < 0.01$) 'non-owners' gave significantly lower points on this scale than listeners in the 'dog owners' group. In the case of the pitch ($F(2,20) = 9.67$; $p < 0.001$), high pitched bark sequences were given the highest playfulness points, and in the case of inter-bark intervals ($F(2,20) = 6.35$; $p < 0.01$), bark sequences with short inter-bark intervals were given the lowest scores of 'playfulness'. Also, we found a significant interaction between the experience and the pitch ($F(2,20) = 8.82$; $p < 0.01$).

Only the pitch ($F(2,20) = 9.68$; $p < 0.001$) had significant effect on the scores of emotional state 'happiness', while the experience of the subjects ($F(1,20) = 2.64$; $p = 0.12$), the tonality ($F(2,20) = 0.25$; $p = 0.78$) and the inter-bark intervals ($F(2,20) = 3.14$; $p = 0.07$) did not. High pitched bark sequences were given higher scores than the ones with medium sound frequency. As with the previous emotion, we found again a significant interaction between the experience and the pitch ($F(2,20) = 4.96$; $p < 0.05$).

4. Discussion

Our results showed that mean dominant frequency, inter-bark intervals and to a lesser extent the tonality of artificially assembled bark sequences convey emotional information for the human listener. The way how acoustic parameters affected the attributed emotional content of the bark sequences was in accordance to Morton's structural–motivational rules (1977): low pitched bark sequences were scored as strongly aggressive; high pitched and tonal barks were scored as non-aggressive, but as fearful and desperate. We found also that the inter-bark intervals have a strong effect on how humans score the emotional content of the bark sequences. Short inter-bark intervals elicited high aggression scores, while sequences with long inter-bark intervals were considered non-aggressive, but as either fearful/desperate, or playful/happy. As it was shown in other studies on acoustic communication between humans and dogs (McConnell, 1990; McConnell and Baylis, 1985), the pulsing of the calls (which can be related to the faster or slower bark sequences due to the shorter or longer inter-bark intervals) can be also an important acoustic factor in the understanding of dog barks.

We should note that certain acoustic parameters differentiated barks not only along the aggressive–submissive axis. It means that high pitched barks with long inter-bark intervals were considered not only ‘‘lacking aggression’’, but they were given high scores of despair, playfulness and happiness too. If we take a closer look, it becomes clear that the scoring of ‘playfulness’ and ‘happiness’ is independent from the tonality of the barks, while ‘despair’ was the only emotional state where the tonality had significant effect on the listeners’ scores. Seemingly human listeners attributed the two ‘positive’ emotions for the bark sequences on the basis of the pitch and the inter-bark interval, regardless to their tonality. This shows that at least three acoustic parameters (and the interactions between them) might make it possible to express a wide range of different emotions. A very interesting comparison can be made if we consider how babies’ preverbal vocalisations convey emotions. It was found that less-than-a-year-old human babies can express a variety of negative and positive emotions with the help of a relatively few acoustic variables, like harmonic-to-noise ratio, call length, peak frequency and frequency range (Schreiner et al., 2002). As young babies are not able to use verbal utterances to express their needs, it is reasonable to hypothesize that their vocalisations would follow the general rules of expressing basic emotions.

It is important to note that the vocalisation system of the wolf (which is usually regarded as being the most closely related species to the dog, Savolainen et al., 2002) is composed of two very distinct sound systems where barking is categorized among other vocalisations that signal aggression, threat, protest or warning (Tembrock, 1976; Schassburger, 1993), and is clearly different acoustically from sounds emitted by individuals with submissive intent or those expressing frustration, fear or pain (e.g. whine, whimper, yelp). There are only a few studies dealing with the effect of dog bark on other dogs, and these report of only low specificity of the elicited responses. For example, when the effect of different artificial and human originated noises was compared with the effect of pre-recorded dog barks on sleeping dogs, it was found that dog barks elicited more bark responses from the subjects than the other types of noises (Adams and Johnson, 1994). The present study, however shows that barks can communicate both types of basic emotions (aggressiveness versus submissiveness/friendliness) because humans were able to associate bark sequences with certain acoustic parameters as being either aggressive or submissive. From this point of view, we can assume that dog bark, which channels a wide variety of emotional states of the signaler, could be itself a useful ‘‘raw material’’ for inter-specific communication between dogs and humans, based on general bioacoustics rules (Morton, 1977). As a following step during the domestication process, humans could select dogs for more specific, or even ‘‘more understandable’’ vocal signals. This kind of selection could be continuously at work in the case of working dogs, such as herding dogs, where acoustic communication is often the predominant inter-specific channel. Although it has often been supposed that communication signals were evolved predominantly to manipulate others (Krebs and Dawkins, 1984), the opposite could be assumed in the case of the dog. Reliable signalling would be favorable on the part of the dog because this could provide him with an advantage in cooperative interactions with humans (Naderi et al., 2001).

Affective models of communication (Owren et al., 1997) assume an alternative but not necessarily exclusive process explaining the effect of a communicative signal upon the receiver. In the case of acoustic signals, it has been hypothesized that some biophysical effects of the sound can directly influence the receiver’s behaviour by affecting directly the neural processing of the sound, which has also an effect on other behavioural systems. For example, sudden, loud sounds lead to the ‘‘startle response’’ in a wide range of species investigated. A similar parallel effect has been described in the case of the dog, when fast pulsing calls have been found to be superior in training a dog for approaching the human whilst low pulsing sounds were favored in teaching passive behavioural sequences on command, e.g. sitting (McConnell and Baylis, 1985). Interestingly, analysing spontaneous vocal behaviour of trainers towards dogs, McConnell (1990), also found that humans rely on these ‘‘rules’’ when trying to increase or decrease the speed of the dog during task performance. Ritualisation as an evolutionary process has been often evoked to explain the emergence of communicative signals. The new function of barks to express submissive (or friendly) behavioural state and ‘‘evoke’’ emotions like ‘‘fear’’ or ‘‘despair’’ in humans seems to present such a case where it is likely that this behavioural change in the dog has happened during the last few ten thousand years of domestication (Savolainen et al., 2002).

Although our study showed that human listeners attribute strong emotional content to the dog bark sequences, we should note that present results do not exclude the possibility of referential communication between dogs and humans, but it is more likely that such signals acquire their meaning through ontogenetic ritualisation (Tomasello and Call, 1997) during which the two interacting individuals ‘‘agree’’ on the object of the signal, as it was found in the case of an African grey parrot (Pepperberg, 1990) and a bonobo (Savage-Rumbaugh et al., 1993).

The listeners had different previous experiences with dogs, but we found only minor differences between the results of the three groups. The experience with dogs had no significant effect in the case of ‘despair’ and ‘happiness’. Seemingly, the only characteristic difference between the listeners was that ‘non-owners’ tended to attribute less positive emotions to the dog barks as they gave the highest scores for ‘fear’ but the lowest for ‘playfulness’. The seemingly striking fact that experience with dogs does not affect strongly human understanding of emotions in barking can be understood better if we consider that adults and children can recognize correctly the emotions in the vocalisations of the macaque (*Macaca arctoides*), too (Linnankoski et al., 1994). This finding underlines again the possibly role of the ‘‘common mammalian heritage’’ in acoustic communication of emotions.

The usefulness of vocal signals in dog–human interactions could create a positive evolutionary pressure on the diversification of bark sounds in the dog through domestication. These results provide an interesting comparison with the observations in the visual communicative modality where dogs also display species-specific communicative behaviours. It is likely that these have emerged also as a consequence of domestication (i.e. changes in looking behaviour) and might have also facilitated dog–human communication (Soproni et al., 2001; Miklósi et al., 2004).

5. Conclusion

Our results show that communication between humans and dogs is likely based on features of basic mammalian homology. We can conclude that the acoustic signals (bark) of the dog mostly work through affecting the skills of humans to recognize basic emotions like aggression.

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