

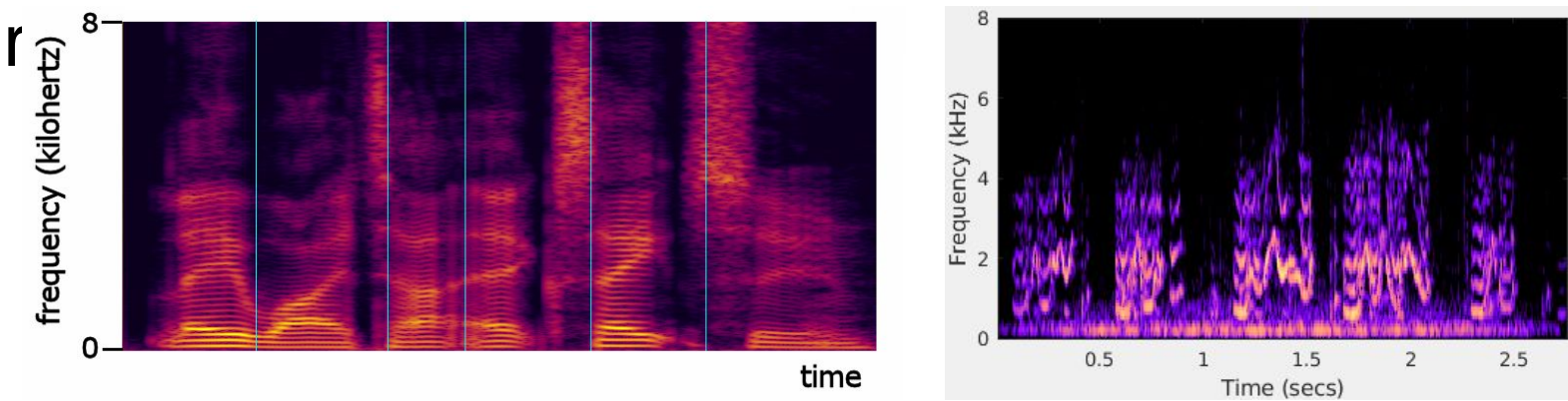
Testing a Feature-Based Model for the Categorization of Complex Sounds

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Background

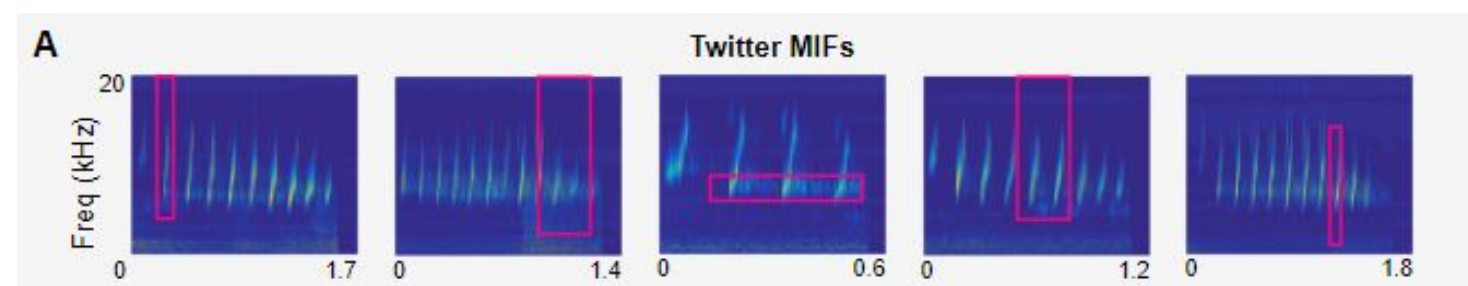
Like many other vocal animals, guinea pigs use complex vocalizations, or calls, to communicate behaviorally relevant information. Call types can be difficult to distinguish when using simple acoustic properties, such as average frequency, loudness, or call length, as there is significant variation in these features within a given call type. At the other extreme, using template calls to classify call categories is also not possible because of high within-category variation. However, animals are clearly capable of distinguishing call categories. One hypothesis is that they do so by using more complex, intermediate, spectro-temporal features.



Spectrograms of human speech (left) and guinea pig vocalizations (right)

Most Informative Features

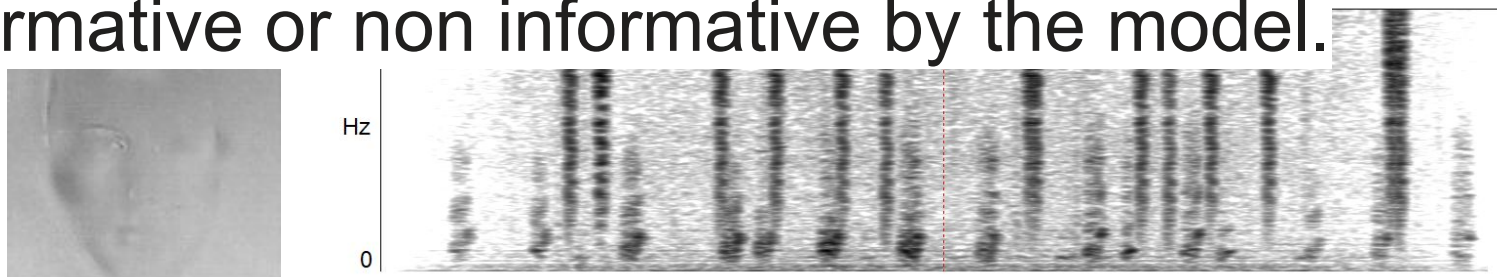
In our lab, we previously developed a computational model that uses information-theoretic analysis to determine which spectro-temporal features are most informative for the classification of call types¹. These features can be used as a template to identify whether or not a given vocalization is an instance of a particular call type. Though a feature could be anything from the presence of a certain frequency to an entire call, the model predicts that features of intermediate length and complexity tend to be most informative, or best at identifying call type. From this model, we can generate predictions about classification errors when particular features are obscured.



Examples of features in marmoset twitter calls¹

Goal

The goal of my project is to test the feature-based model at a behavioral level. To do so, we will test animal categorization behavior on vocalizations that have been edited to be partially obscured by noise. We will use a paradigm adapted from similar experiments on face recognition in visual research ('bubbles')². For calls, noise 'bubbles' stimuli will be constructed that obstruct features that are predicted to be highly informative or non informative by the model.



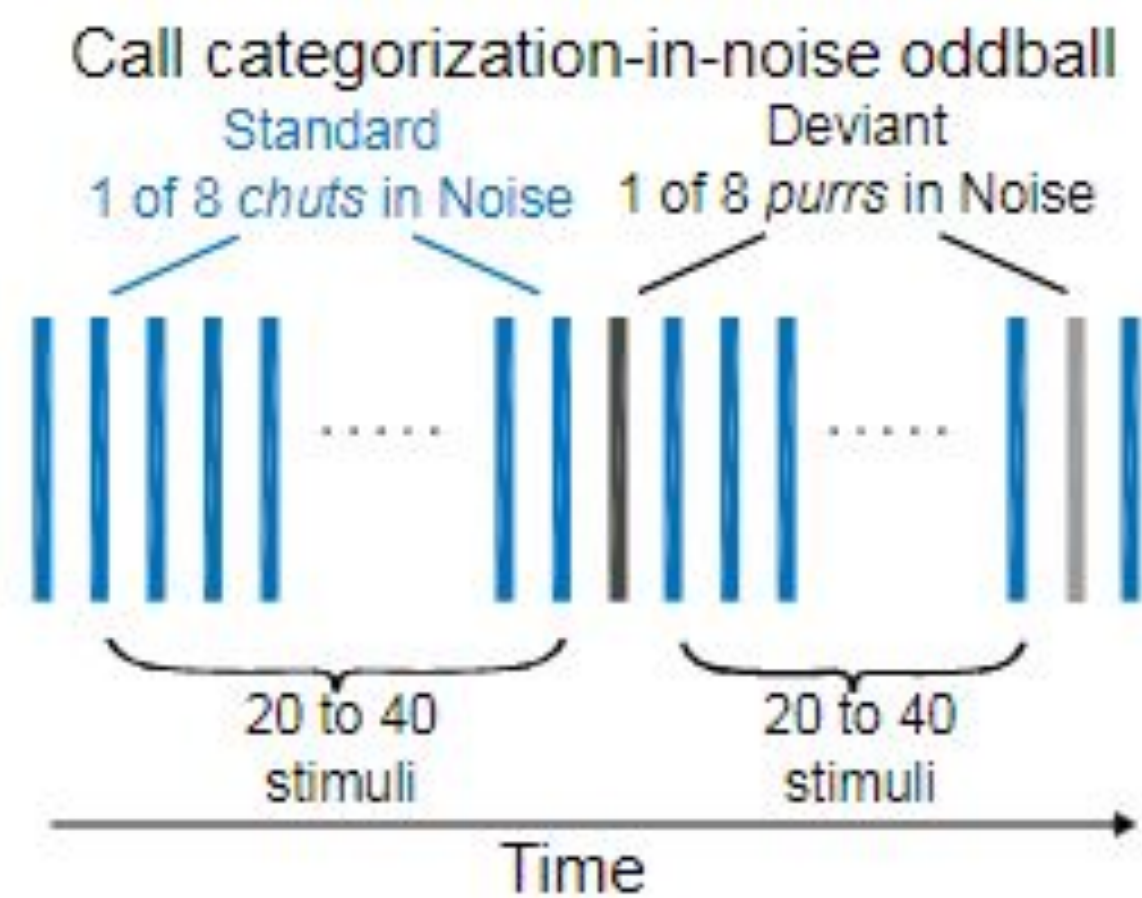
A partially obscured face² (left) and a partially obscured guinea pig call (right)

Pupillometry

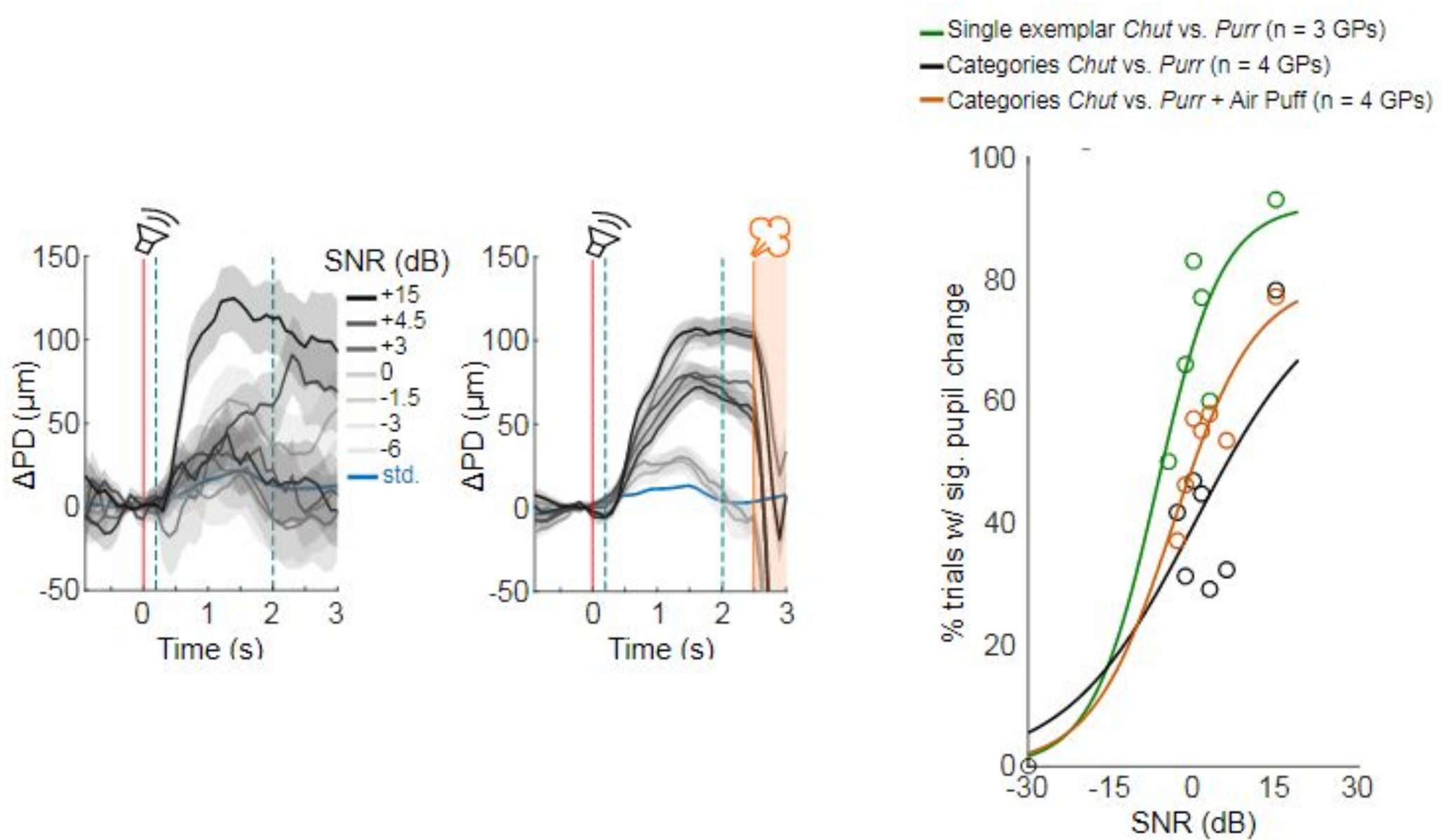
To determine a baseline for call categorization in broadband noise, a pupillometry experiment was conducted.

Methods

Head-fixed animals were exposed to auditory stimuli in a soundproof room. At regular intervals, a vocalization would be played. The majority of the time, instances of one call type (the "standard") were played, and the minority of the time, instances of a second call type (the "deviant") were played. In initial experiments, we obscured all features uniformly using white noise to determine the overall threshold for call categorization in noise. This task was repeated at various signal to noise ratios, and with and without the "deviant" calls being paired with an air puff. Pupil size was monitored throughout.



Results



Trace of pupil diameter after exposure to a deviant call, with (left) and without (center) airpuff; psychometric curve of percentages of trials with pupil change relative to SNR (right)

Conclusions

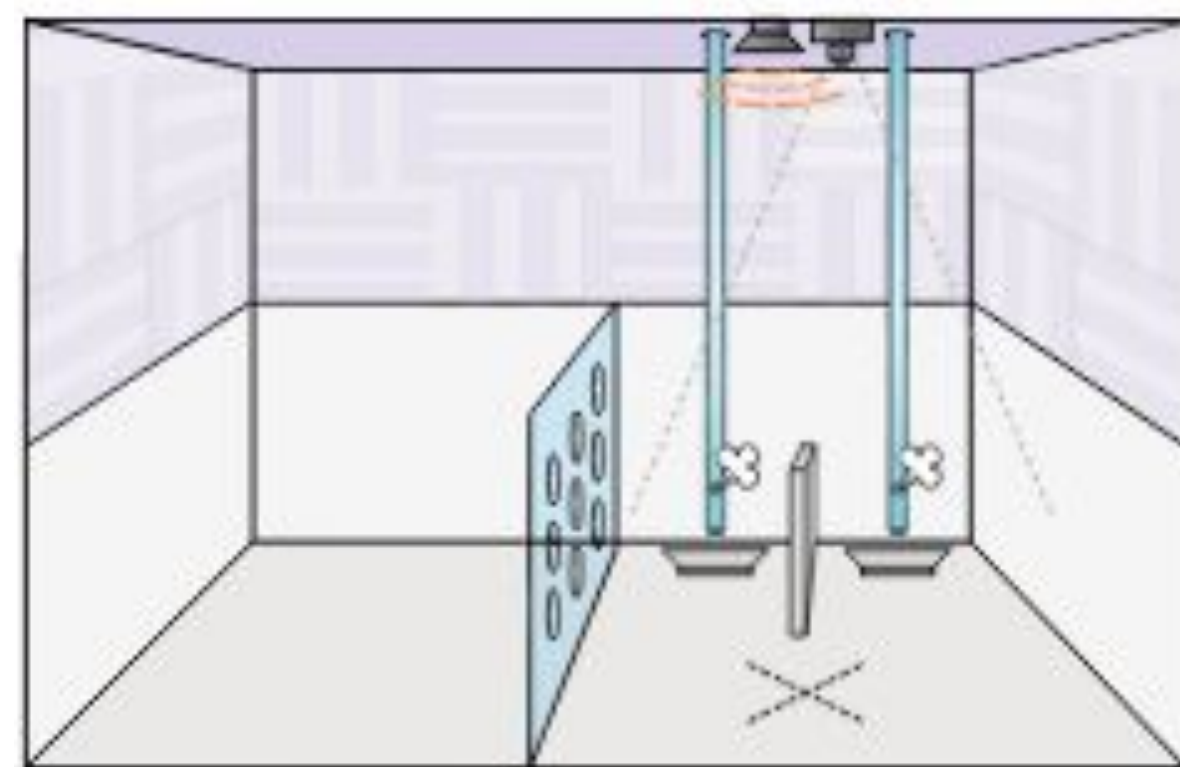
These data suggest that guinea pigs are able to generalize over within-category variability and distinguish between call categories, and that call categorization performance degrades with increasing noise level. However, these data do not clarify which acoustic features are most informative for call categorization. A possible future direction is to use intact calls as "standards" and manipulated calls as "deviants", with the prediction that obscuring more informative features would lead to larger pupil dilation.

Operant Conditioning

While pupillometry is useful in obtaining quick estimates of behavioral abilities from untrained animals, the passive nature of the task and the constraints of the oddball paradigm make it less useful for partially obscured feature testing. The results of the air puff condition suggest that attention and motivation can increase an animal's ability to categorize calls in noise. Therefore, a motivated operant conditioning task is appropriate.

Methods

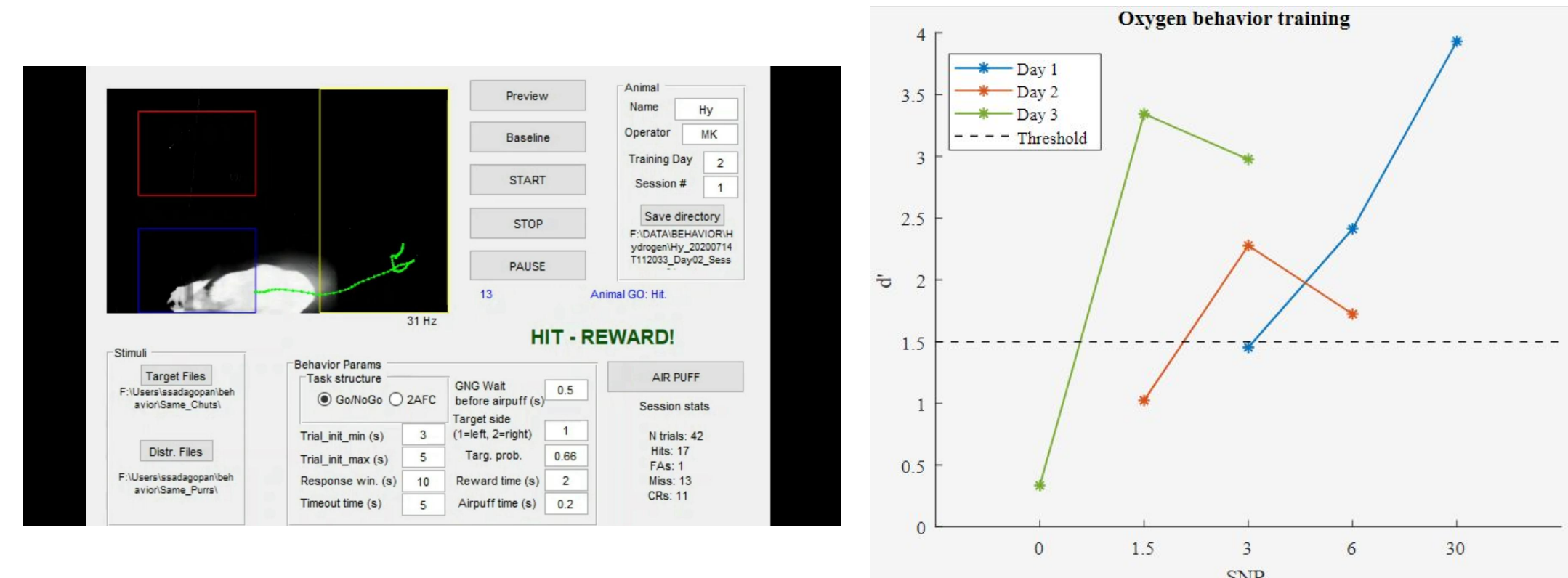
Animals were placed in an enclosure with three distinct regions: the two corners, where both rewards (food) and punishments (airpuff) were administered, and the home base area, where the animal waits for an auditory stimulus to be played. In a "go/no go" task, the animals were trained to approach one corner for a food reward when instances of one call type (the "target") were played and to remain in home base when instances of a second call type (the "distractor") were played. False positives were punished with an air puff, while correct rejections and misses were neither rewarded nor punished.



A diagram of the operant conditioning setup

Preliminary Results

The operant conditioning experiment is still ongoing, but the initial training on clean calls has been successful, and early data are consistent with the results of the pupillometry experiments.



A still of an animal in training phase (left); the sensitivity of an animal tested at several SNRs over three days (right)

Future Directions

The operant conditioning experiment is ongoing, and we hope to test the trained guinea pigs on the partially obscured vocalizations.

Once the operant conditioning experiment is complete, it will be possible to generate "information maps" identifying behaviorally relevant spectro-temporal regions of various calls.

Our future goal is to use these data in neurophysiological experiments to determine if neural response properties correlate with behavior.

Acknowledgements

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The figures from the pupillometry experiments, as well as the diagram of the operant conditioning Y-maze, were created by Pilar Montes-Lourido.

The sensitivity in noise figure was created by Marianny Pernia Rosales and Mannu Kar.

References

- Liu, S.T., Montes-Lourido, P., Wang, X. *et al.* Optimal features for auditory categorization. *Nat Commun* 10, 1302 (2019).
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