

# Dogs discriminate between barks: The effect of context and identity of the caller

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## ABSTRACT

In the present study we explored whether dogs (*Canis familiaris*) are able to discriminate between conspecific barks emitted in different contexts recorded either from the same or different individuals. Playback experiments were conducted with dogs using barks as stimuli in a habituation–dishabituation paradigm. Barks were recorded in two contexts (stranger at the fence and when the dog was left alone) from different individuals. We found that dogs distinguished between barks emitted in these two contexts and were also able to discriminate between different individuals which were barking in the same context. These findings suggest that dog bark may carry context- and individual-specific information for the conspecifics.

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## 1. Introduction

Animal acoustic calls can convey information about the caller's body weight, motivational state, identity, sexual status and communicative context (e.g. Gerhardt, 1992; Hauser, 1996). Several studies have shown that vocal signals have context-specific acoustic features and these characteristics could be influenced by the motivational state. Bugnyar et al. (2001) showed that ravens emit different food related calls corresponding to the caller's actions and/or motivation, and these calls may provide information about the quality of the food as well.

Playback studies have shown that conspecifics can discriminate between alarm calls recorded in different contexts as in vervet monkeys—*Cercopithecus aethiops* (Cheney and Seyfarth, 1982). Individuals of various species and taxa are able to discriminate the identity of the caller based on individual characteristics of the signals as found in playback experiments: banded wren—*Thryothorus pleurostictus* (Molles and Vehrencamp, 2001); tree frogs—*Hylidae* spp (Gerhardt, 1992a); cotton-top tamarins—*Saguinus oedipus* (Miller and Hauser, 2004); African elephant—*Loxodonta africana* (McComb et al., 2000) and Arctic fox—*Alopex lagopus* (Frommolt et al., 2003).

In the last few years some studies have demonstrated that the bark of the dog is also characterized by context-specific acoustic parameters (Yin, 2002; Yin and McCowan, 2004). We found previously that humans with different experience levels with dogs can categorize barks according to their contexts above chance level, and can provide an adequate description about the possible motivational state of the dog (Pongrácz et al., 2005). By using a machine

learning approach (Molnár et al., 2008), we found that dog barks do convey information about the caller's identity, however the cues may be too subtle for humans to rely on them.

It has been established that consistent context-specific acoustic differences were found between barks (Pongrácz et al., 2009). By analyzing the fundamental frequencies, inter-bark intervals and harmonic-to-noise ratios (HNR—see also Riede et al., 2001), we found barks from aggressive situations (like a stranger at the fence) have the lowest fundamental frequencies, the shortest inter-bark intervals and the lowest HNR values. Barks which can be characterized with lack of aggression (like a dog left alone) had higher fundamental frequencies, longer inter-bark intervals and high HNR.

In this paper we hypothesized that dogs are able to discriminate between barks recorded in different situations and between individual dogs. As far as we are aware, no experimental work has been done on dog–dog communication where the role of barking was tested. Dogs were tested in a habituation–discrimination paradigm for their ability to discriminate different types of barks (for an earlier application of this method on dogs see Maros et al., 2008). A separate experiment was also run for eliminating possible owner-given cues during the playbacks.

## 2. General methods

### 2.1. Stimuli

Barks from the Mudi breed (a Hungarian sheepdog) were used for this study. We recorded bark samples from five adult individuals (male/female: 2/3, age:  $4.70 \pm 2.38$  years). These dogs did not participate in the playback tests. The two behavioral contexts, in which the recording took place, were the following: (1) a 'Stranger' arrives to the garden; (2) the dog is left 'alone' in a park, tied to a tree. For detailed description see Pongrácz et al., 2005.

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Recordings were made with a Sony TCD-100 DAT Tape Recorder and a Sony ECM-MS907 microphone on Sony PDP-65C DAT tapes (Sony Corporation, Minato, Tokyo, Japan). During recording the experimenter held the microphone within 2–3 m of distance from the dog. The recorded material was transferred to a computer using a 16-bit quantization and a 44.10 kHz sampling rate, via a TerraTec DMX 6fire 24/96 sound card (TerraTec Electronic GmbH, Nettetal, Germany).

We used four bark sequences from each individual recorded in both contexts. So in sum we used 40 bark samples. In one context the four recordings were made with a given dog on different days. It means that the three stimuli used for habituation in an experiment were not the repetitions of the same recording, nor three sequences cut out from a longer recording. The samples were cut from the point of the first bark in each recording. Each sequence was 10 s long. The barks were saved into single WinPCM wav files which were played from an IBM PC. We set the playback sound pressure level to 60–70 dB. Each subject was tested with a randomly assembled, unique set of bark samples—one set was played back to one subject only.

We conducted two playback experiments, which were based on the habituation–discrimination paradigm. In Experiment 1 we tested if dogs could recognize the difference between (A) barks recorded in different contexts; and (B) if they could recognize the difference between the callers' identity in the same context. We used a group of dogs as (C) baseline control with four bark sequences from the same dog and same context. Experiment 2 served as (D) control for possible owner-given cues. The playback design for the individual test and control groups was the following (each dog participated only once):

- (A) Experiment 1, Context Group ( $N=30$ , sex ratio (male/female): 18/12, age:  $2.61 \pm 2.09$  years): in the habituation phase, three bark sequences were played back from the same dog and same context, the fourth sequence (dishabituation stimulus) came from the same dog but from the other context. Half of the group was habituated to barks from the 'Stranger', the other half to barks from the 'Alone' context.
- (B) Experiment 1, Identity Group ( $N=30$ , sex ratio (male/female): 10/20, age:  $3.68 \pm 2.90$  years): in the habituation phase, three bark sequences were played back from the same dog and same context, the fourth sequence (dishabituation stimulus) was played back in the same context, but from another dog. Half of the group was habituated to barks from the 'Stranger', the other half to barks from the 'Alone' context.
- (C) Experiment 1, Control Group ( $N=30$ , sex ratio (male/female): 18/12, age:  $4.55 \pm 2.17$  years): four stimuli were played back from the same context and the same dog. Half of the group was habituated to barks from the 'Stranger', the other half to the barks from the 'Alone' context.
- (D) Experiment 2, Control for owner-given cues ( $N=20$ , sex ratio (male/female): 10/10, age:  $4.42 \pm 2.38$  years): stimulus arrangement was exactly the same as in case (B), but here the owners had to listen to loud music through headphones. With 2–3 s after the end of a bark sequence, the experimenter switched on a small light to indicate for the owner whether the dog had moved away during the playback, and it was the time to call back the dog to the start position.

## 2.2. Procedures

Playback experiments were conducted in a 3 m × 5 m, visually separated room. The experimenter operated the playback device from the neighboring room. In the middle of the experimental room there was a chair for the owner of the dog. At a distance of 1.5 m from the chair, a speaker was placed on a shelf, 1 m high from the

floor. The speaker was on the left side of the room for half of the subjects and on the right side for the other half. We recorded the experiment with three video cameras.

Before the experiment the dog was allowed to explore the room. During the experiment the dog sat in front of the owner, facing the same direction as the owner. Dogs were not leashed. The first bark sequence was played after the dog waited at least 10 s calmly in the start position. We played back a bark sequence only if the dog was not orienting toward the speaker (angle between the long axis of the dog's head and the speaker was larger than 45°). During playbacks the dog was allowed to move freely in the room. If the dog moved away from the start position, the owner had to call him/her back and place him/her into the start position after the bark sequence had ended. The next bark was played when the dog was in the start position again. (Duration of re-positioning of the dog: max. 60 s, mean: 31.11 s, SD: 10.64 s.) If the dog had not moved from its position while the previous bark was being played, the next bark followed after a minimum 5 s of silence.

## 2.3. Data collection

We measured the duration of orientation toward the speaker(s). Orientation toward the speaker had to start with a definite head movement toward the speaker, resulting in an angle less than 45° between the longer axis of the dog's head and the direction of the speaker. Orienting toward the speaker was considered to be finished if the dog moved his/her head away from the previously described position. The maximum duration of orientation was set at 15 s (10 s long bark sequence plus 5 s as the minimum length between playback intervals).

## 2.4. Statistics

We performed non-parametric Friedman tests for repeated measures for each group in both experiments to see whether dishabituation happened after the 4th playback. The possible effect of habituating context ('Stranger' vs. 'Alone') was analyzed with Mann–Whitney *U*-tests. In Experiment 1, durations of orientation to the four stimuli were compared between the three groups by using Kruskal–Wallis tests. Additionally, we performed Bonferroni post hoc tests for the pair wise comparisons.

## 3. Results

In Experiment 1 the habituating treatment (context or identity) did not cause significant differences in any of the groups, so these data were merged within the individual groups. Friedman tests showed significant results in each group for repetition (Table 1). Bonferroni post hoc tests (Fig. 1) showed that durations of orientation were significantly shorter in playback 3 than playback 1 in each group. However, while in the control group playback 4 had the shortest duration of orientation, in the two test groups playbacks 1 and 4 did not differ from each other. In the two test groups playback 4 had longer durations of orientation than playback 3.

We also compared the duration of orientation between the three groups with Kruskal–Wallis tests. There were no significant differences between the groups during the three habituation playbacks. The duration of orientation to the fourth stimulus differed significantly between the groups (Table 1). Bonferroni post hoc test showed that dogs in the control group oriented significantly shorter toward the speaker than in the test groups. There was no difference between the test groups in playback 4.

In Experiment 2 the Friedman test revealed significant effect of repetition on the durations of orientation, but we did not find a significant effect of the habituating treatment (context or identity, Mann–Whitney *U*-tests) (Table 1). We compared the individual

**Table 1**  
Details of the statistical results of both experiments. The bold and italic characters show significant differences.

| Friedmann test              |          | Repetition    |                  | Post hoc test: Bonferroni |                  |                           |                    |                     |                     |
|-----------------------------|----------|---------------|------------------|---------------------------|------------------|---------------------------|--------------------|---------------------|---------------------|
|                             |          | $\chi^2(3)$   | <i>P</i>         | 1 vs 2                    | 1 vs 3           | 1 vs 4                    | 2 vs 3             | 2 vs 4              | 3 vs 4              |
| Experiment 1                | Control  | <b>31.654</b> | <b>&lt;0.001</b> | 0.243                     | <b>0.002</b>     | <b>&lt;0.001</b>          | 0.236              | <b>&lt;0.001</b>    | <b>0.026</b>        |
|                             | Context  | <b>18.132</b> | <b>&lt;0.001</b> | 1.000                     | <b>&lt;0.001</b> | 0.189                     | <b>0.003</b>       | 1.000               | <b>0.032</b>        |
|                             | Identity | <b>13.280</b> | <b>0.004</b>     | 0.546                     | <b>0.007</b>     | 1.000                     | 0.704              | 1.000               | <b>0.004</b>        |
| Experiment 2                |          | <b>17.855</b> | <b>&lt;0.001</b> | 1.000                     | <b>0.003</b>     | 1.000                     | 0.094              | 1.000               | <b>0.018</b>        |
| Mann–Whitney <i>U</i> -test |          | Experiment 1  |                  | Kruskal–Wallis test       |                  | Post hoc test: Bonferroni |                    |                     |                     |
|                             |          | <i>U</i>      | <i>P</i>         | Groups                    | $\chi^2(2)$      | <i>P</i>                  | Control vs context | Control vs identity | Context vs identity |
| Repetitions                 | 1st bark | 1497          | 0.926            | 1st bark                  | 0.648            | 0.723                     |                    |                     |                     |
|                             | 2nd bark | 1464          | 0.772            | 2nd bark                  | 0.698            | 0.706                     |                    |                     |                     |
|                             | 3rd bark | 1440.5        | 0.665            | 3rd bark                  | 0.940            | 0.625                     |                    |                     |                     |
|                             | 4th bark | 1490.5        | 0.895            | 4th bark                  | <b>12.549</b>    | <b>0.002</b>              | <b>0.03</b>        | <b>0.001</b>        | 0.794               |

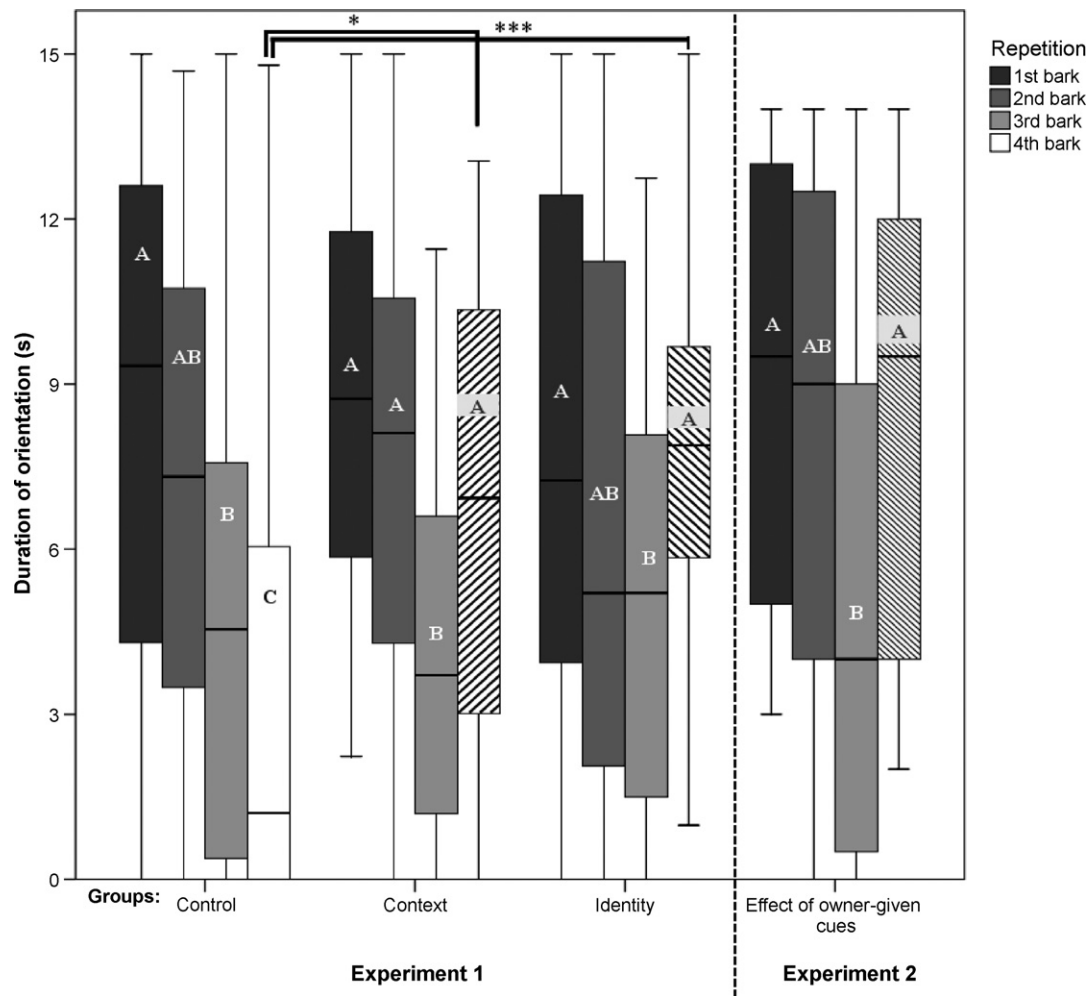
durations of orientation of each playback event with Bonferroni post hoc tests. We found significant differences between the first and third, and the third and fourth playbacks. Duration of orientation was the shortest during playback 3 (Fig. 1).

We can conclude that dogs were able to discriminate between barks recorded in different contexts from the same individual, and also from different individuals in the same context. This latter was

true even if the owners could not hear the playbacks, so the owner-given cues were not responsible for the dishabituation.

#### 4. General discussion

Maros et al. (2008) showed that dogs' heart rate dishabituates, when barks from a different context were used as dishabituating



**Fig. 1.** Duration of orientation after four auditory playback stimuli (barks) in Experiments 1 and 2 (medians + interquartiles). The fourth bark sample was recorded in a different context than the first three in Experiment 1 Context group, and the fourth bark sample was recorded from a different dog than the first three in Experiment 1 Identity test group and Experiment 2. In Experiment 1 control group all four barks were recorded in the same situation and from the same dog. Different letters mean significant difference within a given experimental group. Asterisks indicate significant between-group difference.

stimuli. This effect is not based merely on the novelty of the dishabituating auditory stimulus, as under identical conditions another group of dogs did not show dishabituation if mechanic noises were applied. The present study gives evidence that dogs show reliable behavioral response during dishabituation to a bark from a different context. Additionally, we found evidence for the first time that dogs can differentiate between individuals on the basis of vocalizations.

The context-specificity of barks might be partly based on the different motivational states of the individuals in the different situations. This raises the question how barking became the dominant vocalization type of dogs, since wolves the wild ancestors of dogs, bark only during territorial defense and defending their food from others (Cohen and Fox, 1976; Tembrock, 1976). Several concurrent theories exist (for a review see Pongrácz et al., 2009) for the diversification of dog barking. A series of longitudinal experiments done on silver foxes (*Vulpes vulpes*) shed some light on the possible evolution of this trait (for details, see i.e. Belyaev, 1979; Trut, 1999). Foxes, selected solely for tameness toward an approaching human, became also more vocal after many generations of selective breeding. These tame foxes vocalize more and in a different manner than the “wild” type (Gogoleva et al., 2008). This might suggest that domestication of the dog could have resulted in more frequent barking as a byproduct which later became the medium for communication with humans and also with other dogs.

Other researchers have shown that dogs can be identified by their bark spectrograms independent of the context of the bark (Yin and McCowan, 2004). Molnár et al. (2008) developed computer-based learning software, which recognized individual dogs by their barks with high accuracy. We should note that in the present study we only explored the discriminative ability, which is not equivalent to “recognition”. The presumed ability of dogs to recognize other dogs by their barks should be confirmed in further studies. The results of our individual discrimination task suggest a difference between discrimination (and possibly perceptual) abilities of dogs and humans. We found earlier that humans could not discriminate reliably between barks of different dogs (Molnár et al., 2006). The explanation for this difference may lie not only in the different sensitivity of the auditory systems, but maybe in the different communicative function as well. The recognition of individual dogs’ bark might have more importance for dogs than for humans, and this can explain why dogs were more sensitive in the discrimination task.

Finally we can conclude that recent and other findings (Pongrácz et al., 2005, 2006; Maros et al., 2008; Molnár et al., 2008) strengthen the idea that barks may have a complex communicative role in both dog–dog and dog–human communication. Barks may have context-specific and individually distinctive acoustic features, which are recognizable by other dogs and partly by humans. Hence barking might be an easy to study model of communication systems in the near future.

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## References

- Belyaev, D.K., 1979. Destabilizing selection as a factor in domestication. *J. Hered.* 70, 301–308.
- Bugnyar, T., Kijne, M., Kotrschal, K., 2001. Food calling in ravens: are yells referential signals? *Anim. Behav.* 61, 949–958.
- Cheney, D.L., Seyfarth, R.M., 1982. How vervet monkeys perceive their grunts: field playback experiments. *Anim. Behav.* 30, 739–751.
- Cohen, J.A., Fox, M.W., 1976. Vocalizations in wild canids and possible effects of domestication. *Behav. Process* 1, 77–92.
- Frommolt, K.-H., Goltsman, M.E., MacDonald, D.W., 2003. Barking foxes, *Alopex lagopus*: field experiments in individual recognition in a territorial mammal. *Anim. Behav.* 65, 509–518.
- Gerhardt, H.C., 1992. Conducting playback experiments and interpreting their results. In: McGregor, P.K. (Ed.), *Playback and Studies of Animal Communication*. Plenum Press, New York.
- Gogoleva, S.S., Volodin, I.A., Volodina, E.V., Trut, L.N., 2008. To bark or not to bark? Vocalization in red foxes selected for tameness or aggressiveness toward humans. *Bioacoustics* 18, 99–132.
- Hauser, M.D., 1996. *The Evolution of Communication*. MIT Press, Cambridge, Massachusetts.
- Maros, K., Pongrácz, P., Bárdos, Gy., Molnár, Cs., Faragó, T., Miklósi, Á., 2008. Dogs can distinguish barks from different situations. *Appl. Anim. Behav. Sci.* 114, 159–167.
- McComb, K., Moss, C., Sayialel, S., Baker, L., 2000. Unusually extensive networks of vocal recognition in African elephants. *Anim. Behav.* 59, 1103–1109.
- Miller, C.T., Hauser, M.D., 2004. Multiple acoustic features underlie vocal signal recognition in tamarins: antiphonal calling experiments. *J. Comp. Physiol. A* 190, 7–19.
- Molles, L.E., Vehrencamp, S.L., 2001. Neighbour recognition by resident males in the banded wren, *Thryothorus pleurostictus*, a tropical songbird with high song type sharing. *Anim. Behav.* 61, 119–127.
- Molnár, Cs., Pongrácz, P., Dóka, A., Miklósi, Á., 2006. Can humans discriminate between dogs on the base of the acoustic parameters of barks? *Behav. Process* 73, 76–83.
- Molnár, Cs., Kaplan, F., Roy, P., Pachet, F., Pongrácz, P., Dóka, A., Miklósi, Á., 2008. Classification of dog barks: a machine learning approach. *Anim. Cogn.* 11, 389–400.
- Pongrácz, P., Molnár, Cs., Miklósi, Á., Csányi, V., 2005. Human listeners are able to classify dog barks recorded in different situations. *J. Comp. Psychol.* 119, 136–144.
- Pongrácz, P., Molnár, Cs., Miklósi, Á., Csányi, V., 2006. Acoustic parameters of dog barks carry emotional information for humans. *Appl. Anim. Behav. Sci.* 100, 228–240.
- Pongrácz, P., Molnár, Cs., Miklósi, Á., 2009. Barking in family dogs—an ethological approach. *Vet. J.*, doi:10.1016/j.tvjl.2008.12.010.
- Riede, T., Herzel, H., Hammerschidt, K., Brunnberg, L., Tembrock, G., 2001. The harmonic-to-noise ratio applied to dog barks. *J. Acoust. Soc. Am.* 110, 2191–2197.
- Tembrock, G., 1976. Canid vocalizations. *Behav. Process* 1, 57–75.
- Trut, L.N., 1999. Early canid domestication: the farm-fox experiment. *Am. Scientist* 87, 160–169.
- Yin, S., 2002. A new perspective on barking in dogs (*Canis familiaris*). *J. Comp. Psychol.* 119, 189–193.
- Yin, S., McCowan, B., 2004. Barking in domestic dogs: context specificity and individual identification. *Anim. Behav.* 68, 343–355.