

Seeing with ears: Sightless humans' perception of dog bark provides a test for structural rules in vocal communication

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Prerecorded family dog (*Canis familiaris*) barks were played back to groups of congenitally sightless, sightless with prior visual experience, and sighted people (none of whom had ever owned a dog). We found that blind people without any previous canine visual experiences can categorize accurately various dog barks recorded in different contexts, and their results are very close to those of sighted people in characterizing the emotional content of barks. These findings suggest that humans can recognize some of the most important motivational states reflecting, for example, fear or aggression in a dog's bark without any visual experience. It is very likely that this result can be generalized to other mammalian species—that is, no visual experience of another individual is needed for recognizing some of the most important motivational states of the caller.

Keywords: Dog; Barking; Communication; Blind people; Domestication.

Several studies have reported more efficient perceptual processing (e.g., shorter reaction times) in blind than in sighted people, both in auditory and in tactile discrimination tasks (Kujala, Lehtokoski, Alho, Kekoni, & Näätänen, 1997; Röder, Rösler, Hennighausen, & Näcker, 1996). Neurophysiological recordings have revealed similar neural changes in the blind to those observed in populations with a specific history of perceptual experience (e.g., musicians). For example, both musicians (Pantev et al., 1998) and

blind adults (Röder, Rösler, & Neville, 1999) show an enhanced excitability of neural systems important for auditory processing. Since blind people rely more heavily on auditory information, it has been argued that they should show superior memory for input delivered through this modality. However, Cobb and colleagues (Cobb, Lawrence, & Nelson, 1979) did not find any differences in long-term memory for environmental sounds, nor for common tactile objects, between sighted and blind adults. Nevertheless, Pring, (1988) and

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Pring, Freistone, and Katan (1990) provided evidence for different memory strategies in blind and sighted adolescents. They tested memory for words that had been either read or heard in a group of sighted and blind pupils. Contrary to sighted pupils, blind participants recalled words better if they heard them than if they generated them themselves. The lack of a “generation effect” in the blind was attributed to an impaired or less well elaborated semantic network, which was assumed to be a consequence of the lack of visual input in the blind. As blind people have to acquire many concepts through language with less or without direct sensory experience, Pring (1988) hypothesized that their semantic networks contain more abstract concepts. Furthermore, it was consequently argued that blind people prefer data-driven strategies. That is, they remember items on the basis of (nonvisual) sensory features, rather than on the basis of conceptual relations.

Verbal information is considered as mostly referential for humans. Spoken words can carry additional affective information about the inner state of the speaker, but as humans also understand, for example, written text, it is clear that language mainly contains other than emotional (nonreferential) information. Contrary to human words, animal vocalizations were considered predominantly to be affective (inner-state-based) communicative signals. As Morton (1977) found, some characteristic features of the acoustic cues (e.g., frequency, tonality, pulsing) are assumed to be directly associated with the physical properties (e.g., size) of the sender and/or its particular inner motivational state. Morton concluded that atonal, low-pitched signals bear aggressive meaning, while tonal and high-pitched signals express subordination or the lack of aggressiveness. As this observation was based on acoustic signals of several unrelated species, Morton therefore assumed that these rules could be “universal”, at least among mammals and birds. So in many species such vocalizations seem to have a clear genetic basis and emerge during development without significant environmental influence.

More recently several studies found that vocal signals of many species can be also strongly

context specific, while they share probably the same motivational state. Perhaps the best known examples can be found among alarm calls, which refer to different types of predators of a given species and elicit type-specific avoidance behaviour (Diana monkeys, *Cercopithecus diana*, Zuberbühler, Noe, & Seyfarth, 1997; suricata, *Suricata suricatta*, Manser, Seyfarth, & Cheney, 2002; prairie dog, *Cynomys spp.*, Slobodchikoff, Fischer, & Shapiro, 1986; chicken, *Gallus gallus*, Evans, Evans, & Marler, 1993). These calls are considered as functionally referential and emphasize that animal communication is more than simply sending signals about the caller’s inner state: Showing the proper behavioural response to a referential signal also requires learning from the receivers.

Owren and Rendall (1997), outlining the “affect-conditioning” model for nonhuman primate (and many other animal) vocalizations, argued that the most effective signals are those that directly affect the receivers’ inner state (and consequently their behaviour). The responses of receivers can be unconditioned, when the response is being produced by the signal itself, and conditioned, when the receiver’s response is a result of past social interactions between them—that is, where the caller elicited affective responses in the receiver through other means. This latter approach, especially in nonhuman animal species, is not far from the definition of functional referentiality and gives further support for those opinions, which argue beside the dual (affective/referential) nature of many of the animal signals (e.g., Seyfarth & Cheney, 2003).

Using humans as listeners one could compare the validity of the structural-motivational and the referential/affect-conditioning paradigm on animal vocalizations. If humans can successfully recognize vocal signals of another species independently of the previous experiences, it would support Morton’s (1977) theory. However, if humans with less experience had more difficulties in this task, that would show the importance of the referential/affect-conditioning paradigm. Although it is much easier to evaluate the answers of humans than to record and decipher

the reactions of animals by applying questionnaires, until now only a handful of experiments have been performed that have tested human participants in categorizing animal sounds. It was found that humans can differentiate among individual macaques by their calls (Owren & Rendall, 2003), but participants mostly failed in categorizing cat meows by context (Nicastro & Owren, 2003). Dog barks represent a unique system for study because they seem to be context specific (Feddersen-Petersen, 2000; Yin, 2002), and most of this specificity can be achieved by varying a few acoustic parameters, such as frequency, tonality, and pulsing (Pongrácz, Molnár, & Miklósi, 2006). In the last few years it was also demonstrated that dog barks are characterized by context-specific (and probably motivational-state-specific) acoustic parameters (Yin, 2002; Yin & McCowan, 2004).

Earlier we found that humans have the ability to categorize various barks and associate them with appropriate emotional content (Pongrácz, Molnár, Miklósi, & Csányi, 2005). They categorized the barks into the appropriate contexts above chance level and gave a description about the possible motivational state of the barking dog adequately. In another study we showed that the tonal barks, which had higher frequency and longer intervals between the individual barks, were described as “fearful”, and the atonal barks, whose frequency was higher and interbark intervals shorter, were described as “aggressive” (Pongrácz et al., 2006). The results showed in both studies that previous experience with dogs has only a slight effect on humans’ ability to categorize contextually and understand emotionally dog barks. We found also that the way humans describe the emotions in dog barks follows the above-mentioned Morton’s (1977) structural-motivational rules. However, we could not rule out the effect of general (visual + auditory) experience with dogs even in those people who never owned a dog in their lives. Using visually challenged people, however, could solve this problem.

In this study we compared the performances of sighted and sightless people in a bark recognition and description task. Considering the theory of

Pring (1988) and Pring et al. (1990), we expected congenitally blind people to perform better in the emotional scoring than in the recognition of the context of dog barks. If a priori visual experience (learning) is important for recognizing a particular context (like “the dog is left alone in a park, leashed to a tree”), congenitally blind people would show the poorest performance, while late-blind participants would reach or almost reach the results of sighted participants. In the case of emotional scoring of barks we expected the same level of accuracy of sighted and sightless participants, because as our earlier results showed (Pongrácz et al., 2006), the same acoustic parameters were similarly connected to particular inner states of dogs, as in general in the other mammalian species. Therefore sightless people should be able to decipher these basic emotions from the vocal signals of dogs equally as well as the sighted participants.

Method

Participants

We formed three experimental groups: congenitally sightless people ($n = 15$, mean age = 31.2 years, with a range from 21 to 55 years, male/female = 4/11); sightless people with prior visual experience ($n = 15$, mean age = 36.3 years, with a range from 26 to 60 years, male/female = 9/6); sighted people ($n = 15$, mean age = 26.8 years, with a range from 19 to 52 years, male/female = 9/6).

Procedure

Source and collection of sound recordings. Barks of the Mudi breed (a Hungarian sheepdog listed at the 238th Standard of the FCI, Fédération Cynologique Internationale) were used for this study. This breed is used traditionally for herding flocks of sheep and cattle. Bark recordings from 26 Mudis (15 males and 11 females; average age, 4.3 years; range, 1 to 9 years) were collected for this study. All the dogs were kept as pets (by 15 owners) in family houses or apartments. We collected bark recordings in six different behavioural contexts, most of which could be arranged

at the homes of the owners, with the exceptions of the “fight” situation, which was staged at dog training schools, and the “alone” situation, which was staged on a street or in a park. The six situations are as follows:

1. “*Stranger*”. The experimenter (male, age 23 years), who was 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 2–3 minutes.
2. “*Fight*”. For dogs to perform in this situation, the trainer encouraged the dog to bark aggressively and to bite the glove on the trainer’s arm. We recorded the barks of the dogs during their training for 1–2 minutes.
3. “*Walk*”. The owner was asked to behave as if he or she were preparing to go for a walk with the dog. For example, the owner took the leash of the dog in his or her hand and told the dog, “We are leaving now”. We recorded the barks of the dogs during such situations for 1–2 minutes.
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 minutes. The somewhat bigger distance between the experimenter and the dog was necessary in this case to elicit the required barks more easily from the dogs.
5. “*Ball*”. The owner held a ball (or some favourite 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 minutes.
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 game.

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 a distance of 1–4 m from the dog. The experimenter tried to stand in front of the dog if it was possible. 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 wave form so that its highest amplitude peak was at 6 dB.

Playback experiments. Bark sequences were presented to the participants via a Philips MMS 305/A 3.500 multichannel soft flat panel PC speaker system. Each listener was exposed to three of the sounds recorded in all the six situations from different individuals, chosen randomly, before the trial. Therefore each person listened to 18 barking sequences, and all the barking sequences were played to 3 listeners of the three groups. The bark sequences were played back one by one to the listeners. The listeners had to answer the experimenter’s questions during the experiment. Two questionnaires were used because we presented two playback series to the participants. These series were done one after the other, so the participants answered only one type of question at the same time. After playing back a given bark sequence, the experimenter stopped the device and asked the participant a question. The experimenter did not give suggestions or any specific help for the participants but, if needed, played back once more the given bark sample. Participants performed the playback tests alone with the experimenter. For the “emotionality ratings” the participants had to rate each bark sequence for five different kinds of “emotion”. Then we played the same sound set once more for the listeners, but now they had to guess the situation where the bark sequence might have been recorded (categorization). We did not inform them directly that they were given the

same sound set, but if they asked we told them that the same barks might be in both of the sets.

Emotionality ratings. Listeners had to rate each bark sequence on a 5-item scale for different content of emotionality: 1–aggressiveness; 2–fearfulness; 3–despair; 4–playfulness; 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, participants could scale a given bark sequence for the lack of aggression (rating 1 on the aggressiveness scale) but indicate high levels of playfulness (rating 5 on the playfulness scale). Listeners had to rate each bark sample for each emotion separately by answering the experimenter’s questions. For each barking sequence the experimenter asked the participants to scale the different contents of emotionality in a random sequence.

Categorization. The participants were told the possible situations of the barking sequences before this period of the experiment. They had to categorize each bark sequence into one of the six situations listed on their sheets. The listeners did not know that each situation in the recordings occurred only three time in the series. After each of the six barking sequences or if the participants asked, they were told the possible situations of the barking sequences again.

Data analysis

We analysed the effect of different situations on the categorization of the bark samples by Friedman test with Dunn’s post hoc test separately in the three groups of the participants (sightless from birth, sightless with visual experience, and sighted persons).

The analysis of the categorization was based on the percentage of the correctly categorized barking sequences by the participants (treating the different groups separately). The accuracy by which participants categorized the bark situations were examined by one-sample t test and one-way analysis of variance (ANOVA) with Student–Newman–Keuls (SNK) post hoc tests.

Results

Categorization of contexts

The participants’ categorization performances were compared with the chance level of 16.67%. (On the questionnaire six possible situations were provided, and the participants’ tasks were to choose one from them.) All three groups were over chance level in assigning the bark into the correct situational category—one-sample t test: sightless people, $t(14) = 5.70$, $p < .001$; sightless people with earlier visual experience, $t(14) = 5.96$, $p < .001$; sighted people, $t(14) = 7.99$, $p < .001$. There was no difference between the groups—one-way ANOVA: $F(2, 42) = 0.23$, $p = .80$ (Figure 1).

The contexts of recordings had a significant effect on the performances of all the three groups of participants (one-way ANOVA, SNK post hoc): sightless people, $F(5, 84) = 10.33$, $p < .001$; sightless people with earlier visual experience, $F(5, 84) = 5.84$, $p < .001$; sighted people, $F(5, 84) = 5.16$, $p < .001$. The listeners categorized most accurately the barks of dogs in the “stranger”, “fight”, and “alone” situations. At the same time, they showed the poorest results in recognition of “ball” and “walk” barks. We did not find differences between the performances of the groups (Figure 2).

To explore which situations the listeners thought of when they made an error in categorizing the contexts we calculated a “confusion matrix”

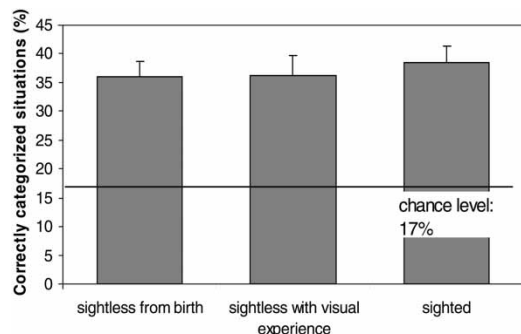


Figure 1. Categorization of barks by humans with different visual experiences. Each group performed significantly over the chance level (one-sample t tests), and the individual groups did not differ from each other (one-way ANOVA).

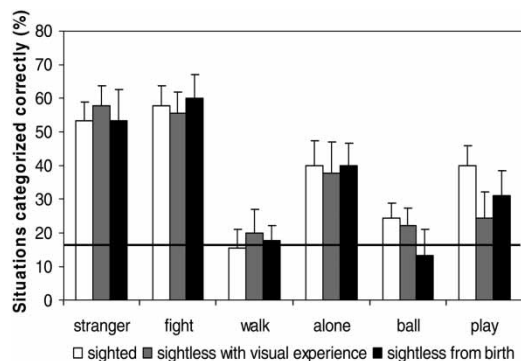


Figure 2. Accuracy of categorization performances of humans with different visual experiences listening to barks recorded in different contexts. Participants in each group categorized “stranger”, “fight”, and “alone” barks with high accuracy. There were no significant differences between the three groups of human listeners (one-way ANOVA).

(see Table 1). When the participants misinterpreted the “stranger” situation, the preferred alternative was the “fight” context and vice versa. The “walk” and “ball” situations were more difficult to identify for the participants. For the “alone” situation the wrong answers were distributed quite equally among the other situations.

Describing the motivational states

We analysed whether there are differences among the emotionality scores given by the participants in the three groups for barks recorded in different situations (Friedman ANOVA with Dunn’s post hoc tests, because the data did not follow Gaussian distribution, see Table 2). We found significant differences in only 4 cases from the 30 comparisons made: The groups’ performances differed when they

Table 1. “Confusion matrix” about distribution of answers given by all human listeners to different situations

Context	Answers (%)					
	Stranger	Fight	Walk	Alone	Ball	Play
Stranger	<i>54.81</i>	14.81	8.89	6.67	8.15	6.67
Fight	23.70	<i>57.78</i>	0.74	5.19	3.70	8.89
Walk	11.85	2.96	<i>17.78</i>	18.52	26.67	22.22
Alone	17.04	3.70	14.07	<i>39.26</i>	14.07	11.85
Ball	20.00	6.67	19.26	14.07	<i>20.00</i>	20.00
Play	9.63	16.30	11.11	11.85	19.26	<i>31.85</i>

Note: As participants in each group could categorize situations over the chance level, we merged the results of the groups. In the rows the recording contexts are represented; in the columns there are the answered situations. Percentages of correct answers are in italics.

Table 2. Analysis of the emotionality scores given by the participants in the three groups for barks recorded in different situations

Emotionality	Context					
	Stranger	Fight	Walk	Alone	Ball	Play
Aggression	0.74	0.58	5.92	1.97	1.62	1.93
Fear	4.32	1.43	2.18	0.88	3.26	<i>6.69</i>
Despair	<i>6.12</i>	1.28	1.2	0.05	2.05	<i>9.17</i>
Playfulness	1.33	<i>11.95</i>	2.86	2.90	2.09	4.38
Happiness	3.31	4.29	0.28	5.40	2.63	5.77

Note: Values are χ^2 , Friedman ANOVA. Significant differences (ANOVA, $\alpha = .05$) are in italics.

scored the despair in the “stranger” situation, $\chi^2(2, N = 14) = 6.12, p < .05$, playfulness in “fight”, $\chi^2(2, N = 14) = 11.95, p < .01$, and fearfulness, $\chi^2(2, N = 14) = 6.69, p < .05$, and despair, $\chi^2(2, N = 14) = 9.17, p < .05$, in the “play” context, but the post hoc test had a significant result in only one case: For the “fight” context sighted participants gave significantly higher scores than the congenitally sightless people. In most cases there was no difference among the emotionality scores given by the participants in the three groups, so the scores were pooled for further analyses.

We compared the emotional scores given by the participants to barks recorded in different situations (Friedman ANOVA with Dunn’s post hoc). The situations had the following effects on emotional scales in the groups of participants: “stranger” barks, $\chi^2(4) = 124.81, p < .001$; “fight”, $\chi^2(4) = 186.46, p < .001$; “walk”, $\chi^2(4) = 33.83, p < .001$; “alone”, $\chi^2(4) = 39.82, p < .001$; “ball”, $\chi^2(4) = 28.18, p < .001$; “play”, $\chi^2(4) = 23.59, p < .001$. For mean emotional scores given by the three groups of participants to barks recorded in (a) “stranger”, (b) “alone”, and (c) “play” situations, see Figure 3a–3c.

We found only slight differences among the emotional scoring of the people with different sight abilities. All groups gave the highest aggression scores when they were listening to barks recorded in “stranger” and “fight” situations. The other situations were given significantly lower scores. The “fearfulness” and “despair” scores given by the sighted and “sightless with prior visual experience” people differed significantly, but in the born sightless group they did not; however, the trend was the same: The “alone” barks were described as most fearful and desperate. On the other hand, “ball” and “walk” situations received the lowest values. The playfulness and happiness ratings were very similar to each other. As it was expected, the “play” and “ball” barks were given the highest values on both the playfulness and happiness scale along with “walk” barks.

Discussion

Results have shown that all three groups (congenitally sightless, sightless with prior visual

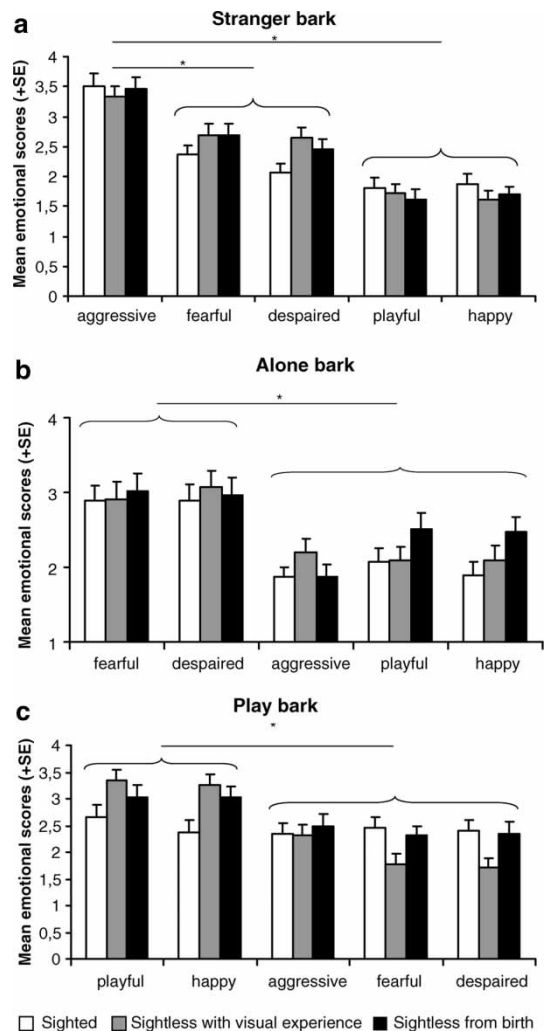


Figure 3. Comparison of emotional ratings of the barks recorded in the (a) “stranger”, (b) “alone”, and (c) “play” situations. The asterisks show significant differences between the categories of motivation. Brackets connect those categories, which do not differ significantly from each other (Friedman ANOVA with Dunn’s post hoc test).

experience, and sighted people) were over chance level in assigning the bark into the correct situational category. There was no difference between the groups: All three groups were equally successful in categorizing barks recorded in the “stranger”, “fight”, “alone”, and “play”. In parallel, participants in all groups encountered similar difficulties when

judging the context of barks obtained in situations like “walk” and “ball”.

Sighted and blind people revealed similar skills in describing the emotional content of the barks. Out of the 30 possible comparisons with regard to different emotionality scales and situations, only 4 showed some difference among the three groups tested. In addition, people independent from their visual experience described barks emitted at the “stranger” as being most “aggressive” and least “happy” or “playful”. In contrast, barks recorded when “alone” were characterized by high scores for fear and despair, and “play” barks were found as most “playful” and “happy”.

Röder and Rösler (2003) found that congenitally and late blind participants both have equally as effective auditory capacities as sighted people. Furthermore, their study gave evidence that blind adults showed elevated memory both after physical and after semantic encoding—which means that they could recall sounds very successfully labelled previously either by their origin (like “saw” or “flute”) or by their acoustic quality (like “harsh” or “soft”). Although their blind participants performed somewhat better (with lower error rate) in the case of physical encoding, Röder and Rösler’s results showed that blind persons have an excellent compensatory capacity for replacing the lack of visual input even in the case of semantic/conceptual relations. Our results are in accordance with Röder and Rösler’s study, because contrary to the theory of Pring (1988)—which is that blind people remember items on the basis of (nonvisual) sensory features, rather than on the basis of conceptual relations—blind participants were highly successful in both the emotional scoring and the context-recognizing task of dog barks.

According to the “motivational–structural rules” hypothesis, atonal, low-pitched signals convey aggressive “meaning”, while tonal and high-pitched signals express subordination or the lack of aggressiveness. It is assumed also that there is no need for any prior learning in the receiver to perform the adequate response to the signal (Morton, 1977). Our results support this idea in the broader sense, especially in the case of the

scoring of motivational states. It is very likely that congenitally sightless people could not have performed so accurately in the test if they had required vision-based learned skills to categorize the barks into contexts and describe the possible motivational state of dogs. Our results show a strong predisposition for the development of such skills. Belin and colleagues (2008) had very similar results, when they tested human listeners’ cerebral activity with functional magnetic resonance imaging (fMRI) during playbacks of familiar (cat) and unfamiliar (rhesus monkey) animal vocalizations. They found that negatively and positively valenced vocalizations elicited activity on different parts of the brain, independently from the familiarity of the species. This, as well as our study with the sightless participants, refers to the general ability of humans to decipher basic affective states in heterospecific vocalizations.

According to the affect-conditioning model, the responses of receivers can be unconditioned, when the response is being produced by the signal itself, or conditioned, when response is influenced by past social interactions between the communicating partners. Our findings suggest that either (a) the ability of humans to describe dogs’ motivational state by hearing their barks is mostly not a learned, conditioned response, because congenitally sightless people who had never owned a dog hardly had enough interactions with dogs in the past to develop such a conditioned skill, or (b) this ability for recognition of barks can develop through sporadic access to nonvisual sources of information about emotional encoding of dog barking.

The somewhat surprising fact that even congenitally sightless people were able to assign dog barks to the correct context over chance level provides another interesting aspect of canine vocalizations. While the recognition of motivational states of others may be mostly nonreferential (following the Morton, 1977, rules), extracting context-specific information from the barks emphasizes also the possible referential content of these signals. As Manser and colleagues (2002) found in the case of *suricatas*, most likely dog barks convey affective and referential information at

the same time, too. The ability of contextual understanding develops obviously during the interaction with the social and asocial environment in both sighted and sightless people. It is important to note, however, that human listeners had the best results with the recognition of those contexts, which had the most unambiguous and strongest motivational description at the same time ("stranger", "fight", "alone", and "play"). This shows that the motivational and referential contents of the signals may have a complex interaction not only at the moment of recognition, but in the learning processes during the development, too. Humans may find it easier to learn and later extract such contextual information, which originates from strongly emotional vocal signals.

These experiments gave further evidence to the extent of highly developed skills of humans to recognize and categorize the vocal signals of our oldest domesticated companion, the dog. The main difference between the barks of wolves and dogs is that dog barks are more variable in their pitch and harshness; in contrast the barks of wolves are mainly low-pitch and atonal sounds. From an evolutionary perspective, the change in dogs' barking repertoire might have happened as a consequence of indirect selection through humans' perceptual and cognitive capacities.

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REFERENCES

- Belin, P., Fecteau, S., Charest, I., Nicastro, N., Hauser, M. D., & Armony, J. L. (2008). Human cerebral response to animal affective vocalizations. *Proceedings of the Royal Society B: Biological Sciences*, 275, 473–481.
- Cobb, N., Lawrence, D. M., & Nelson, N. D. (1979). Report on blind subjects' tactile and auditory recognition for environmental stimuli. *Perceptual and Motor Skills*, 48, 363–366.
- Evans, C. S. Evans, L., & Marler, P. (1993). On the meaning of alarm calls: Functional reference in an avian vocal system. *Animal Behaviour*, 46, 23–28.
- Feddersen-Petersen, D. U. (2000). Vocalization of European wolves (*Canis lupus lupus* L.) and various dog breeds (*Canis lupus f. fam.*). *Archiv für Tierzucht, Dummerstorf*, 43, 387–397.
- Kujala, T., Lehtokoski, A., Alho, K., Kekoni, J., & Näätänen, R. (1997). Faster reaction times in the blind than sighted during bimodal divided attention. *Acta Psychologica*, 96, 75–82.
- Manser, M. B., Seyfarth, R. M., & Cheney, D. L. (2002). Suricate alarm calls signal predator class and urgency. *Trends in Cognitive Sciences*, 6, 55–57.
- Morton, E. S. (1977). On the occurrence and significance of motivation-structural rules in some bird and mammal sounds. *American Naturalist*, 111, 855–869.
- Nicastro, N., & Owren, M. J. (2003). Classification of domestic cat (*Felis catus*) vocalizations by naive and experienced human listeners. *Journal of Comparative Psychology*, 117, 44–52.
- Owren, M. J., & Rendall, D. (1997). An affect-conditioning model of non-human primate vocal signaling. In D. H. Owings, M. D. Beecher, & N. S. Thompson (Eds.), *Perspectives in ethology: Vol. 12. Communication* (pp. 299–346). New York: Plenum Press.
- Owren, M. J., & Rendall, D. (2003). Salience of caller identity in rhesus monkey (*Macaca mulatta*) coos and screams: Perceptual experiments with human (*Homo sapiens*) listeners. *Journal of Comparative Psychology*, 117, 380–390.
- Pantev, C., Oostenveld, R., Engelien, A., Ross, B., Roberts, L. E., & Hike, M. (1998). Increased auditory cortical representation in musicians. *Nature*, 393, 811–814.
- Pongrácz, P., Molnár, C., & Miklósi, Á. (2006). Acoustic parameters of dog barks carry emotional information for humans. *Applied Animal Behaviour Science*, 100, 228–240.
- Pongrácz, P., Molnár, C., Miklósi, Á., & Csányi, V. (2005). Human listeners are able to classify dog barks recorded in different situations. *Journal of Comparative Psychology*, 119, 136–144.
- Pring, L. (1988). The "reverse-generation" effect: A comparison of memory performance between blind and sighted children. *British Journal of Psychology*, 79, 387–400.
- Pring, L., Freistone, S. E., & Katan, S. A. (1990). Recalling pictures and words: Reversing the generation effect. *Current Psychology*, 9, 35–45.
- Röder, B., & Rösler, F. (2003). Memory for environmental sounds in sighted, congenitally blind and late

- blind adults: Evidence for cross-modal compensation. *International Journal of Psychophysiology*, 50, 27–39.
- Röder, B., Rösler, F., Hennighausen, E., & Näcker, F. (1996). Event-related potentials during auditory and somatosensory discrimination in sighted and blind human subjects. *Cognitive Brain Research*, 4, 77–93.
- Röder, B., Rösler, F., & Neville, H. J. (1999). Effects of interstimulus interval on auditory event-related potentials in congenitally blind and normally sighted humans. *Neuroscience Letters*, 264, 53–56.
- Seyfarth, R. M., & Cheney, D. L. (2003). Signalers and receivers in animal communication. *Annual Review of Psychology*, 54, 145–173.
- Slobodchikoff, C. N., Fischer, C., & Shapiro, J. (1986). Predator-specific alarm calls of prairie dogs. *American Zoologist*, 26, 557.
- Yin, S. (2002). A new perspective on barking in dogs (*Canis familiaris*). *Journal of Comparative Psychology*, 119, 189–193.
- Yin, S., & McCowan, B. (2004). Barking in domestic dogs: Context specificity and individual identification. *Animal Behaviour*, 68, 343–355.
- Zuberbühler, K., Noe, R., & Seyfarth, R. M. (1997). Diana monkey long-distance calls: Messages for conspecifics and predators. *Animal Behaviour*, 53, 589–604.