THETA RHYTHM IS WIDESPREAD IN VOCAL PRODUCTION ACROSS THE ANIMAL REALM.

THÉOPHANE PIETTE[*1], CHUNDRA CATHCART[2], CHIARA BABRIERI[3], DIDIER GRANDJEAN[4], ÉLOÏSE DÉAUX[1], ANNE-LISE GIRAUD[1]

[*]Corresponding Author: theophane.piette@unige.ch

[1]Department of Basic Neuroscience, University of Geneva, Geneva, Switzerland

[2]Center for the Interdisciplinary Study of Language Evolution, University of Zurich, Zurich, Switzerland

[3] Department of Evolutionary Biology and Environmental Studies, University of Zurich, Zurich, Switzerland

[4]Swiss Center for Affective Sciences, University of Geneva, Geneva, Switzerland

1. Introduction

Speech production rate, conserved between 2 to 8 syllables per second, plays a key role in comprehension. Recent studies that highlighted the presence of the same rhythm in vocal productions and mouth movements of non-human primates, suggest that it may be inherited from mastication (Risueno-Segovia et al, 2020). However, other factors could constrain vocal rhythm. Notably, syllabic rate also matches the frequency of theta brain oscillations (2 -7 Hz). While oscillations are rhythmic electrical activity spontaneously generated by neural tissues, they can also be stimulus-driven and research has demonstrated that theta oscillations entrain to speech during listening (Giraud et al, 2014). As brain oscillations frequencies are conserved in animals, syllabic rate may instead be constrained by the recipient's neuronal activity (Buzaski et al, 2013). To determine what factor(s) may have contributed to the emergence of the theta vocal rhythm, we collected vocalizations for 90 species of animals. We used phylogenetic regression to assess whether weight, mastication or environmental constraints explain the variation in animal vocal rhythms while controlling for phylogenetic relationships.

2. Methods

2.1 Vocal, physical and environmental data

We gathered, when they were available, recordings for one species per infra-order of tetrapods as well as some fishes and insects (N=92, mammal = 24, bird = 58, amphibian = 4, reptile =1, insect = 4 and fish= 1). To obtain vocal production

rhythm, we then extracted sequences, consisting of one subject vocalizing for at least 2s, with less than 1s of silence between two sounds. For each sequence, the envelope, was computed, and analyzed using a wavelet transform to extract the peak rhythmic changes of amplitude (Tilsen et al 2014). Bodyweight data were collected (N=92), habitat type was defined as either closed, semi-closed, open, wetland or water, and mastication status as yes or no. We obtained data on the context of production, but these were only available for 35% of the recordings. Therefore, we assumed that such effect would relate to flexible rhythm adjustment within an already physically constrained rhythmic range (Martin et al, 2022).

2.2 Statistical analyses

Given the extent of the current dataset, we are still in the process of building the corresponding phylogenetic tree. Thus using log-transformed weight, mastication, environments, and their interactions as fixed effects, and random slopes of log weight by groups and random intervals for orders, we built a linear mixed model investigating the variation of the median log-transformed rhythm frequency.

3. Results

We can observe in our preliminary results that most of our species (74.4%) have a median frequency located between 2Hz to 7Hz. When testing our linear mixed model, we noticed that our random effects did not explain the variance of rhythm in our species. We also found that none of our predictors significantly influenced vocal rhythm (Most impacting factor: Environment, F=1.0570, p.value=0.3748).

4. Conclusion

Theta production rhythm seems widespread across animal vocal productions, independently of their physical characteristics, mastication status or environment. As it is present in most species, even the ones that do not masticate, it appears unlikely that this rhythm is constrained by a limit of the natural movement of the articulators. Furthermore, the lack of effect of weight and environmental constraints tends to point towards a more common and endogenous constraint for vocalization rhythm. As brain oscillations and neurons characteristics, in general, are well conserved across species, it could be that the rhythm of the vocalizations has adapted to them as a form of 'neuronal exploitation', to ensure the efficient reception by the listener. As the range of oscillations in animals' brains is not documented for most species, further work on phylogeny and the direct link between vocalizations and brain oscillations in animals will be needed to strengthen this hypothesis or lead the way for alternative explanations.

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