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From sounds to meaning: Neural representation of calls in the avian auditory cortex

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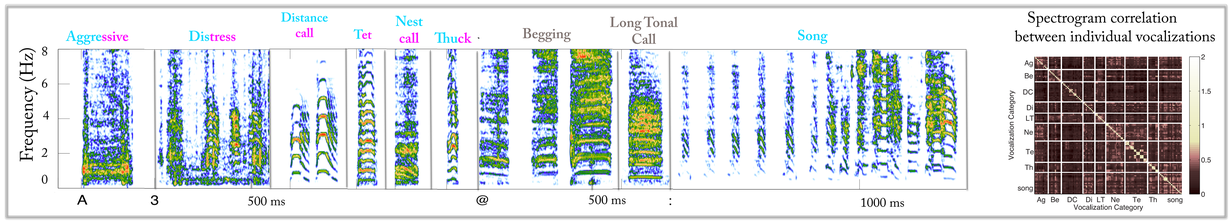
Introduction

Understanding how the brain extracts meaning from communication sounds is a central question in auditory research. Communication sounds distinguish themselves not only by their acoustical properties but also by the information content of the message. To study how the auditory system could differentially treat signals that have different social meanings, we investigated in the zebra finch (*Taeniopygia guttata*) the perception of vocalizations that are used in clearly distinct social contexts. We first recorded all the social calls of zebra finches. We then investigated the neural representation of these calls in higher auditory areas. We analyzed the neural responses both in terms of spike rates and spike patterns to investigate emerging semantic information beyond the coding of variations in the acoustic features of the calls.

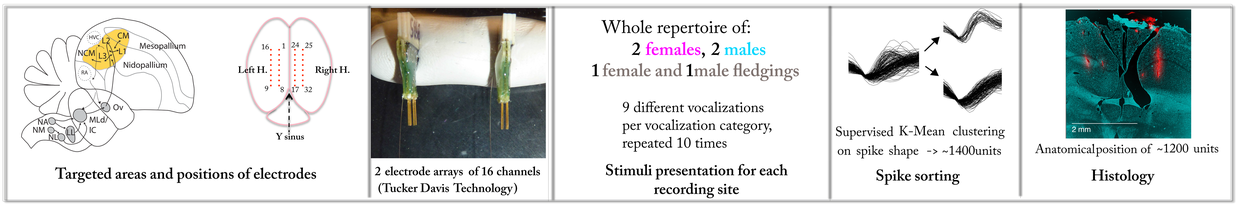
Methods

1. Vocalization library

Recordings of 4 groups of paired adults: 4 X (3 females + 3 males) and 20 fledgings from 5 families. Manual extraction and annotation of vocalizations.



2. Multi-unit recording in superior auditory areas



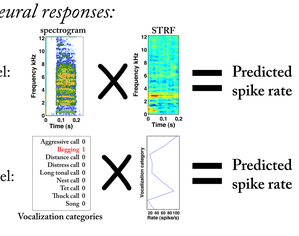
3. Finding semantic neurons using spike rates and PSTHs

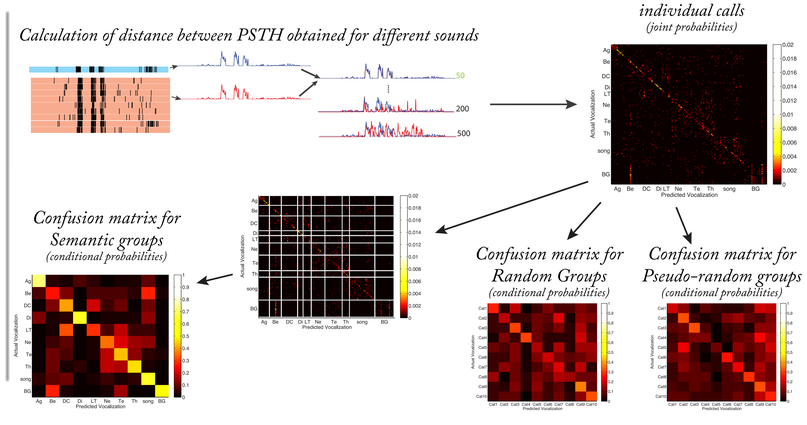
$$Dprime_{i,j} = 2 \times \frac{MeanRate(cat_i) - MeanRate(cat_j)}{\sqrt{(StdRate(cat_i)^2 + StdRate(cat_j)^2)}}$$

$$LRI_i = \log 2\left(\frac{MeanRate(cat_i)}{MeanRate(allOthers)}\right)$$

A unit is considered as selective if abs(LRI)>1

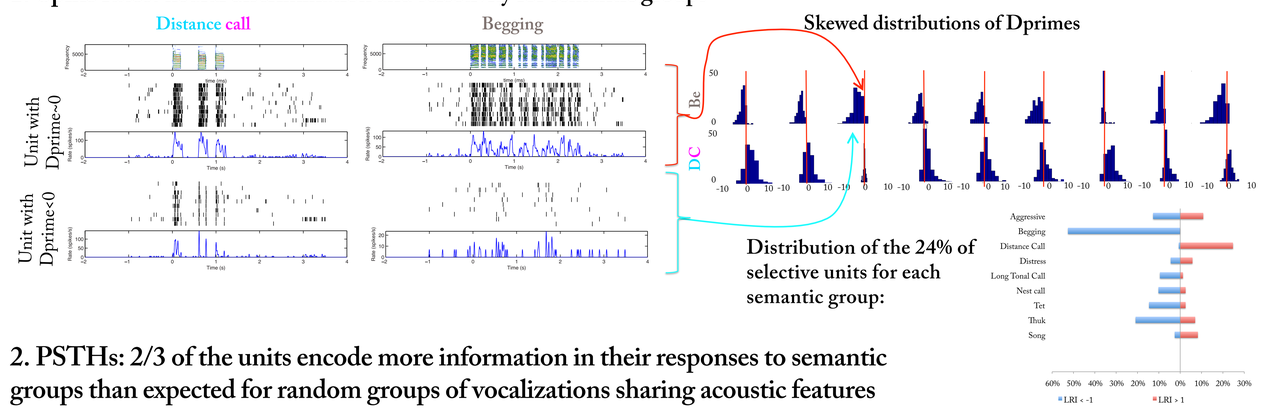
Models of neural responses:



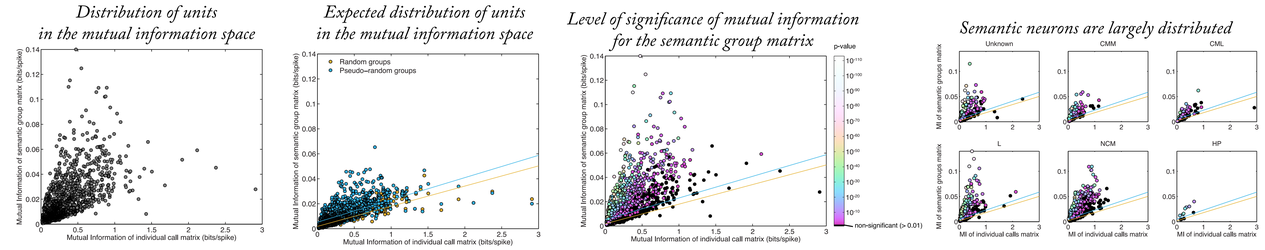


Main Results

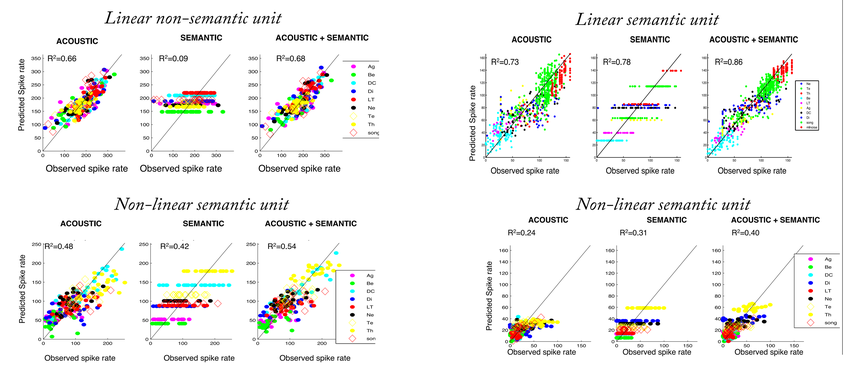
1. Spike rates: neural discrimination and selectivity for semantic groups



2. PSTHs: 2/3 of the units encode more information in their responses to semantic groups than expected for random groups of vocalizations sharing acoustic features



3. Generalized Linear Models: neural discrimination of semantic groups is due to both linear tuning for spectro-temporal features and non-linear tuning for semantic features



Conclusion

Zebra finches emit a full repertoire of social vocalizations that have different meanings. These semantic groups are mirrored in higher auditory areas by neurons with discriminative and selective responses.

On one hand, measures of information encoding on confusion matrices indicate that 2/3 of the neurons encode more information in their PSTHs than expected from the correlation between acoustic features. On the other hand, models of the neural activity show that tuning for spectro-temporal features can explain some of the semantic group coding and that non-linear tuning for semantic features can provide additional semantic group invariance.

The neural basis of social communication in the zebra finch is a promising model to study a complex cognitive process: how does the brain extract meaning from sounds?