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DOES CHAOS MAKE MAMMALIAN CALLS SOUND MORE ALARMING TO HUMAN LISTENERS?

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ABSTRACT

Mammalian vocalisations are extremely diverse, and evolutionary approaches to understanding this diversity assume that much of their acoustic form maps onto their function, with specific features serving universal roles. Here, we hypothesize that nonlinear phenomena (i.e., deterministic chaos, sidebands, subharmonics, and frequency jumps), which make the voice perceptually rough or harsh, contribute to the alarming quality of mammalian vocalisations. To test this, we investigated whether adding such acoustic irregularities to synthetic replicas of calls produced by a range of terrestrial mammals increased their alarming quality. We found that, independently of the species, the presence of nonlinear phenomena, especially chaos, made calls more alarming for human listeners. While these results hint at a universal function of NLP in the mammalian vocal repertoire, future studies should now investigate whether the alarming effect of nonlinear phenomena holds for non-human species.

Keywords: *Nonlinear vocal phenomena, Human perception, Mammalian communication*

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1. INTRODUCTION

Commonalities within the wide acoustic diversity of the mammalian vocal repertoire suggest that specific characteristics play universal roles: for example, distress vocalisations designed to alarm receivers by grabbing their attention and signalling negative valence are typically long, relatively high-pitched, and often affected by acoustic irregularities called nonlinear phenomena, which are responsible for perceptual harshness [1, 2, 3]. While these features are assumed to increase the perceptual salience of the calls and their alarming quality [4], their specific role has never been systematically investigated across a range of mammalian species.

Nonlinear phenomena have been suggested to signal relatively high arousal in threatening [5], painful [6], or separation [7] contexts, while also making vocalisations unpredictable and thus difficult to ignore [8]. Accordingly, playback experiments investigating their function show that calls containing NLP leads to stronger behavioral responses, such as flight or avoidance, and reduced foraging activity in meerkats [4]. In humans, listeners attribute their presence in conspecific nonverbal vocalisations to high emotional states and perceive an aversive valence when the context is acoustically ambiguous [6]. Also, adding chaos to domestic dog puppy whines increases perceived distress in human listeners [7]. Interestingly, the same neural mechanisms are recruited when processing human and heterospecific affective vocalisations [9]. Beyond humans, some ungulates have been shown to discriminate the valence of vocalisations produced by heterospecifics [10]. Together these examples indicate that nonlinear phenomena

evoke distress in both intra- and inter-specific interactions and suggest that their perceptual effects are shared across species.

Here, to investigate the acoustic and perceptual bases of this apparent universality, we conducted a psychoacoustic experiment testing the effect of the presence of specific types of nonlinear phenomena in the vocalisations of several mammalian species on perceived alarm in human listeners.

2. MATERIAL & METHODS

We created fully synthetic copies of 36 natural mammalian calls, from 6 different terrestrial species, with or without nonlinear phenomena, using parametric sound synthesis. This method, performed with R package *Soundgen*, allowed us to experimentally compare the perceptual effects of different types of nonlinear phenomena while also controlling for possible acoustic confounds (e.g., fundamental frequency and duration [1]). Because nonlinear phenomena often occur in relatively long distress vocalisations [1], we also aimed to verify whether nonlinear phenomena would have the same effect regardless of call duration (initial duration, increased by 25% and by 50%). Thus, for each initial recording, we created 15 synthetic stimuli, leading to a total of 540 stimuli tested in the psychoacoustic experiment. Human listeners were recruited online and asked to rate the level of alarm conveyed by each acoustic stimulus, using a continuous scale ranging from 0 (*Not alarming at all*) to 100 (*Extremely alarming*).

3. RESULTS

The results of a Bayesian linear multilevel beta-regression show that nonlinear phenomena affected human perception of alarm. Experimentally adding any type of nonlinear phenomena (except subharmonics; median and 95% credible interval +0.5% [-1.9,2.8]) increased perceived alarm relative to the same vocalisations without nonlinear phenomena (Figure 1). Specifically, the presence of frequency jumps and sidebands increased alarm perception by 2.5% [0.0,4.9] and 3.1% [0.7,5.4], respectively. The largest effect was caused by chaos (8.1% [6,10]).

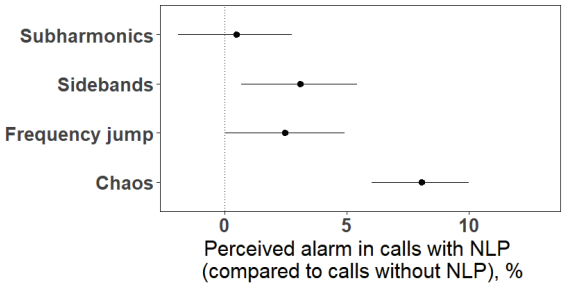

Figure 1. Effect of nonlinear phenomena (NLP) on human perception of alarm. Results of the psychoacoustic experiment. Solid markers correspond to medians of posterior distribution with their 95% credible intervals. The plot shows the effect of nonlinear phenomena on alarm ratings of mammalian calls compared to the same vocalisations without nonlinear phenomena. Note that chaotic calls sound more alarming than calls with other nonlinear phenomena (8.1% [6, 10]).

4. CONCLUSION

In sum, our study shows that the presence of nonlinear phenomena, and especially chaos, in mammalian calls increases perceived alarm in a context of intra- and inter-specific vocal interactions. Playback experiments should now be conducted using similar stimuli to test the independent effects of each nonlinear phenomena type on non-human mammalian receivers.

5. REFERENCES

[1] T. Aubin and N. Mathevon: "Coding Strategies in Vertebrate Acoustic Communication. Vol. 7. Animal Signals and Communication", *Springer International Publishing*, 2020.

[2] WT. Fitch, J. Neubauer and H. Herzel: "Calls out of chaos: the adaptive significance of nonlinear phenomena in mammalian vocal production," *Animal Behaviour*, vol. 63, Issue 3, pp. 407-418, 2002.

[3] A. Anikin, K. Pisanski, M. Massenet, D. Reby: "Harsh Is Large: Nonlinear Vocal Phenomena Lower Voice Pitch and Exaggerate Body Size," *Proceedings of the Royal Society B: Biological Sciences,* vol.288, no. 1954, 2021.

[4] SW. Townsend, MB. Manser: "The function of nonlinear phenomena in meerkat alarm calls," *Biology Letters*, vol. 7, no. 1, pp.47-49, 2011.

[5] S. W. Townsend et M. B. Manser, "The function of nonlinear phenomena in meerkat alarm calls", *Biol. Lett.*, vol. 7, no. 1, pp. 47-49, 2011.

[6] A. Anikin, K. Pisanski, D. Reby: "Do nonlinear vocal phenomena signal negative valence or high emotion intensity?" *Royal Society open science*

[7] M. Massenet, A. Anikin, K. Pisanski, K. Reynaud, N. Mathevon and D. Reby: "Nonlinear vocal phenomena affect human perceptions of distress, size and dominance in puppy whines," *Proceedings of the royal society B: Biological Sciences,* vol. 289, no. 1973, 2022.

[8] D. Karp, M. B. Manser, E. M. Wiley, et S. W. Townsend, « Nonlinearities in Meerkat Alarm Calls Prevent Receivers from Habituating », *Ethology*, vol. 120, nº 2, p. 189-196, 2014

[9] P. Belin, S. Fecteau, I. Charest, N. Nicastro, M. D. Hauser, et J. L. Armony, « Human cerebral response to animal affective vocalizations », *Proc. R. Soc. B.*, vol. 275, nº 1634, p. 473-481, 2008

[10] A.-L. Maigrot, E. Hillmann, et E. F. Briefer, « Cross-species discrimination of vocal expression of emotional valence by Equidae and Suidae », *BMC Biol*, vol. 20, nº 1, p. 106, 2022

6. ACKNOWLEDGMENTS

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