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## Review

## Barking in family dogs: An ethological approach

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## ABSTRACT

Although it is one of the most conspicuous features of dog behaviour, barking has received little attention from ethologists or from an applied perspective. In this review, an ethological look is taken at the communicative aspect of dog barking. Emerging new research has indicated that in the repertoire of dog vocalisations barking has unique features in showing wide ranges of acoustic parameters, such as frequency, tonality and rhythmicity. Barking has been shown to be context dependent, and provides information for humans about the inner state of the dog although there are few indications that barking is used for intra-species communication. It is assumed that dog barking emerged through selective processes in which human preferences for certain acoustic aspects of the vocalisation may have been paramount. A more experiment-oriented approach is required for the study of dog vocalisation that could shed light on the possible communicative function of these acoustic signals.

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## Introduction

The casual human observer is often inclined to assume that certain animal actions have a communicative role but ethologists interested in the natural behaviour pattern of animals use a complex methodology to identify action patterns as communicative signals. There is, however, a general agreement that animal signals should provide the sender (or both the sender and the receiver) with some sort of advantage. In addition there should be indications that the behaviour has evolved to fulfil a signalling function (Krebs and Davis, 1993).

Ethological theories emphasise the role of ritualisation in the genesis (evolution) of signals (Smith, 1977; but see also Hauser, 1996). Accordingly, most signals have evolved from behaviour actions that closely affected survival and are associated with biological (physiological) controlling processes. For example, Andrew (1962) proposed that the facial and vocal signals associated with fear might have originated from behavioural responses aimed at protecting the individual from noxious stimuli. Such actions include closing the eyes, lowering the eyebrows and flattening the ears. In addition, rapid closing or narrowing of the glottis may have been associated with the production of some noise (vocalisation) that provided the 'raw' material for the evolution of vocal signals. If there is a behaviour pattern for evolution to act on then the ritualisation process is likely to have led to changes that distinguish behaviour signals from general patterns of behaviour, so making the signal less ambiguous. Such behavioural (vocal) actions become more exaggerated, repetitive and stereotyped.

Other theories place more emphasis on the observed correlation between the sender's advantageous (adaptive) traits and the features of the signal. Comparing the vocalisation of many mammalian and avian species, Morton (1977) argued that acoustic structure might basically reflect a correlation between body size and sound frequency, based on the physical rule that larger bodies produce sounds that are characterised by lower frequencies and a wider band range. In this case, the quality of the signal would in some way predict the physical qualities of the sender that (in the long run) could be advantageous for both the sender and the receiver.

Other selective forces on the part of the receiver may also influence the form of the signal (see, for example, Guilford and Dawkins, 1991). Owren and Rendall (1997) assumed that during evolution the sender's ability to form special signals was influenced by the effect the signals had on the receiver. McConnell (1990) found that young herding dogs could be more easily trained to go to the trainer when short, rising frequency sounds were used instead of long, descending ones. Examining the acoustic signals used by shepherds from very different geographic regions, it was found that dogs can be encouraged to work with short, high pitched whistles whereas they are stopped by long, descending whistles (McConnell and Baylis, 1985). Although whistling shepherds have appeared relatively recently in the evolutionary history of the dog, their acoustic signals most probably exploit the dogs' inherited preference to respond in a certain way to acoustic stimulation. The studies by McConnell and Baylis (1985) showed that simple and well described acoustic rules work uniformly in the case of human–dog vocal communication.

Although in many cases the primary form of the signal is under strong genetic control and there is little need for experience on the

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part of the sender, the amount of learning depends on the species and the context in which the signal is used. Janik and Slater (2000) distinguished between learning the signal (or about it) and learning the context in which the signal was effective. No such data are currently available on acoustic signalling, but with visual signalling there is some evidence that although wolves do not need to be exposed to conspecifics to be able to show certain forms of species-specific agonistic signals, they do need to learn about the use of the signals and also how to react to the signals of group members (Ginsburg, 1975).

Joint adjustment in communicative signalling between interacting group members has been described as *ontogenetic ritualisation* (Tomasello et al., 1994). In this case, not only species-specific signals but other patterns of behaviour could increase communicative function through learning on the part of both the sender and receiver. This process can play an important role in interspecies communication systems when signals in different species might well have different evolutionary origins, and its effectiveness may depend on whether the receivers can learn about the signal and the senders can to adjust their signalling behaviour to the constraints of the receiver.

In this review we use the ethological concept of animal communication to the functional-contextual analysis of dog barks. Recent research has shown that barking might have been under selected and (1) may have been modified according to the so-called motivational-structural rules of vocal communication in mammals (Morton, 1977), (2) may play a role in human–dog communication (and possibly also in dog–dog communication), and (3) is affected by learning through the process of ontogenetic ritualisation (Tomasello et al., 1994). Thus, there is a possibility that barking has been acquired and is used in a novel function in dogs in comparison to the ancestral species.

### Barking and the vocal repertoire of canids

Domestic dogs, like their closest wild relatives (wolves, jackals and foxes), have a rich vocal repertoire. They vocalise in a wide variety of social contexts and this behaviour undergoes considerable alteration during development (Tembrock, 1976). Early studies on dog vocalisation focused mainly on the formal (physical) description and categorisation of the different kind of acoustic signals (Bleicher, 1963), but subsequent comparative approaches have concentrated more on functional aspects (Cohen and Fox, 1976; Tembrock, 1976; Lehner, 1978). Importantly, whilst the vocal behaviour of the fox, wolf and jackal was mainly studied in nature or in a semi-natural environment by observing interacting conspecifics, no similar systematic study has been performed in dogs.

### The relation between canid vocalisations and barking

The comparative works of Tembrock (1976) and Cohen and Fox (1976) provide a description of the vocal repertoire of the most common wild canids, as well as the domestic dog. The studies showed that dogs have very similar vocalisations to wolves, while jackals, and especially foxes, display a wider range of vocal signals. Tembrock (1976) classified vocalisations on the basis of acoustic features such as frequency, roughness/noisiness and rhythmicity. Cohen and Fox (1976) created functional classes for the vocalisations based on observations that in wild canids and dogs the use of the signal depends on the particular social situation (see Table 1). Comparing dogs to their closest relatives, the wolf and the coyote, the most interesting difference is that dogs bark in a wider range of circumstances than the other two species, in which barking accompanies mainly defensive actions or is used as a warning call.

### Acoustic features of barking

Compared to other well known vocalisations (such as howling, growling, whining), dog barking seems to be a very variable acoustic signal particularly obvious in terms of frequency, tonality and rhythm (Fig. 1). Furthermore, investigating barking is difficult because of the huge variability in size, anatomy and behaviour within the species. It is impossible to investigate in an ethological experiment any sample of dogs that would represent the whole spectrum of dog-morphs.

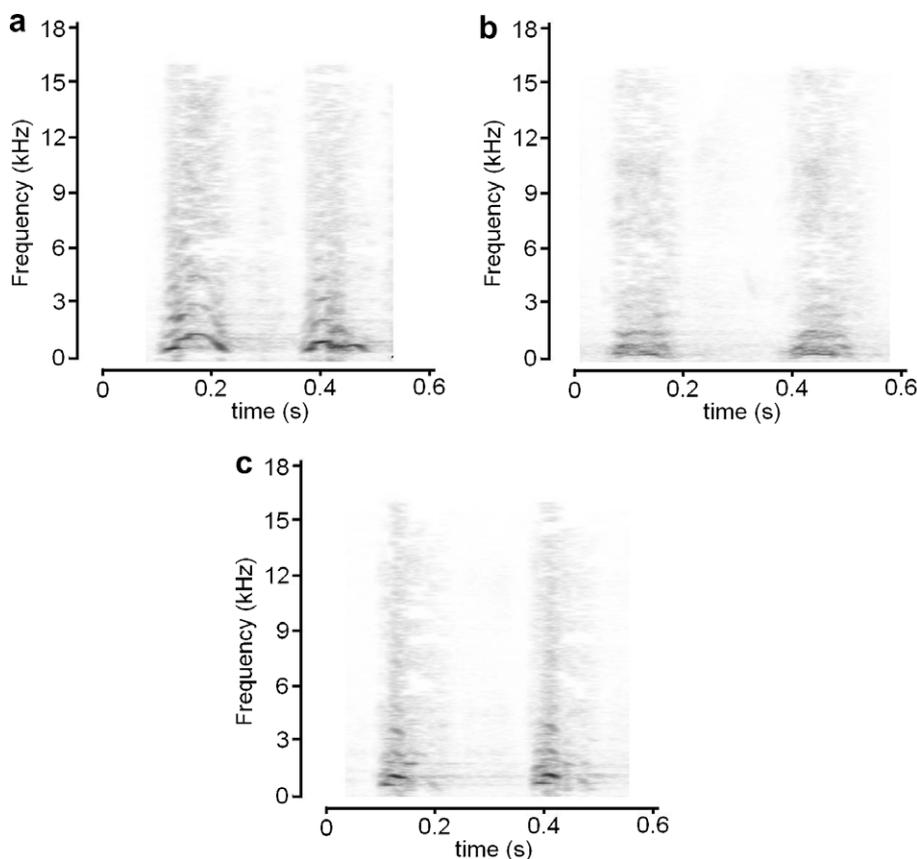
In general, two main approaches exist: (1) testing as many kinds ('breed') of dogs, as possible in the experiment, or (2) conducting the experiment on the same breed. The first approach is usually suitable for those cases where the experimenters do not expect a breed, or look-specific variability, while the second approach is employed to reduce the effect of different anatomical structures. Both methods can be found in those few experimental papers, which deal with dog barking. Multi-breed investigations are reported by Yin (2002) and Yin and McCowan (2004), and single breed studies by Ohl (1996) in the Standard Poodle, and by Riede et al. (2001) in the Dachshund, and Pongrácz et al. (2005, 2006), Molnár et al. (2006) and Molnár et al. (2008) in the Mudi.

Investigating one breed is likely to be preferable because the acoustics of barking are obviously affected by the size and structure of the dogs' vocal tract. Riede and Fitch (1999) demonstrated that the pitch of the barking in particular showed the effect of vocal tract length. However, other acoustic factors, such as harmonic-to-noise ratio (tonality) and pulsing (inter-bark interval) can be less dependent on size and breed and the comparison between the results of Yin (2002) and Pongrácz et al. (2005) support this idea (see Table 2a and b).

**Table 1**  
The comparative functional categorisation of canid vocalisations (based on Cohen and Fox, 1976).

	Meows	Grunts	Whines	Yelps	Screams	Whimpers	Howls	Bleats	Growls	Yaps	Barks	Clicks	Snapping the teeth	Pants
Greeting	F	WD	W C D	D	F	C	WD	F	WD	–	D	–	–	F
Play initiation	–	–	D	D	–	–	–	–	–	–	D	–	WD	FD
Submission	F	–	W C D	D	W C D	–	–	–	–	–	–	–	–	–
Defence	–	–	WCD	D	CF W	–	W	–	WCDF	WCDF	WD	F	WCD	–
Threaten.	–	–	–	–	CF	–	–	–	WCDF	WCDF	WCDF	F	WCD	–
Contact seeking	nbF	DW	nb, D W C	nb-W nb-C D	F	C	–	F	–	–	D	–	–	–
Pain	nb	–	nb, D W C F	nb-W nb-C D	nb, D W C F	–	–	–	D	–	D	–	–	–
Loneliness	–	–	nb, D W C	D	–	–	W C D	F	–	–	D	–	–	–
Group	–	–	nb, D W C	–	–	C	W C D	–	W C D	–	–	–	–	–

Abbreviations: C = coyote, D = dog, F = red fox, W = grey wolf, and nb = newborn.



**Fig. 1.** Sonograms of barks of the Mudi dog breed from three markedly different situations: (a) 'play', (b) 'stranger' and (c) 'left alone'. Note the structure of harmonics in the first and third sonograms, while the bark from the 'stranger' context lacks this structure. Dogs emitted mostly atonal barks when they reacted aggressively to the presence of a stranger at the gate. In contrast they barked more tonally during play or when left alone.

Tembrock (1976) described barking as a mostly repetitive sound consisting of very short individual barks (one single bark lasts <0.5 s), and characterised by relatively low dominant frequency (<2000 Hz). According to Feddersen-Petersen (2000), wolf barks are invariably typified by low-frequency (the dominant frequency is between 145 and 170 Hz), atonal (harsh) sounds and are repeated only once or twice. In contrast, dog barks cover a very wide frequency range (dominant frequency range 160–2630 Hz). Measuring the acoustic features of dog barks collected from a variety of breeds, it was found that the range of the harmonic-to-noise-

ratio (HNR) that describes tonality is almost as wide as the range of all other types of vocalisations taken together (Riede and Fitch, 1999; Riede et al., 2001). The long repeated sequence that can contain several dozen single barks is a further characteristic species-specific feature.

### Dog barking

Although there has been no scientific investigation on the breed differences of barking, we know that some breeds do not (or only rarely) show any propensity to bark (for example, the Basenji, Chow-chow, Shar-pei), whereas others bark excessively. In the case of the latter, some breeds were probably selected for a specific kind of barking, such as various types of hounds that are bred to follow the trail of game. The importance of characteristic forms of barking is even mentioned in some dog breed standards. For example, the official Fédération Cynologique Internationale (FCI) breed standards state for the Transylvanian Hound (FCI241): 'when he finds a fresh scent, he yaps with a whining sound; during the hunt giving tongue to the scent, his barking is resounding, high pitched and ringin'; for the Basset Hound FCI163: 'hunts by scent, possesses pack instinct and a deep, melodious voice'; and for the Finnish Hound FCI151: 'pursues the quarry with resonant barking'. However, it is important to note that these vocal traits have been neither studied nor reported in the scientific literature.

Interestingly, very little attention has been paid to the functional aspects of dog barking (see below), although three aspects of barking have received some consideration, namely, (1) the inter-specific comparative evolutionary perspective, (2) the effect of domestication, and (3) evolutionary changes that might have affected dog development (heterochrony).

**Table 2**

(A) Acoustic parameters (means) of bark recordings from 19 adult Mudi dogs (after Pongrácz et al., 2005). (B) Acoustic parameters (means) of bark recordings from 10 adult dogs of various breeds (after Yin, 2002). Note that the 'Stranger' response in Pongrácz et al. (2005) is very similar to 'Disturbance' in Yin (2002). In the former, a stranger arrived at the garden gate, in the latter an arriving stranger rang the door bell. The 'Isolation' response in Yin (2002) is comparable to the 'Alone' situation in Pongrácz et al. (2005). In the former the dog was left alone in a room, while in the latter case the dog was left alone on the street or in a park tethered to a tree.

	Stranger	Fight	Walk	Alone	Ball	Play
(A)						
Bark duration (ms)	210	170	211	165	170	170
Inter-bark interval (ms)	570	400	480	600	790	600
Mean frequency (Hz)	763	895	1032	1079	855	1063
Fundamental frequency (Hz)	327	430	450	477	379	448
HNR (tonality)	27	28	27	29	27	28
(B)						
	Disturbance		Isolation			'Play'
Bark duration (ms)	345		247			272
Mean frequency (Hz)	686		860			840

### *Barking as a homologue trait*

Jackals (Heltai et al., 2000) and arctic foxes (Frommolt et al., 2003) emit single barks as territorial signals (having somewhat similar function to the territorial songs in songbirds). Frommolt and colleagues (2003) found that some acoustic features of fox barks are individual specific and may therefore play a role in recognition. Heltai and his colleagues (2000) used the playback territorial barks of the golden jackal (*Canis aureus*) to monitor the population size by noting the number of responding individuals.

Wolves and dogs share a common ancestor that lived around 25,000–50,000 years ago (Vilá et al., 1997; Savolainen et al. 2002; Miklósi, 2007). As such, dog barking could be regarded as homologous to that of the acoustically similar wolf. In contrast to foxes and jackals, sporadic field evidence has, however, shown that wolves bark mostly at agonistic encounters with non-pack members (Cohen and Fox, 1976; Schassburger, 1993), which suggests that barking has a more diverse function in this more social species. In parallel, Fox (1970) argued that there is a positive correlation between sociability and the variability in communicative signals comparing the facial expressions of wolves, foxes and jackals. After observing wild wolf populations, Schassburger (1993) reported that barking is mostly associated with territorial and resource protecting aggression. Thus it seems safe to hypothesise that dog barking has evolved from the atonal, low-frequency barks of wolves that are emitted mostly in agonistic contexts.

### *The effect of domestication on dog barking*

Domestication is an evolutionary process during which a population undergoes genetic changes in order to adapt to a human-controlled environment (Price, 1999). Some researchers have assumed that this adaptation changed the vocal behaviour of dogs and, in particular, affected the acoustics of barking. Feddersen-Petersen (2000) was the first to introduce the idea that barking behaviour of dogs might have changed as a result of domestication involving not only acoustic characteristics (like pitch, tonality, repetitiveness) but that novel forms of barking gained a functional significance in dog–human communication. She emphasised that modern dog breeds rely to a lesser degree on long distance calls (howling) when communicating with humans in contrast to intra-species communication. Feddersen-Petersen (2000) suggested that various forms of barking have emerged as means of short-distance, human directed forms of acoustic communication.

There is some indirect evidence that selection for living in an anthropogenic environment could also change vocal behaviour. Evidence for this was gathered when Belyaev and colleagues (for review, see Trut, 2001) showed that after farmed foxes had been selected for tame behaviour over several generations the animals displayed an enhanced propensity to vocalise in social situations, including contact with humans. (It seemed that enhanced vocalisation in these foxes was a by product of the selection process). Thus one can assume that during the early phase of domestication similar selection process led to more vocal dogs. Of course, an overtly vocal ('noisy') predator might well find it difficult to catch prey, but in the human environment such constraints do not apply. Thus the inclination to be more vocal, and especially more 'barky', may have produced a novel behaviour trait in dogs on which subsequent natural and/or artificial selection could have acted ('directional and diversifying selection') (see also Miklósi, 2007).

### *Developmental aspects of barking*

Many have assumed that differences in the barking pattern of dogs and wolves are related to a shift in the developmental process (heterochrony) (see also Albrecht et al., 1979; Miklósi, 2007).

Accordingly, dog barking is often regarded as a paedomorphic trait that would mean that frequent barking (a juvenile characteristic of wolves) is retained in the mature adult dog. Unfortunately, there is confusion with regard to such developmental shifts, and so far there has been little experimental support for these ideas. For example, in order to show that barking is a paedomorphic trait it is necessary to provide evidence for such changes in dogs either in the time of onset and/or offset or the rate of development of the trait in dogs in relation to wolves.

There are a few studies on vocal ontogeny of wolf cubs and dog puppies and, in general, they show a similar pattern of early vocal development. Neonates of both species emit vocal signals during or after physical distress (cold, hunger, pain), and these vocalisations are mostly tonal sounds (yelps, whines). Some of the neonatal vocalisations disappear during later development and others develop and change form in adults. In contrast, barking emerges almost at once without any vocal precursor in dogs and wolves. Coscia et al. (1991) and Schassburger (1993) found that atonal and mixed vocalisations (such as grunts and barking) emerge in parallel with the development of social behaviour (play, play/fight).

In the first 2 weeks of life, neonatal puppies emit tonal distress calls, and the first atonal barks can be detected at 18–21 days of age when the external ears open (Tembrock, 1976; Ohl, 1996). In a small scale study, Feddersen-Petersen (2001) reported that barking in wolves emerged on day 19 whilst individuals of various breeds of dogs (Labrador, Bull terrier, Siberian Husky) started to bark earlier, around days 7–9. According to the same authors, elaborated barking, which resembles the bark of the adult, develops at 2–3 months of age in dog puppies. The interesting difference emerges only later in that barking is rarely used by wolves whereas in dogs it becomes one of the most used forms of acoustic signals. Unfortunately, there are no data as to whether the human social or the intra-specific environment has any effect on the emergence and/or nature of barking and it is possible that perinatal learning might have some influence on this trait.

### **The possible function of dog barking: Inter- and intra-specific communication**

When investigating a behavioural feature of any species ethologists are keen to find the functional significance of the trait. Without much experimentation or systematic work some researchers have argued that barking may have been a by product of domestication and so lacks any functional value (Coppinger and Feinstein, 1991), whilst others have underlined the selective role of the human environment (Feddersen-Petersen, 2000). Below we present some evidence to support claims of the latter type that, in our view, dog barking functions as a means of communication in dogs and conveys 'information' about the signaller's inner state.

### *Utilisation of barking in dog–human communication*

If used as a signal for acoustic communication, barking should show situation-specific (as related to the inner state) consistency revealed either by acoustic measures or by testing the behaviour of potential receivers. Both types of analysis show that the acoustic character of dog barks follows the 'structural-motivational rules' proposed by Morton (1977) (see above).

### *Acoustic analysis*

Yin (2002) studied the context-specificity of barking by collecting recordings in three situations, namely (1) disturbance (a doorbell ringing), (2) isolation (the dog was left alone in a room), and (3) play. They found that barks emitted by different individuals

in different contexts were distinguishable on the basis of acoustic parameters such as frequency and amplitude. In a different paper Yin and McCowan (2004) further analysed the same sample of 10 dogs and using several acoustic parameters were able to distinguish between individual dogs across the different contexts.

A comparison of data from Yin (2002) and Pongrácz et al. (2005) shows some striking similarities (Tables 2a and b). Although the contexts of recording and the analysed parameters differ to some extent, it is noticeable that in both studies dogs from various breeds used the lower frequencies when a stranger arrived at the house, and emitted high pitched barks when left alone. Similarly, both studies showed that the duration of single barks was longest when a stranger arrived at the house where the dog lived. These similar results from two independent investigations indicate that dog barking has reliable acoustic features that are specific to particular contexts or inner states.

Molnár et al. (2008) used a machine learning approach to differentiate barks recorded from a single breed (Hungarian Mudi, a herding dog; average wither height, 42–46 cm; average weight 12–15 kg) in six contexts: (1) barks at a stranger; (2) during Schutzhund-fight training; (3) while the owner is preparing for a walk; (4) left alone leashed to a tree; (5) begging for a ball, and (6) during play). Over 6000 barks were recorded in known contexts from known individuals and the computer was programmed to select the feature-set (a small set of acoustic variables) with which the best classification could be achieved. The algorithm sorted novel barks (not included in the training set but collected from the same dogs) into the correct contexts with an efficiency of 43% (chance level 16%). A similar training and testing procedure revealed that by using a different feature-set the software identified individual dogs with a probability of 52% (chance level 7%). Interestingly, the programme was most successful in classifying the contexts of barking at a stranger and in fight training, whereas other contexts were categorised less efficiently. In the recognition of individual dogs, the 'Stranger' and 'Fight' barks were the most difficult to categorise for the algorithm and the success of categorisation was higher for barks emitted in other contexts.

#### Testing the receivers' behaviour

In order to provide a perspective from a potential receiver, Pongrácz et al. (2005) conducted playback experiments with three groups of adult human listeners. All barks were recorded from Mudis as described above. Three groups of humans were tested: (1) Mudi-owners; (2) dog-owners who had never owned a Mudi, and (3) persons that had never owned a dog.

In two separate experiments, participants were asked either to categorise the context of barking or to score the motivational state signaller (five independent scales were used, namely aggression, fear, despair, happiness and playfulness). The results showed that people (regardless of their prior experience) categorised the barks correctly with a similar success rate above chance level. Interestingly, a similar playback experiment using cat meows did not find such an effect in human listeners (Nicastro and Owren, 2003).

The human listeners uniformly described the assumed inner ('emotional') states of dogs. For instance, barks at a stranger were considered to be more 'aggressive', those recorded during a play session were judged as 'happy' and 'playful', while barks of a dog left alone in a park were thought to be 'despaired'. A correlation analysis found that barks characterised by lower frequency, less tonality and more rapid pulsing (shorter inter-bark intervals) were felt to be more aggressive. More tonal, high pitched and slow-pulsing barks were considered 'happier' and/or more 'despaired' (Pongrácz et al., 2005). This finding was supported by further experiments in which people were asked to categorise and score a number of artificially assembled bark sequences that differed in

frequency, tonality and pulsing according to the previously established rules (Pongrácz et al., 2006).

More recent findings have revealed that children as young as 5-years-old show some ability to categorise the three most basic types of dog barks (aggressive, fearful, playful) and can associate them with the expected inner states. The children's responses reach the level found in adults by the age of 8 years (Cs. Molnár et al., unpublished data).

#### Environmental effects

Little is known about the effect of environmental (especially social) factors on barking. There is evidence that barking can be brought under operant control (Juarbe-Diaz and Houpt, 1996, 1997), but this does not explain consistent individual differences that seem to exist across contexts. According to the machine learning analysis (Molnár et al., 2008) barks appear to be more uniform (and less individual specific) in contexts evoking aggressive motivations whereas barks emitted before going for a walk, during ball play or in requesting situations are more individual specific. We suspect that the increased variability of barks in these contexts is the result of idiosyncronic learning processes (ontogenetic ritualisation), and the interactions between dogs and their owners shape the acoustic form of the barks.

It has often been noted that feral and stray dogs bark rarely, despite the possibility that they have lived with humans or are first generation descendants of such individuals (Boitani and Ciucci, 1995). This 'silencing' might be the result several processes. Noisy, barking feral dogs could be detected and removed by humans more rapidly, thus only dogs with a lowered motivation to bark survive in the wild. Alternatively, one could suppose that the continuous interaction with humans maintains the trait and the breaking of this relationship decreases barking in dogs. Both theories need to be tested experimentally.

#### Barking in dog-dog communication

It is surprising that no study has systematically examined the role of barking in an intra-species context. Two recent studies (Maros et al., 2008; Cs. Molnár et al., unpublished data) have shown for the first time that dogs are able to notice the acoustic difference between barks that have been recorded in different contexts. They used the so-called 'habituation-dishabituation paradigm' in which dogs in a quiet experimental room were presented with a series of barks (three times in a row) collected in the same context but emitted by different individuals. This was followed either by a bark from within the same context or by a bark from a different context (dishabituation). Generally, dogs habituated to the contextual stimulus after three presentations (decreased orientation reaction, e.g. longer looking latencies at the loudspeaker) but showed evidence of dishabituation (increased reaction, e.g. shorter looking latencies at the loudspeaker) when a bark from a different context was played back. Similar experimental arrangements suggested that dogs are able to discriminate individuals on the basis of their barking.

These results indicate that dogs can distinguish both between barks recorded in different situations and possibly between barks emitted by different individuals (Cs. Molnár et al., unpublished data) although this cannot yet be taken as evidence for a communicative role of barking in an intra-specific context as the findings need to be supported by observations of dogs in the field.

#### Possible veterinary implications of barking

The most common cases leading to concerns about an animal's health are (1) excessive barking (separation anxiety; see, for

example, Sherman and Mills, 2008); (2) bark prevention (i.e. anti-bark collars and 'de-barking' with surgery of the vocal cords where too much barking was considered as a nuisance; see, for example, Steiss et al., 2007); and (3) barking as a possible indicator of animal welfare in dog shelters (for example, Sales et al., 1997). In general, the *quality* of barking is not an issue in these cases, and preventive measures concentrate on the *quantity* of vocalisation.

The acoustic features of a dog bark have been little investigated from a veterinary perspective. Riede and colleagues (2001) attempted to use the HNR (harmonic-to-noise ratio) of dog barking for pain detection in Dachshunds with spine afflictions, because they hypothesised that dogs in pain emit more tonal barks, but they failed to prove the hypothesis. Kim and colleagues (2005) found that hormonal changes caused by ovariohysterectomy could affect the acoustic characteristics of the barks of female dogs with the bark of spayed females more highly pitched than that of entries.

The results of Yin and McCowan (2002, 2004), Pongrácz et al. (2005, 2006), Molnár et al. (2006) and Molnár et al. (2008) showed that dogs reliably use acoustically different barks in different contexts. As such, the *qualitative* analysis of dog barks could offer a promising tool in veterinary practice. By analysing the acoustic features of dogs that bark excessively there is a chance that we may better understand the motivational background of the vocalisation. As there are significant differences between for example aggressive and fearful barks (Pongrácz et al., 2006; Molnár et al., 2008), behavioural therapy could then be better directed if the acoustic analysis indicated differences between these in the dog patient.

## Conclusions

It is apparent that (1) dog barking shows context-specific acoustic features, (2) humans from different age groups and with different amounts of dog-experience can recognise the context within which a dog is barking, and (3) humans are able to attribute basic inner states to barking with particular acoustic features. In addition, acoustic differences when barking is recorded in different contexts seem to follow the motivational–structural rules described by Morton (1977). These results emphasise that dog barking has a communicative role in dog–human interactions. Preliminary results from recent studies have indicated that dogs have the ability to discriminate between barks that are a prerequisite for the use of barking in an intra-specific context.

The fact that humans can judge the inner state of a barking dog through certain acoustic features is not surprising because we seem to utilise similar acoustic effects when expressing anger, fear or happiness in the acoustic modality. Humans can also tell between aggressive or submissive vocalisations in other species (Linnankoski et al., 1994). In the case of barking, the preference for a certain acoustic structure in vocalisations, which reflect the inner state of the signaller, could have been a selective force and humans may have preferred to interact with dogs that displayed similar acoustic variability in barking. Dogs could have gained a selective advantage over their companions in an anthropogenic environment if they were producing barks that were more 'attractive' to humans. In addition to being used in a repetitive way, barking has evolved towards an acoustic signal that can have a 'universal' utility in dog vocal communication.

## Conflict of interest statement

None of the authors of this paper has a financial or personal relationship with other people or organisations that could inappropriately influence or bias the content of the paper.

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