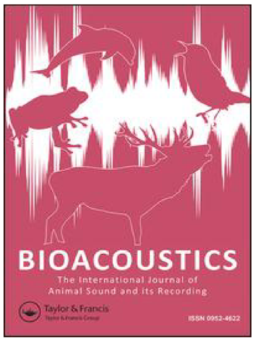

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A bark of its own kind – the acoustics of 'annoying' dog barks suggests a specific attention-evoking effect for humans

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ABSTRACT
Dog barks represent a major source of noise pollution worldwide. However, the exact reasons why dog barks annoy people and why particular people show stronger reactions to dog barks than other noises, are poorly understood. In a sound playback study, we tested Hungarian participants (N= 153) from three age groups and three residential areas. Each participant was tested with 12 different bark sequences, assembled from original barks, based on their pitch, inter-bark intervals and tonality. Subjects rated each sequence according to the degree of annoyance caused by the barks and also to the apparent inner state of the dog. The results showed that the residential area did not have an effect on annoyance ratings. However, compared to children and older adults, young adults found high-pitched barks to be the most annoying. This finding is consistent with earlier results of the effects of baby cries on humans. The most annoying barks showed unique acoustical structures (high pitch, low tonality), this combination was not associated with the extremities of any other emotional scales. We assume that the strong attention eliciting effect of particular barks could be one of the evolutionary reasons why barking has become the main vocalization of the dog during domestication.

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Communication; dog barking; acoustic features; functional analogy; baby cry

Introduction

In the last two decades, the investigation of dog barking has attracted interest in terms of dog-human interspecific communication. In previous studies it was found that specific acoustic features of dog barking (e.g. fundamental frequency, tonality and inter-bark-intervals) play an important role in interspecific communication, as they convey contextual and emotional information and even individual characteristics – such as age or sex – of the dog (Yin 2002; Yin and McCowan 2004; Molnár et al. 2010; Pongrácz et al. 2010, 2011; Larrañaga et al. 2015). Compared to their wild relatives (e.g. wolves, jackals), domesticated dogs bark in more varied contexts and much more frequently (Cohen and Fox 1976). According to some researchers (Lord et al. 2009), barking of dogs shows the typical acoustic and behavioural features of mobbing signals, therefore, primarily serves the purpose of dog-dog communication in the new (anthropogenic)

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Supplementary data for this article can be accessed here.

environment of the dog. Indeed, later in an experimental study, it was found that dogs react differently to other dogs' bark depending on the context (agonistic barks elicited a stronger response than barks of a left-alone dog), and they also discriminated between familiar and unfamiliar dogs' barking (Pongrácz et al. 2014). However, there is an even larger wealth of evidence showing that dog barks may play an important role in dog-human communication. Human listeners, independent of their previous experience with dogs, can recognize the context of barks, not only in the more ancient agonistic circumstances but when dogs bark in isolation or during play (Pongrácz et al. 2005, 2011; Molnár et al. 2010). According to one theory, since domestication, barking in dogs evolved to a more acoustically diverse vocalization that partially overtook the role of other vocal signals (e.g. howls, growls, whines) in expressing more various inner states of dogs than originally occurred in wolves (Pongrácz 2017).

Despite its assumed role in dog-human interspecific communication, 'excessive' dog barking is often considered a nuisance in urban areas (Senn and Lewin 1975; Attenborough et al. 1976; Utley and Buller 1988; Murray 2003; Flint et al. 2013, 2014). Based on reports about noise, to the Institution of Environmental Health (in England), reported that almost 30% of complaints were about dog barking. Utley and Buller (1988) concluded that dog barking makes a significant contribution to urban noise pollution. Flint et al. (2014) investigated some of the factors affecting public attitudes toward barking dogs in New Zealand and documented a clear divide in attitudes towards dog barking, whereby people living in rural environments were more 'tolerant' of dog barking than residents of city flats.

In a previous study, we tested whether the nuisance caused by dog barks was related to its role in interspecific communication between dogs and humans. Specifically, we used a playback experiment to test whether the level of annoyance registered by human participants was influenced by some of the acoustic features of the barks and/or the dogs' perceived emotional state. Our results showed that barks which were either high-pitched or low-pitched and fast pulsing, were the most annoying types. Male participants were typically more annoyed by barks than female participants, while the perceived emotional state of the dog was negatively correlated with nuisance scores when barks were suggestive of positive emotions (such as happiness and playfulness) and positively correlated with nuisance scores when barks were suggestive of a negative emotional state (e.g. fear, despair, aggression) (Pongrácz et al. 2016).

Comparing these results with some earlier studies (Pongrácz et al. 2005, 2006; Lord et al. 2009), we assumed that the most annoying barks are typical in such social contexts, where barking might have a strong interspecific attention-eliciting function. The most annoying bark types had acoustic parameters that were typical for the contexts where barks could have a functionally urging (e.g. a left alone dog) and/or an alarming role (e.g. a dog that barks at a stranger). Recent findings have also shown that humans are able to use similar acoustic cues in animal calls to assess the emotional arousal of the individual, independently of its species (Faragó et al. 2014; Maruščáková et al. 2015; Filippi, Congdon, et al. 2017; Filippi, Gogoleva, et al. 2017). This suggests the presence of biologically rooted emotion-attribution rules that are used for assessment of con- and heterospecific calls (for review see (Andics and Faragó 2018), which can be adaptive in cross-species communication contexts, but also promotes the nuisance effect of biological noise. We concluded this effect as the theory of communicative relevance of auditory nuisance (Pongrácz et al. 2016). This theory is based on the attention eliciting effect of particular sounds, which in turn can cause annoyance in humans when the intervention is not possible.

From the aspect of communication, perhaps the most relevant biological 'noise' is baby crying for adults. Baby crying is one of the main signal types used for expressing the urgent or chronic needs and negative emotional states of an infant. The effectiveness of the signalling is important because the infant's well-being/survival may strongly depend on evoking parental attention (Bowlby 1958), as many studies have shown (Porter et al. 1986; Dessureau et al. 1998; Out et al. 2010; Parsons et al. 2012). Parallel with the theory of the communicative relevance of auditory nuisance, the valence and quality of the noise-elicited response may depend on such additional factors that can modify the meaning of the vocal signals for the receivers. In case of distress calls, one could hypothesize that listeners' sex (Pongrácz et al. 2016), age (Pongrácz et al. 2011) and experience with the signal/signaller (Swain et al. 2008) could likely act as modifying factors.

In our present study, we investigate whether the nuisance effect elicited by dog barks would be different in groups of human participants from different age groups and different residential areas. We hypothesize that participants from different age groups would react with different levels of annoyance and we expect higher attention eliciting from the adult groups. We base our prediction here on the potentially higher capacity of adults to provide useful intervention/help when responding to alarming sounds. Basically, they have already reached that period of their life when a higher reaction to distress calls would be adaptive for the baby from the younger and older adults as well.

Regarding the residential area of the participants, based on the results of Flint et al. (2014), we hypothesize that people from the countryside will evaluate the bark sequences with lower nuisance scores than the residents of urban flats. Finally, based on the responses of a balanced sample of participants from various age groups and residential areas, we wanted to conduct a more reliable acoustic comparison between the information content of dog barks with high and low scores of annoyance. Partly based on the theory of Lord et al. ((Lord et al. 2009) – barks act as 'mobbing signals'), we expected that the acoustic structure that is attributed to the most fearful and/or aggressive dogs would also elicit the highest scores of annoyance.

Materials and methods

Supporting data availability

The datasets supporting this article have been uploaded as part of the supplementary material.

Subjects

As a sum, 153 participants were included in the tests (Table 1). We tested children who were 10–11 years old; young adults (from 18 to 35 years old) and a group of older adults (from 50 to 70 years old).

The sex ratio of the individual test groups is shown in Table 2.

Table 1. The number of participants in each generation/residential area combination.

		Residential area types			
		Urban environment with flats	Urban environment with gardens	Countryside	Total *N*
Age groups	**10–11 y-o**	15	27	5	47
	18–35 y-o	27	16	21	64
	50–70 y-o	9	12	21	42

Table 2. The sex ratio of participants in each age and residence category.

	Age groups				Residential area types		
	Children	Young adults	Older adults	Total *N*	Urban area with flats	Urban area with gardens	Countryside
Male	27	27	20	74	19	23	32
Female	20	37	22	79	32	32	15

Participation was voluntary in the experiment. In the case of the children, their parents had to give their *a priori* acquiescence to the school's staff about the participation of their children. Informed consent was obtained from each adult participant, as well as from the children's parents. The data are used only for research purposes. The protocol was approved by the University Ethical review board. Ethical permission number: PEI/2016/003.

Participants were sorted into three groups based on their residential area: urban area with blocks of flats; urban area with houses with garden; and countryside. The sex ratio of participants in each group is indicated in Table 2.

Sound samples

We used assembled dog bark samples that were composed of units of original bark recordings (Figure 1, also there are samples of sound sequences in the Supplementary material). The source was 26 individual dogs of the Mudi breed (a Hungarian herding dog, standard No. 238 at Fédération Cynologique Internationale). Original barks were recorded in six different contexts ('stranger at the gate'; 'Schutzhund training'; 'left alone'; 'before walk'; 'asking for ball'; and 'play' – see details in Pongrácz et al. 2005). We selected 1,452 single barks from a pool of units, based on their tonality (two levels of Harmonic-to-Noise-Ratio: low: −2.1–4.6; high: 11.6–35.4) and pitch (two levels of fundamental frequency: low: 401–531 Hz, high: 732–1,833 Hz). We assembled bark sequences from these single bark units (10 units long each), using three levels of inter-bark-intervals (short: 0.1 s; medium: 0.3 s, long: 0.5 s). Based on the results of Pongrácz et al. (Pongrácz et al. 2016), we excluded the 'medium' values of tonality and pitch from the selection, because our goal was to create bark sequences of the two extremities on the nuisance scale: 'most annoying' and 'least annoying' dog bark samples (for further details on creating sound samples from the original recordings see (Pongrácz et al. 2016)). At the end, we had 12 different types of bark sequences (N_{total} = 2160), from which we created playlists for the playback study. Bark sample types were sorted to the playlists in a randomized order, one playlist contained one copy from each type of sequences. Each playlist was used for only one participant.

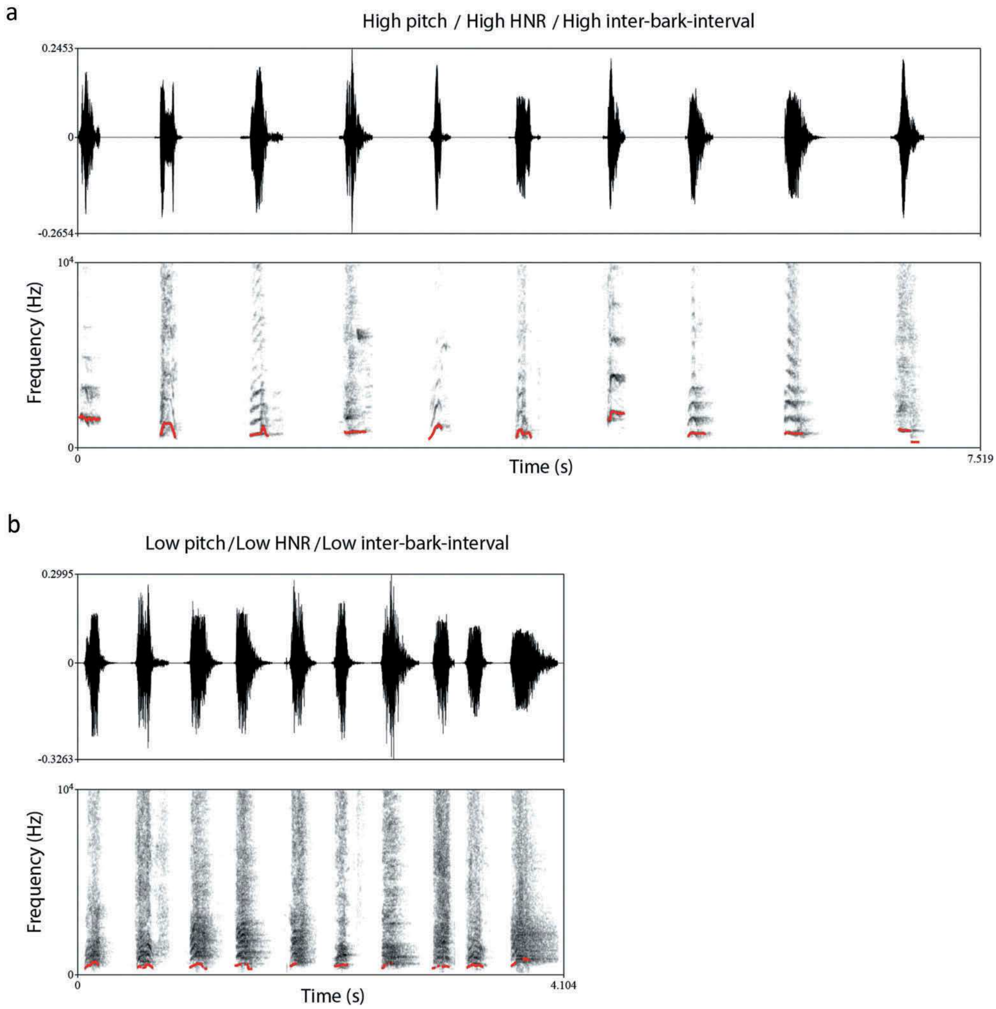

Figure 1. Spectrograms that show two exemplars of artificially assembled dog bark sequences. (a) and (b) represent sequences that differ in each of those acoustic parameters that were used during the selection and assembly of individual bark recordings (fundamental frequency, tonality and inter-bark interval). Fundamental frequencies of the individual barks are highlighted with red on the frequency spectrograms. From a pool of original bark units, we selected individual barks based on their tonality (two levels of HNR: low: −2.1–4.6; high: 11.6–35.4) and pitch (two levels of fundamental frequency: low: 401–531 Hz, high: 732-1833 Hz). We assembled bark sequences from these single bark units (10 units long each), using three levels of inter-bark-intervals (short: 0.1 s; medium: 0.3 s, long: 0.5 s).

Questionnaire sheet

Participants were asked to rate one by one how annoying they felt the dog bark samples were; and additionally, they also had to rate the dogs' apparent inner state. The q-sheet had two main parts. The first, self-reported part, was about the participants' demographic data (age, residential area). The second part contained a table with four modified Likert-scales consisting of small pictures (their size increased proportionately from 1 (smallest) to 7 (biggest) size). With the help of these scales, participants were requested to evaluate three different emotional states (‘happy-playful’; ‘scared-desperate’; ‘aggressive-angry’) based on each bark sequence on the playlist. The fourth scale was for rating the annoyance level that a given sound sample caused for the participants (i.e. ‘How annoying was this barking for you?’) (Figure 2).

The stylized pictures were used for making the task easier and more understandable for the children. For the sake of uniformity, the same type of sheet was used for the adult participants as well. These small figures were happy-, scared/crying-, and angry dog faces, and stylized, annoyed-looking human faces were used for the rating of the nuisance level elicited by the barks. The participants had to mark one of the pictures on each scale, choosing the size variant that symbolized for them most accurately the intensity of a given inner state or the level of annoyance.

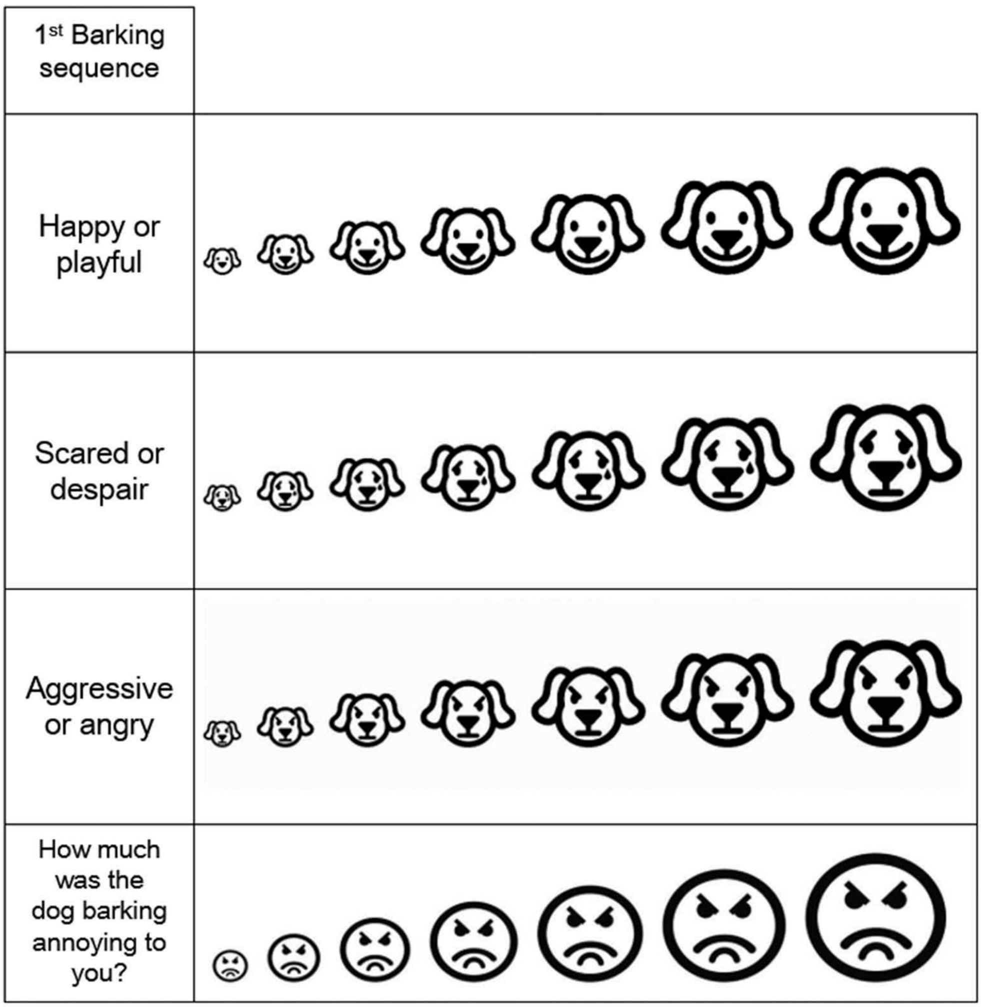

Figure 2. Excerpt of the questionnaire sheet. Depending on the apparent effect of the given sound sample, the listeners had to mark one of the stylized pictures on each of the seven-grade scales after listening to each barking sequence.

Statistical analysis

Cumulative Link Mixed Models fitted with the Laplace approximation (ordinal:clmm) were used for ordinal regression analysis in R (RCoreTeam 2017) to test which factors affected the emotional and nuisance ratings of the bark sequences. We used AIC change based forward model selection to find the most parsimonious model. Two fixed factors (pitch and HNR (Harmonic-to-Noise Ratio) were entered as two-level grouping variables, meanwhile inter-bark-interval had three levels. We also added to the model the participants' age, sex, type of residential area and experience level with dogs (whether they currently have a dog; had a dog in the past; never had a dog) as possible confounding factors. We tested the main effects and all possible 2-way interactions of the grouping variables. For post-hoc pairwise comparisons, Tukey test was applied (emmeans, see Supplementary Material for the detailed results of the post-hoc test). Finally, we checked the pairwise correlations between the scales with Kendall tau tests.

Results

Annoyance

The parsimonious model ($LR = 4.178$; $p = 0.041$) showed a significant main effect of Gender (males reported higher nuisance) and interactions between Pitch and HNR, Pitch and age, HNR and age (Table 3). Post-hoc comparisons revealed that low-pitched and tonal barks were the least annoying, while high-pitched and harsh barks received the highest annoyance scores (Figure 3). Young adults were the most annoyed by barks, old participants reported the lowest annoyance level, while children were in-between in general. Post hoc tests showed a significant pitch effect within young adults being more sensitive for the high pitch (Figure 4), while tonality affected children's ratings negatively: they rated harsh barks to be more annoying (Figure 5).

Happiness/playfulness

The parsimonious model ($LR = 59.36$; $p < 0.001$) showed a non-significant trend effect of Gender (males reported higher nuisance) and interactions between Pitch and HNR (Table 3). Low pitched and tonal barks were rated to be the happiest.

Anger

The parsimonious model ($LR = 341.24$; $p < 0.001$) showed a significant main effect of Gender (males gave higher aggression scores) and interactions between Pitch and HNR, HNR and age (Table 3). In the case of Pitch*HNR interaction, we found that harsh barks were rated to be the angriest independently of their pitch, while tonal low-pitched barks received medium ratings, and high-pitched tonal ones were given the lowest scores of anger. Within each age group, we found the same pattern (harsh barks scored higher); children rated the barks as being the angriest and the older participants gave the lowest anger scores.

Table 3. Results of the cumulative link mixed models analysis. The first column shows the main factors and interactions that have been entered to the models. Grey fields indicate those comparisons that were dropped from the most parsimonious models. Significant effects are marked with *italic*. * P < 0.05; ** P < 0.01; *** P < 0.001; HNR = Harmonic-to-Noise Ratio; i2, i3 = medium short inter-bark interval; y.adult = young adult; o.dult = older adults.

		Annoyance					Happiness/playfulness					Anger					Fear/Despair				
Factor	Contrast	Estimate	Std. Error	z value	Pr(>|z|)		Estimate	Std. Error	z value	Pr(>|z|)		Estimate	Std. Error	z value	Pr(>|z|)		Estimate	Std. Error	z value	Pr(>|z|)	
Pitch	high vs low	*−0.49413*	*0.07833*	*−6.308*	*2.82e-10*	***	*0.51424*	*0.07101*	*7.242*	*4.44e-13*	***	*0.56485*	*0.07200*	*7.845*	*4.34e-15*	***	*−1.5055273*	*0.0010020*	*−1502.510*	*<2e-16*	***
HNR	tonal vs harsh	−0.04637	0.07662	−0.605	0.54502		*0.17297*	*0.07139*	*2.423*	*0.0154*	*	*1.31874*	*0.10526*	*12.528*	*< 2e-16*	***	*−1.1106463*	*0.0009701*	*−1144.873*	*<2e-16*	***
Inter-bark interval	slow vs medium																*−0.0653499*	*0.0010020*	*−65.217*	*<2e-16*	***
	slow vs fast																*−0.0380989*	*0.0010020*	*−38.021*	*<2e-16*	***
Age	children vs young adult	−0.37402	0.21133	−1.770	0.07676	.						0.14465	0.11684	1.238	0.215698		*0.1028668*	*0.0010227*	*100.580*	*<2e-16*	***
	children vs old adult	*−1.03376*	*0.18591*	*−5.561*	*2.69e-08*	***						−0.11344	0.12947	−0.876	0.380942		0.1892331	0.1405589	1.346	0.178209	
Gender	male vs female	*−0.43613*	*0.21232*	*−2.054*	*0.03996*	*	−0.14718	0.08601	−1.711	0.0871	.	*−0.24558*	*0.08401*	*−2.923*	*0.003464*	**	*−0.3742924*	*0.0010228*	*−365.959*	*<2e-16*	***
Pitch:HNR	high pitch/tonal vs low pitch/harsh	*0.46532*	*0.10677*	*4.358*	*1.31e-05*	***	*−0.52464*	*0.10004*	*−5.244*	*1.57e-07*	***	*−0.45393*	*0.09930*	*−4.571*	*4.84e-06*	***	*1.2479965*	*0.0009702*	*1286.344*	*<2e-16*	***
Age:Gender	children/male vs y.adult/female																*0.4394949*	*0.0010228*	*429.705*	*<2e-16*	***
	children/male vs o.adult/female																0.0776826	0.1595217	0.487	0.626278	
HNR:Age	tonal/children vs harsh/y. adult	−0.09167	0.10435	−0.878	0.37968							*−0.39472*	*0.11757*	*−3.357*	*0.000787*	***					
	tonal/children vs harsh/o. adult	*0.23818*	*0.08757*	*2.720*	*0.00653*	**						*−0.37216*	*0.13101*	*−2.841*	*0.004503*	**					
Pitch:Age	high pitch/children vs harsh/y. adult	−0.05263	0.10423	−0.505	0.61359												*−0.0604941*	*0.0010021*	*−60.369*	*<2e-16*	***
	high pitch/children vs harsh/o. adult	*0.40015*	*0.08770*	*4.563*	*5.05e-06*	***											*0.2476781*	*0.0943396*	*2.625*	*0.008655*	**
i2:Age2	slow/children vs medium/y. adult																*0.0719955*	*0.0010021*	*71.845*	*<2e-16*	***
i3:Age2	slow/children vs fast/y. adult																−0.0001251	0.0010021	−0.125	0.900636	
i2:Age3	slow/children vs medium/o. adult																0.0515543	0.1146224	0.450	0.652872	
i3:Age3	slow/children vs fast/o. adult																*−0.4072106*	*0.1159721*	*−3.511*	*0.000446*	***

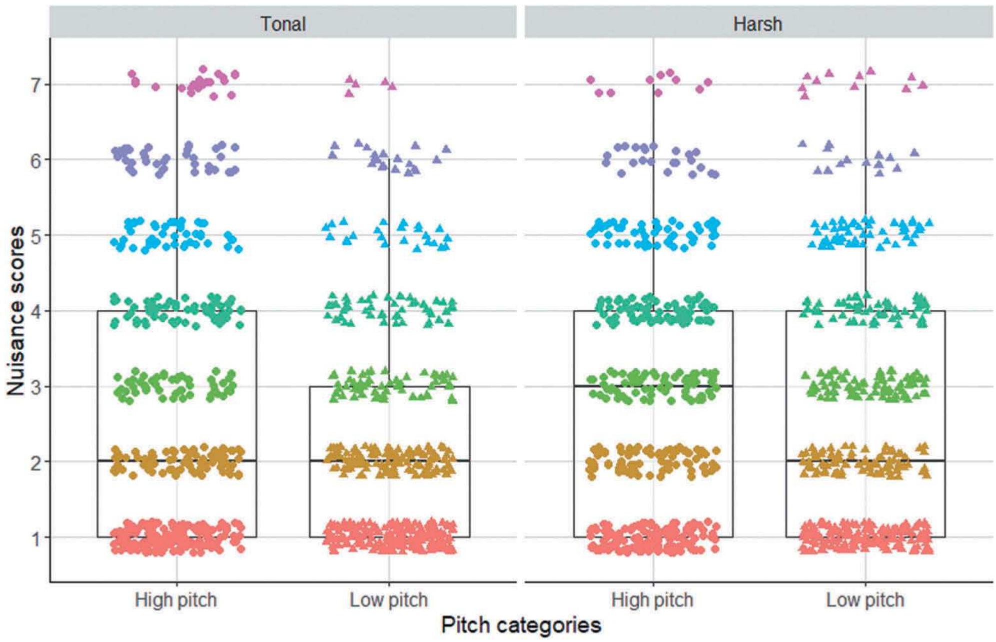

Figure 3. Effect of the HNR (Harmonic-to-Noise Ratio) and pitch of dog barks on the caused annoyance in human listeners. Individual responses are mapped on the box-plots as scatter of dots and triangles. Response score levels are colour-coded to make them more distinguishable. Bark sequences were assembled from original bark units of combinations of low (triangles) or high pitch (dots) and tonality. Categories of HNR are indicated over the bars (Tonal = high HNR; harsh = low HNR). Harsh, high-pitched barks were rated as being the most annoying.

Fear/despair

The parsimonious model (LR = 524.66; $p < 0.001$) showed significant interactions between Gender and age, Pitch and HNR, Pitch and age, Inter-bark interval and age (Table 3). High pitched and tonal barks received the highest scores of fear, while low-pitched and tonal barks were found as the least fearful. In general, a high pitch was associated with stronger fear. In this scale, we found opposite gender effect in children and young adults. Boys and young women gave higher fear scores to the barks than girls and young adult men. Pitch had the same effect across age categories, with the weakest difference in the older subjects' group. In general, children gave the lowest fear ratings while young adults the highest. Inter-bark intervals had a different effects across age groups. Children rated fast pulsing barks to be more fearful than slow ones. Older participants rated the barks in the opposite way, slow pulsing ones were the most fearful, and fast pulsing ones the least. In contrast, young adults rated the medium interval to be the most fearful. Children, in general, gave the lowest fear scores.

Correlations between scales

The Nuisance scale correlated negatively with Happiness (tau = −0.218, $p < 0.001$), while positively with Anger (tau = 0.254, $p < 0.001$) and Fear (tau = 0.147,

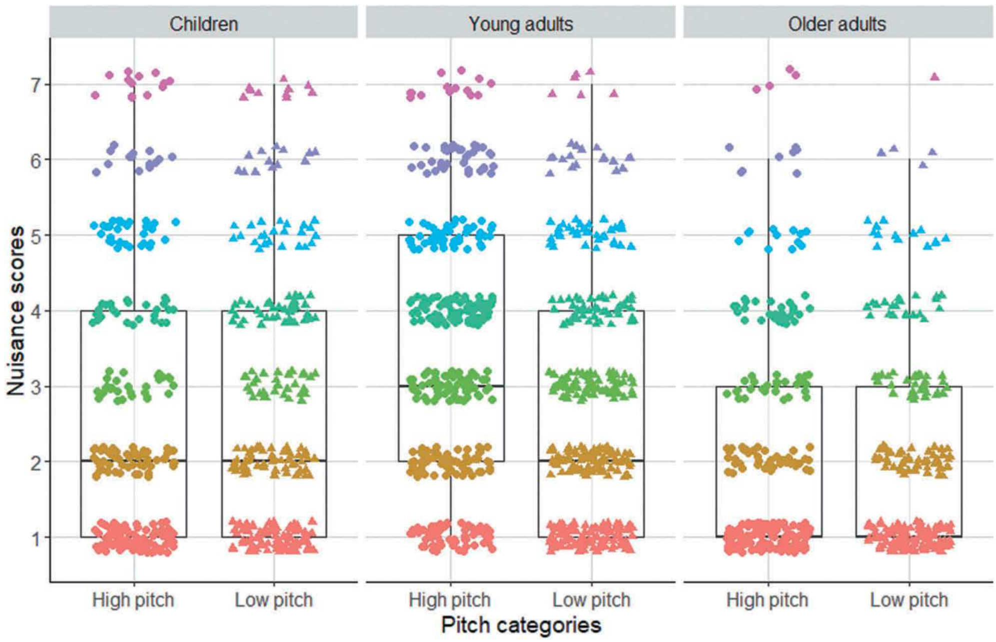

Figure 4. Effect of participants' age and the pitch of dog barks on the annoyance scores. Individual responses are mapped on the box-plots as scatter of dots and triangles. Response score levels are colour-coded to make them more distinguishable. Age categories are indicated over the bars. Young adults found high-pitched barks more annoying than low-pitched ones.

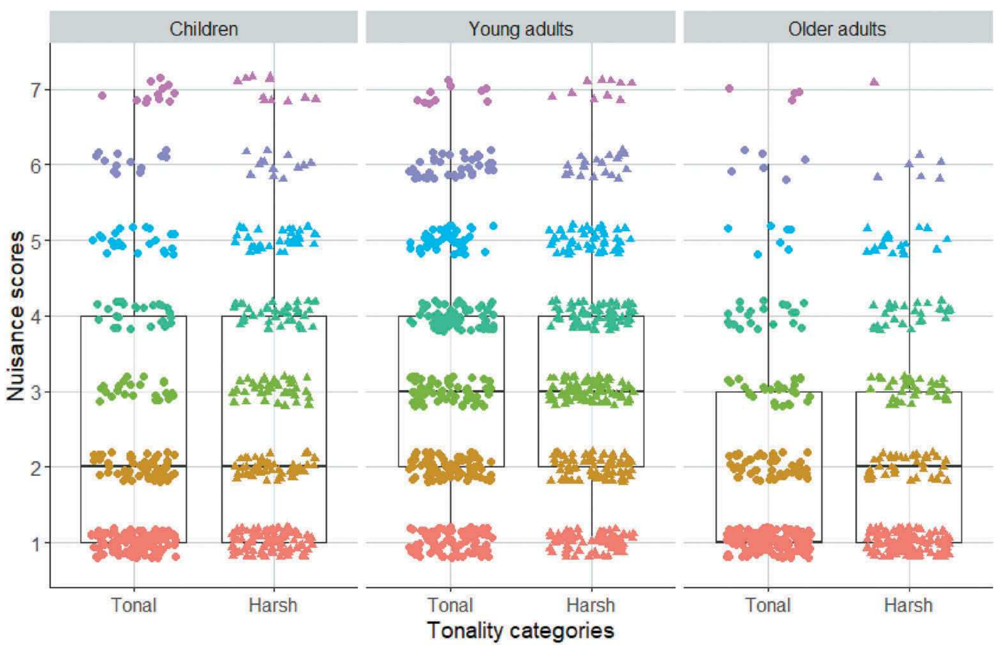

Figure 5. Effect of participants' age and the HNR (Harmonic-to-Noise Ratio) of dog barks on the annoyance scores. Individual responses are mapped on the box-plots as scatter of dots and triangles. Response score levels are colour-coded to make them more distinguishable. Age categories are indicated over the bars. Children gave higher scores to barks with low HNR.

$p < 0.001$). Happiness correlated negatively with Fear (tau = −0.236, $p < 0.001$) and Anger (tau = −0.268, $p < 0.001$), while the latter two did not correlate significantly (tau = 0.0113, $p = 0.531$).

Discussion

The results of the playback test showed that both the acoustic features of dog barks and the characteristics of listeners had a significant effect on how annoying someone perceived the barking of a dog to be.

It was found earlier that people living in the city were more likely bothered by dog barking than by people who lived in a rural area (Flint et al. 2014). However, we found that residence type did not affect the level of perceived annoyance in the participants. The study of Flint et al. (2014), was based on the participants' opinion about dog barking, meanwhile, our empirical study provided sound playbacks for evaluation. Therefore, in our case, the answers could be more influenced by the actual acoustic features of dog barks than by general tolerance or dislike against dogs and their vocalizations. Although theoretically the lack of residence-effect could be caused by the similar ratio of people with a more and less positive attitude towards dogs and dog barking living in rural and urban conditions in our study, this would most probably only affect the annoyance scores. Our results show however that the effect of acoustics, as well as the emotional scoring, was not affected by residence type either, and these parameters would be less dependent on the dog-directed attitudes of the listeners. It seems that acoustic parameters (such as pitch and tonality) may affect the participants in a similar way, independently of their dog-related experiences and consequently developing attitudes toward dogs (the latter may strongly depend on the residential area). This finding supports the theory of communicative relevance of the auditory nuisance (Pongrácz et al. 2016) because the annoying effect seems to be rather uniform among participants from different residential areas.

Annoyance scores were significantly affected by the interaction between pitch and tonality. In general, the high-pitched but atonal bark sequences were the most annoying for the listeners. Senn and Lewin found that human ears are more sensitive to high-pitched sounds than the lower pitched ones (Senn & Lewin 1975) in the case of a dog barking. The present results support our previous findings about the annoyance effect caused by specific acoustic features (Pongrácz et al. 2016), where we also found the high-pitched, atonal sounds as being the most annoying dog barks on a larger, multicultural, balanced sex sample. Barks with these acoustic characteristics are usually emitted in such situations where the evoked attention of humans can be adaptive for dogs (Pongrácz 2017). For instance, dogs that were left alone in a confined situation (i.e. tethered somewhere) typically emit high-pitched barks, and dogs that defend their (and the owner's) property use atonal barks (Pongrácz et al. 2005). In these situations, theoretically the owners can easily intervene, therefore it would be adaptive for the dog to use such types of vocal signalling that humans are more sensitive to (Senn & Lewin 1975).

The acoustics of baby crying (Michelsson 1971; Michelsson et al. 1983; Porter et al. 1986; Dessureau et al. 1998), as well as particular acoustic components of cats' purr that were shown as having an 'urging' effect on human listeners (McComb et al. 2009) show similarity with the most annoying (high-pitched and atonal) dog barking. It is assumed that baby crying serves as a highly effective auditory key stimulus that triggers parental caregiving behaviour in adults (Out et al. 2010). At the same time, there are indications which show that high-pitched baby crying can provoke harsh reactions from adults too. Subjects scored higher in the Child Abuse Potential Inventory after listening to high pitched baby cries than those who listened to lower pitched ones (Crowe and Zeskind 1992). This means that stress, induced by particular baby cries, can be potentially connected to child abuse from adults. This can show a functional/acoustic homology in the harsh reactions of human listeners in the case of both sound types if we compare these previous findings on baby crying with the high numbers of complaints about dog barking (e.g. Utley and Buller 1988).

According to the two-way interaction between the listeners' age and the pitch of dog barks, young adults were the most annoyed in the case of the high-pitched dog barking. This result can be explained by the theory of functional analogy between the baby crying and particular dog barks. We assume that sensitivity toward the acoustic key stimuli that resembles distressed infant calls would be the most adaptive in young adults, who are biologically the closest to be parents themselves. As an alternative hypothesis, one could assume that barks with high alarming effect would evoke the strongest response from those people who would be the most effective defenders against potential danger – the young males. Our results are also in good agreement with this assumption. It is important to see that in the case of high-pitched barks, the most likely contextual background for this type of vocalization involves such strongly stressful situations that are hallmarked by fear, despair – for example, being separated from the owner (e.g. Pongrácz et al. 2005, 2006). As the acoustics of affective vocalizations between human cultures and among mammalian species show strong similarity within the particular basic inner state (e.g. Scherer and Kappas 1988; Sauter et al. 2010; Bryant 2013), once dogs began to bark in non-agonistic stressful contexts along the domestication process, these vocalizations may have become almost necessarily similar in their main acoustic features to the ones of highly stressed human infants. Apart from phobic reactions (e.g. (Doogan and Thomas 1992), the physiological responses of humans to dog barking is largely unknown, so in the future, it would be useful to compare the elicited responses to baby crying and dog barks from a physiological point of view.

According to the interaction between participants' age and the tonality of dog barks, young adults gave significantly higher annoyance scores than the older adults, regardless of the tonality of the barks. Tonality however affected the annoyance scores given by the children: they found the atonal barks more annoying than the tonal sounds. Besides eliciting annoyance, atonal barks are usually assessed as aggressive (e.g. (Pongrácz et al. 2016)). In an earlier playback study, children of various age groups had to categorize dog barks by their context and also recognize the most likely inner state of the dogs (Pongrácz et al. 2011). It was found that the aggressive barks (e.g. 'Stranger at the fence') were the easiest to recognize for children: even 6-years-olds could recognize this context (but not the other two contexts: 'Play' and 'Alone'). Accordingly, we also found in this study that harsh barks were rated higher on aggression by children compared to the older participants. The high sensitivity to potential aggression through the perception of other's visual and/or acoustical signals could be highly adaptive for children, who are more vulnerable than adults in agonistic encounters. The results of our present study suggest a similar effect: higher annoyance level for atonal dog barks might be the consequence of an ‘alarm’ response against potential danger in children.

Annoyance scores showed a positive correlation both with the aggressiveness and despair scores and negative correlation with the rating of happiness. The direction of the correlations is the same that we found earlier in a multicultural sample of participants (Pongrácz et al. 2016). Regarding the associations in case of the emotional ratings, we found that the listeners attributed clearly distinct inner states to particular combinations of acoustic characteristics. According to this, the happiest bark type was characterized by a low pitch and high tonality. Low tonality resulted in the highest aggression scores (where male participants and children, in general, found the sequences more aggressive). High pitched and tonal sounds were rated as being the most desperate/fearful. These results are in agreement with previous findings of the human ability for assessing the apparent inner states of dogs on the basis of their barks (Pongrácz et al. 2005, 2006). The effectivity of artificially assembled sequences of dog barks indicates that the evaluation of the suspected inner states of dogs is mostly driven by the acoustic structure of the dog barks instead of other cues (e.g. individual-specific characteristics of the barking dog, and contextual information).

Although we found correlations between the suspected inner states of dogs and the scores of elicited annoyance, it is important to see that the most annoying form of a dog barking (high-pitched and harsh/noisy) is a unique type of sound. It is characteristically different from the ‘angriest’, the ‘most desperate’ and the ‘happiest’ barks. According to Lord et al. (Lord et al. 2009), dog barks may fit to the general purpose of ‘mobbing signals’, which express the inner conflict of the signaller, therefore elicit approach/interest from conspecifics, but make intruders withdraw at the same time. Lord and colleagues based their theory on the fact that dog barks, in general, show a relatively high pitch and contain both tonal and atonal components. Although the interpretation of our study is limited by the fact that we did not test whether the more annoying dog barks are stronger attention grabbers, at the same time our results highlighted the combination of high pitch and high proportion of noisy (atonal) elements, creating a bark type that is especially hard to get used to by human receivers. Therefore, we propose an additional theory, namely that there could be barks that directly evolved for urgently grabbing the attention of humans through this unique acoustical structure, exploiting the acoustic-based general emotion-attributing system that makes arousal and valence assessment across species possible (Faragó et al. 2014; Filippi et al. 2017; Andics and Faragó 2018). This result showed that the interspecific communicative background of the auditory nuisance may be based mostly on the acoustical features’ structure, and it can evoke human attention independently of the emotional or contextual information of the barking. Additionally, with this high sensitivity of humans toward these ‘annoying type’ of sounds (such as baby cry and the high-pitched and atonal dog barking), these results can also confirm our theory about the communicative relevance of the auditory nuisance by providing an evolutionary analogy, why barking could evolve to be the most characteristic type of vocalization of the dog during domestication (Cohen and Fox 1976; Tembrock 1976).

In summary, the attention eliciting effect can be considered as one of the communicative functions of dog barking. At the same time, this can trigger annoyance in human listeners in the case of inability to intervene, which effect seems to be present in all age groups of humans. When we survey various age groups together, the elicited level of auditory nuisance was independent of the type of residential area of the listeners. However, we found evidence that young adults showed higher scores of annoyance to dog barks that showed an acoustic similarity to baby cries regarding their high pitch and low tonality. This age group may also comprise those who are the most sensitive toward the acoustically similar baby crying. The evoked attention in humans may ensure that the dog will be taken care of faster and in a more appropriate way. This ability to evoke human's attention is why we assume a functional analogy between barks and baby crying. We can conclude that as none of these vocalizations can be ignored, eventually they may become a source of nuisance if the listeners cannot intervene or the intervention is unsuccessful.

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Competing interests

We have no competing interests to declare.

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