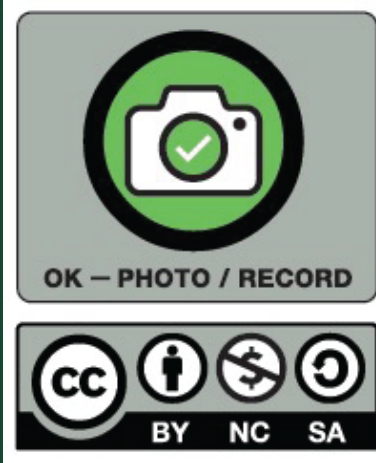


# Basal ganglia lesions induce stuttering in canaries.

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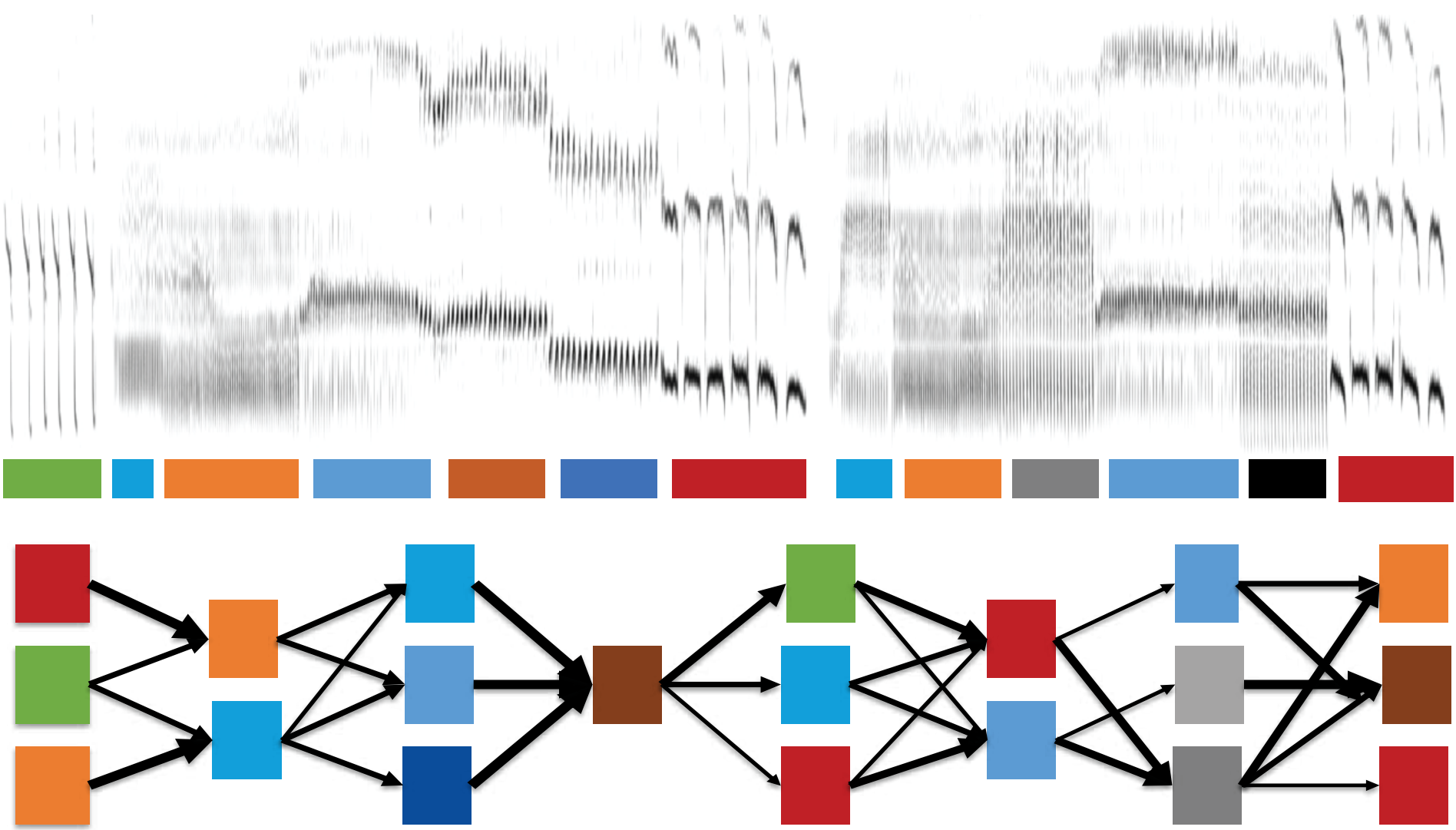


Poster #:



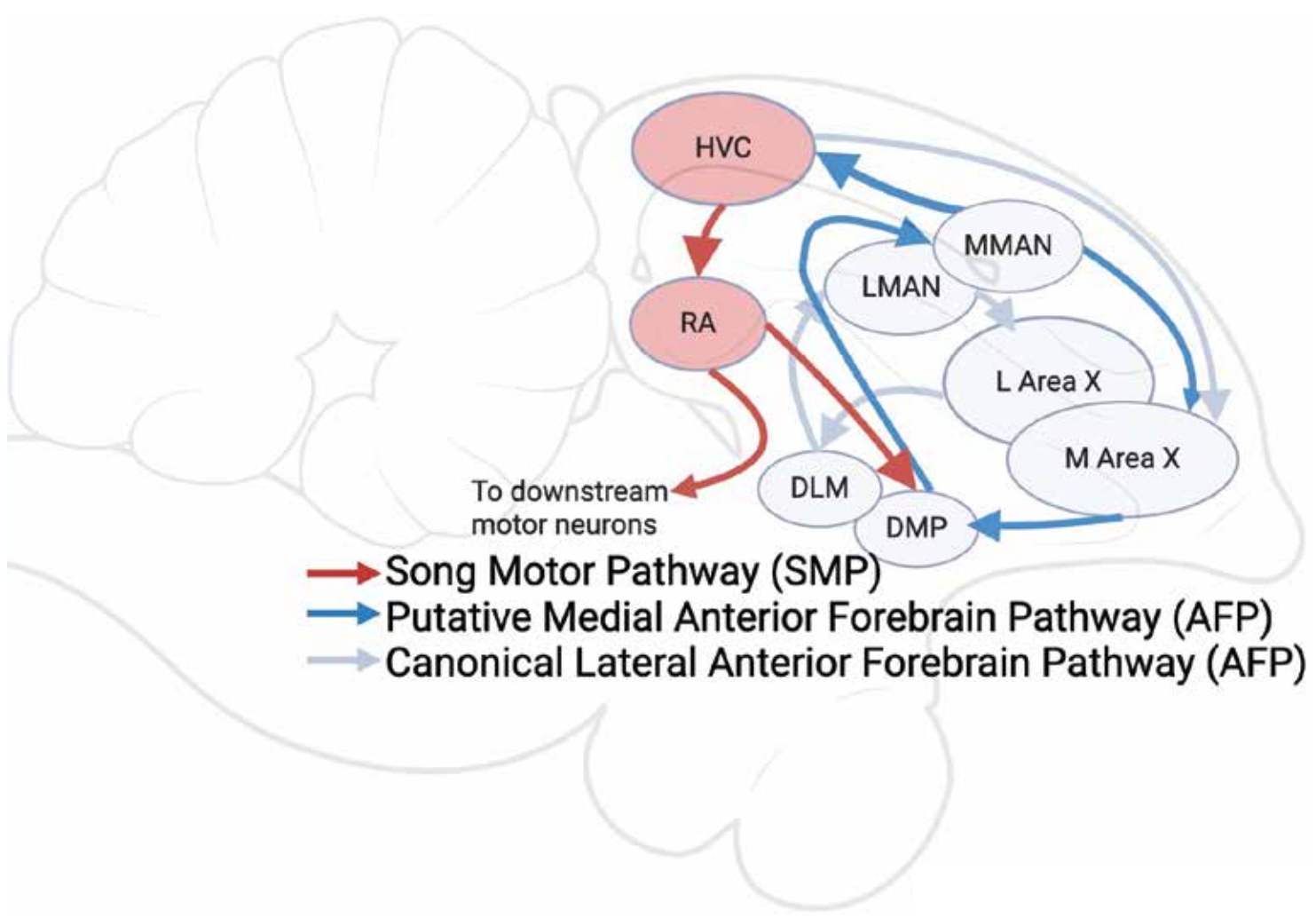
## Introduction

Canary song is a motor sequence with long-range syntax.



Canary song is made up of phrases of repeated syllables. Phase order shows long-range syntax: what is sung next can be impacted by what was sung 3-5 phrases prior<sup>1</sup>.

Songbird song motor control & acquisition pathways.



The Anterior Forebrain Pathway was thought to only impact juvenile song learning. However, findings in Bengalese finches suggest it may impact adult song in birds with complex song structure<sup>2,3</sup>.

Does the basal ganglia nucleus Area X contribute to adult canary song syntax?

## Methods

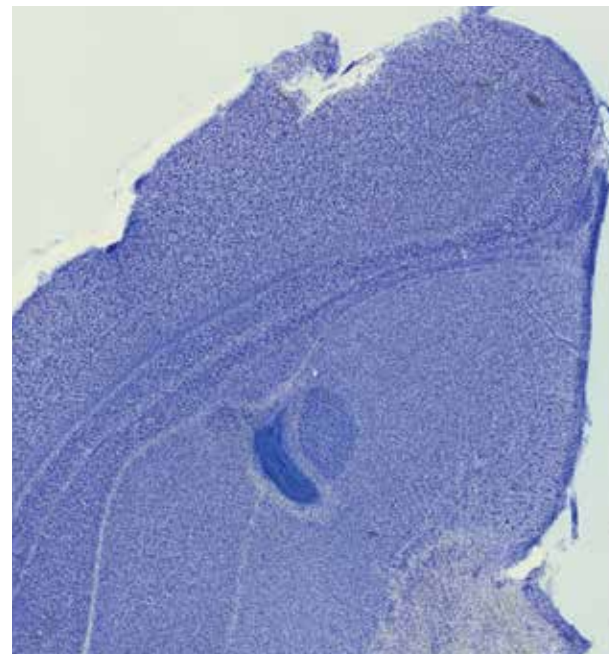
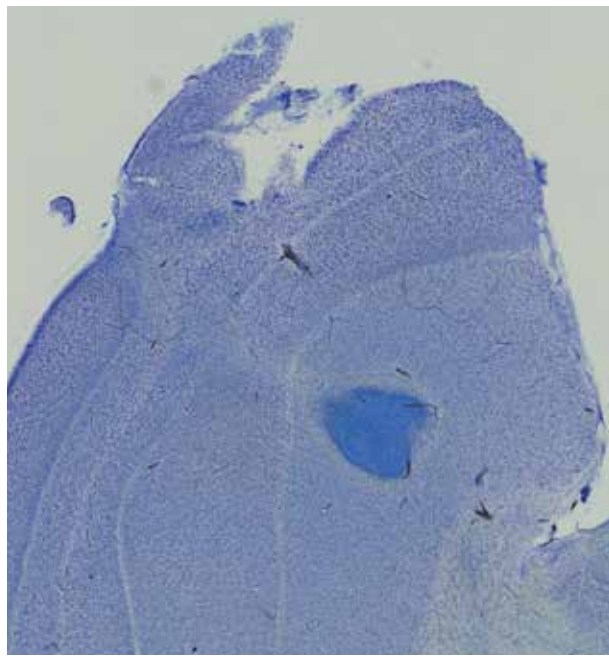
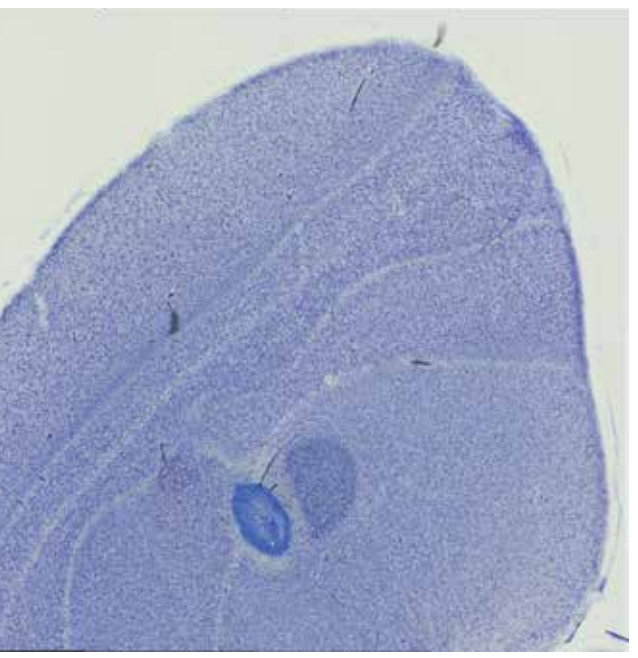
### Overview.

Adult male American Singer canaries received bilateral injections of 4% NMA targeting Area X. Location and size of lesion was assessed via NISSL staining. Songs were sorted and annotated using TweetyBERT. Annotations were used to assess changes to phrase duration and song syntax.

### Bilateral excitotoxic basal ganglia lesions.

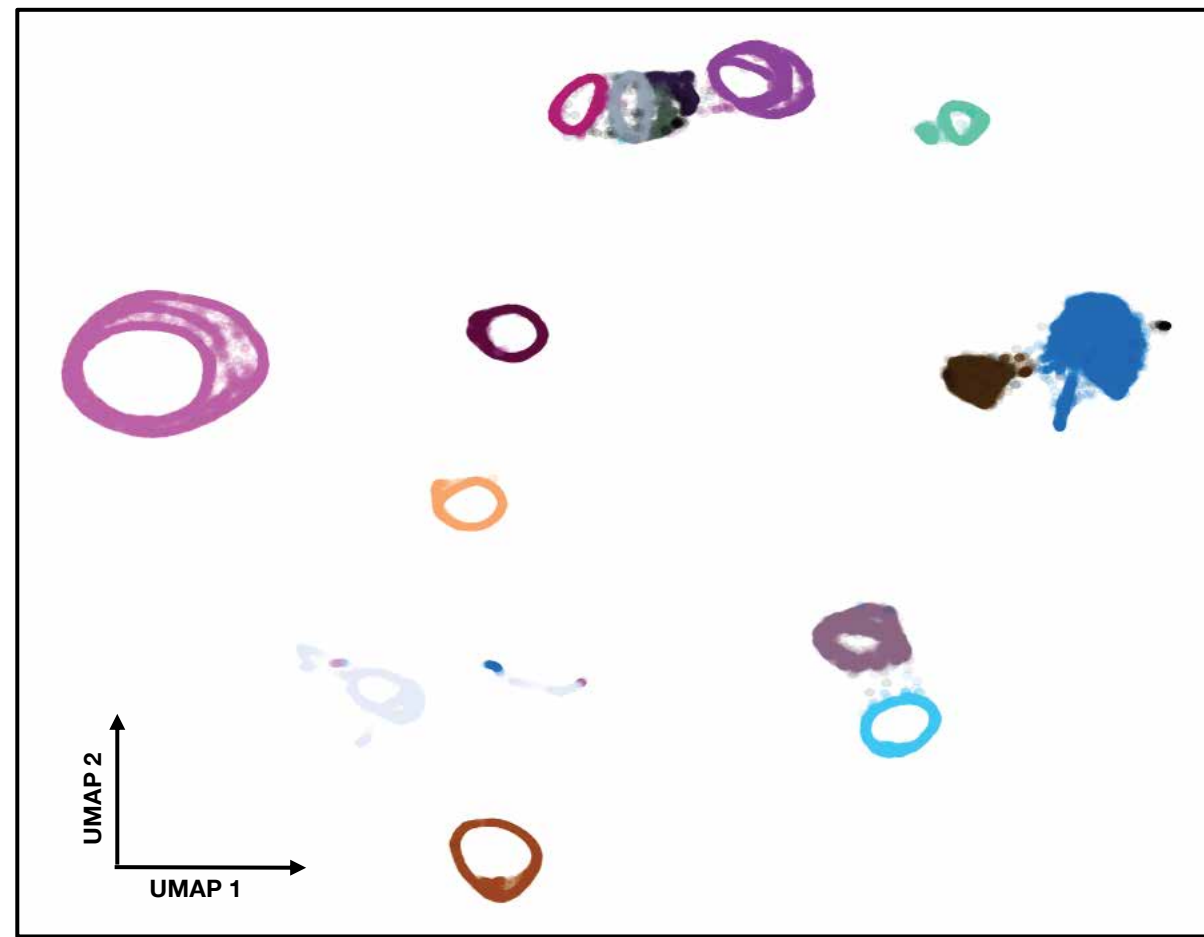
No stutter - Small portion of Area X lesioned, LMAN partially lesioned.

Stutter observed - Greater volume of Area X lesioned, partial LMAN lesion in some cases.

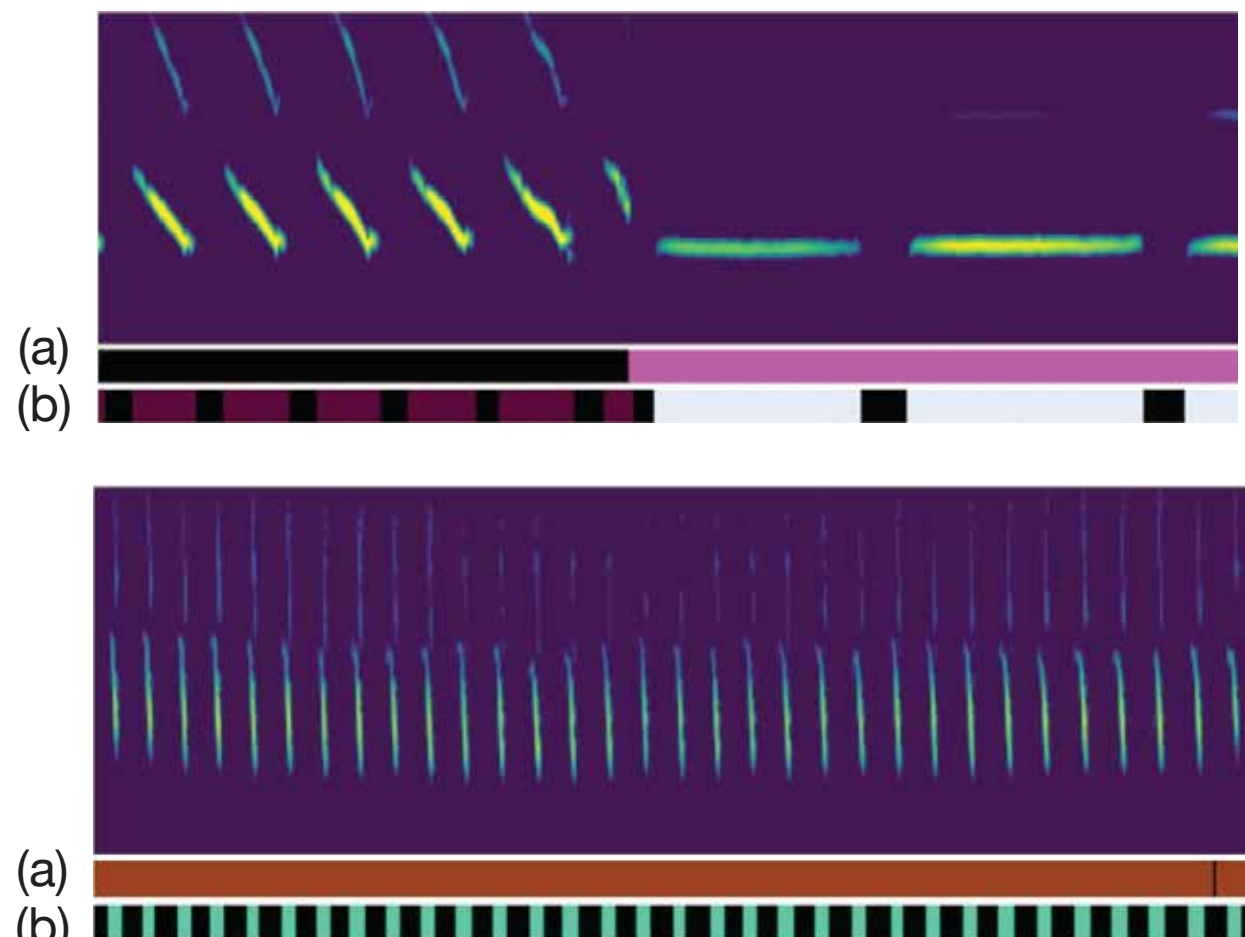


### TweetyBERT automated song annotation.

Canary song embedding colored by HDBSCAN cluster.



Spectrogram of canary song; HDBSCAN phrase labels (a) and ground truth syllable labels (b).

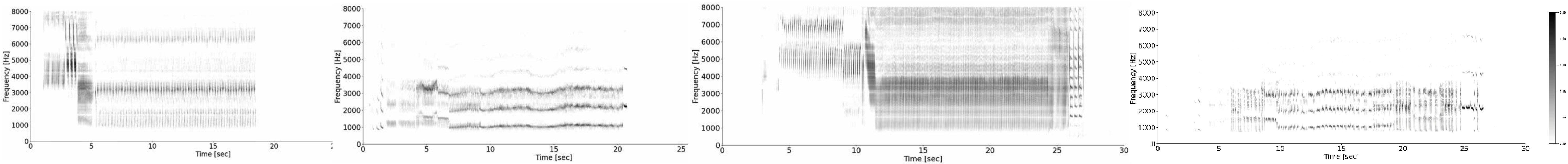


TweetyBERT Github repository

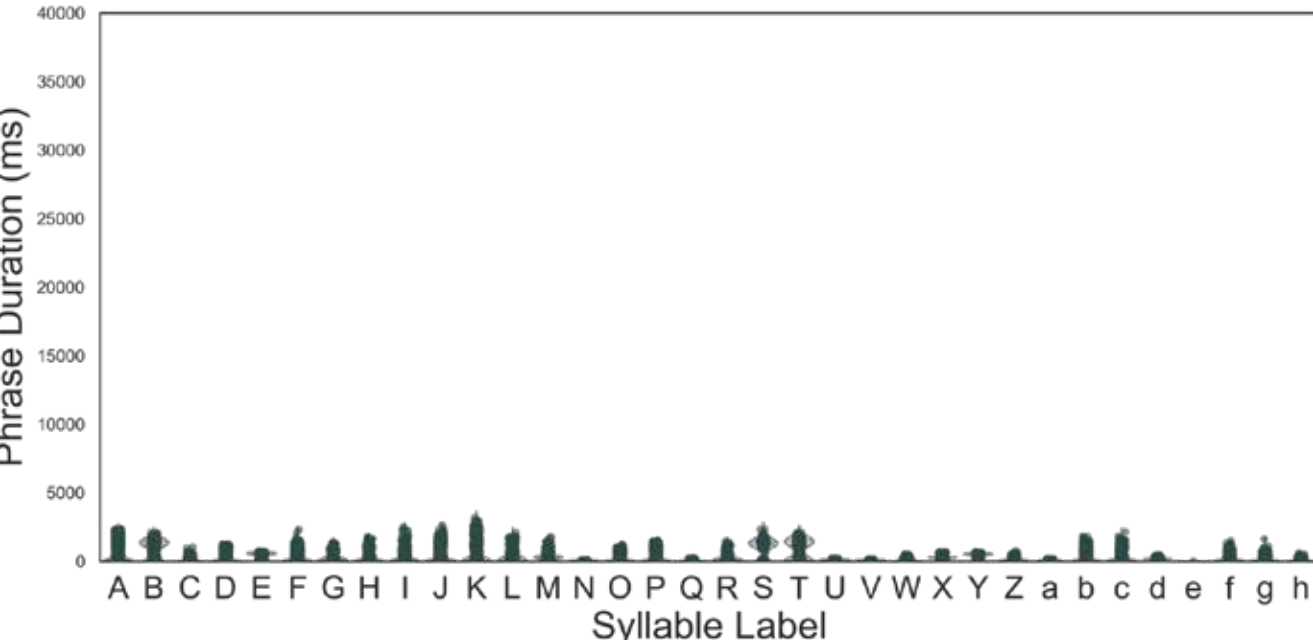


## Results

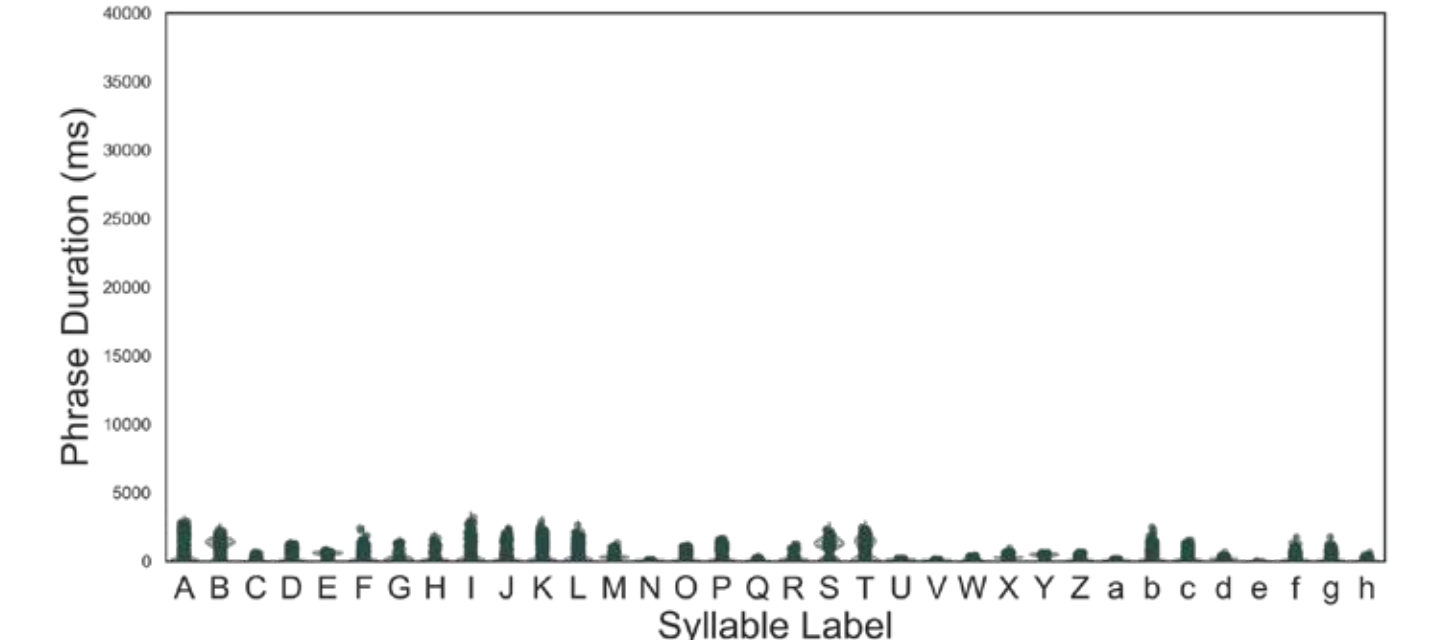
Impacts to phrase duration. Spectrograms of sample songs with stuttering.



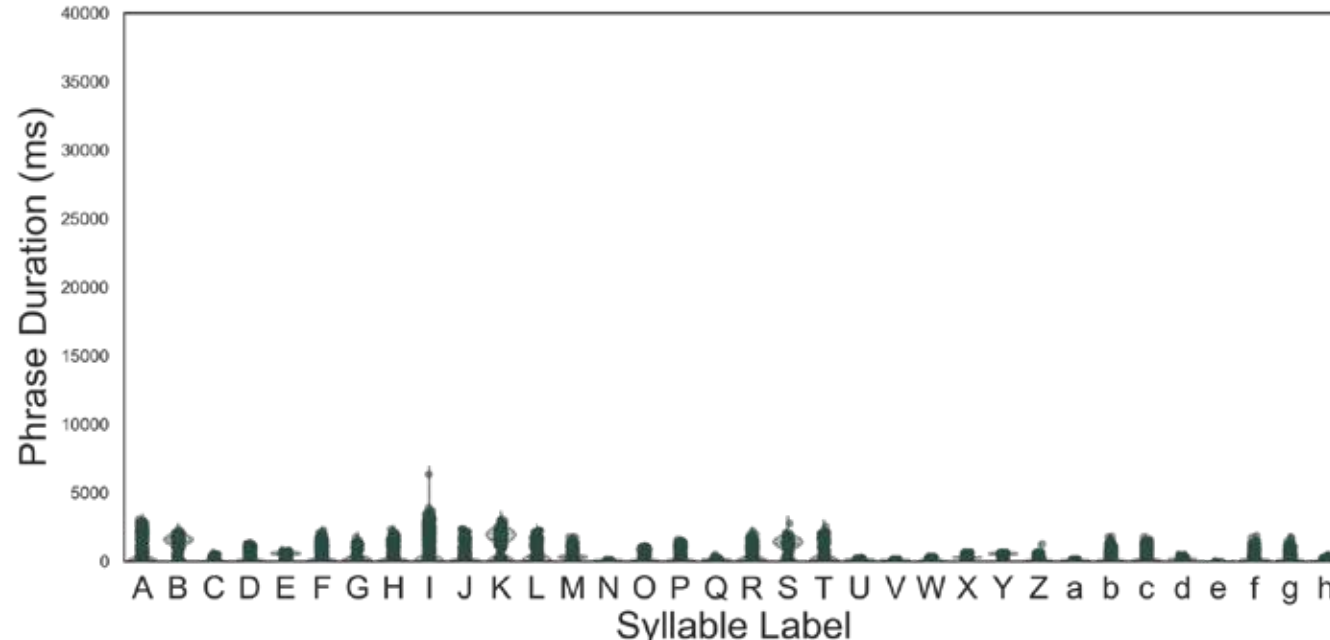
First half of pre-lesion songs



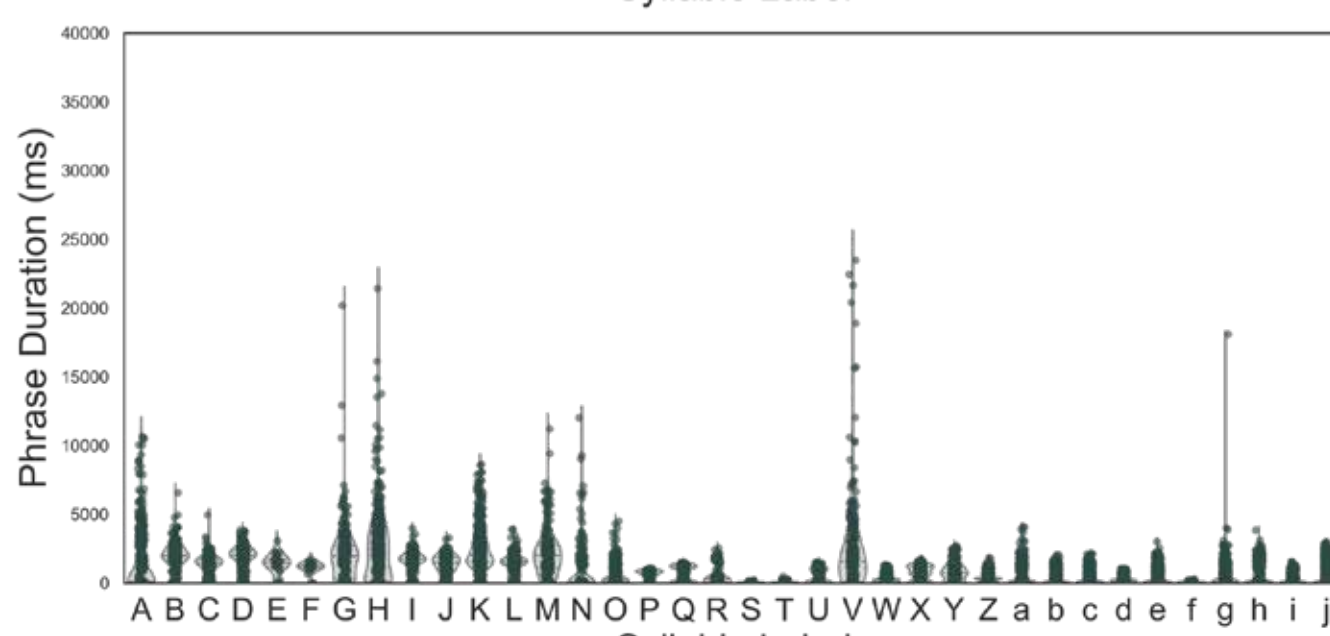
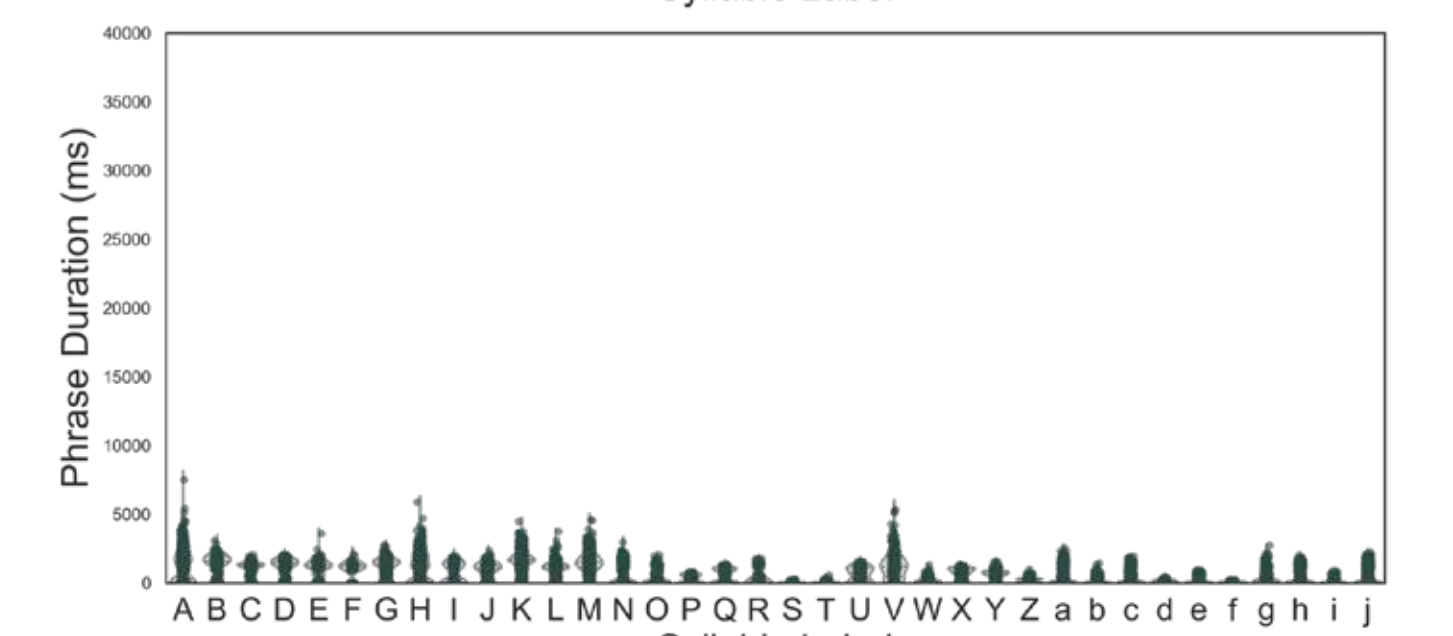
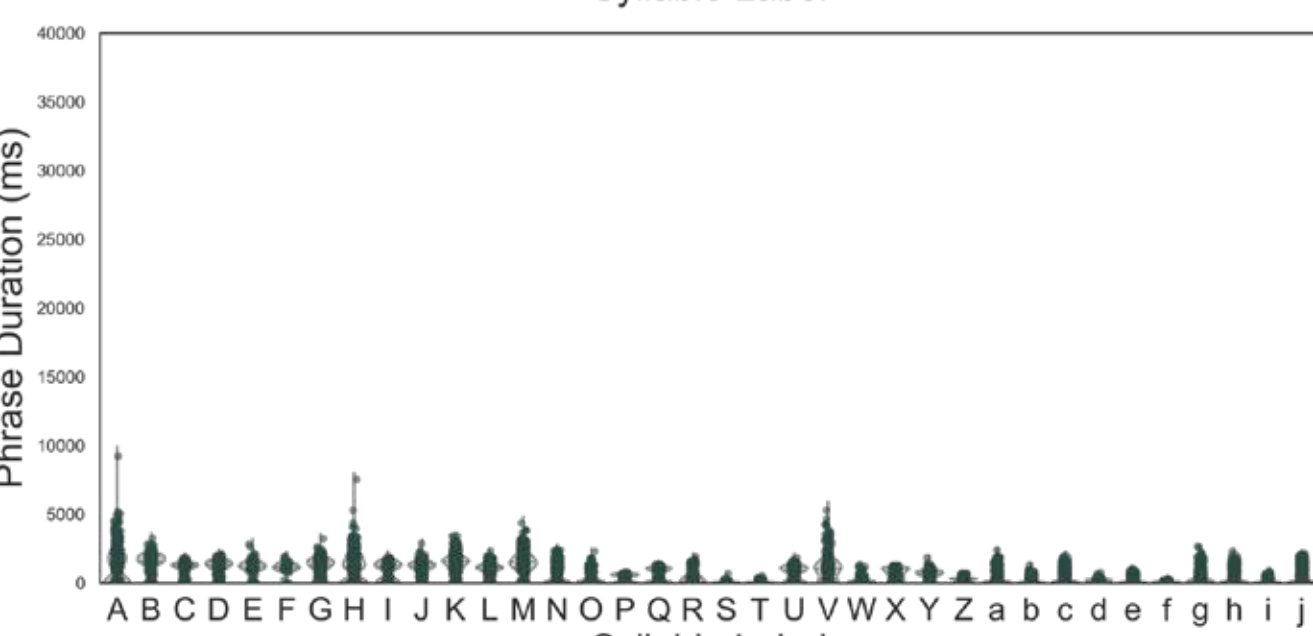
Second half of pre-lesion songs



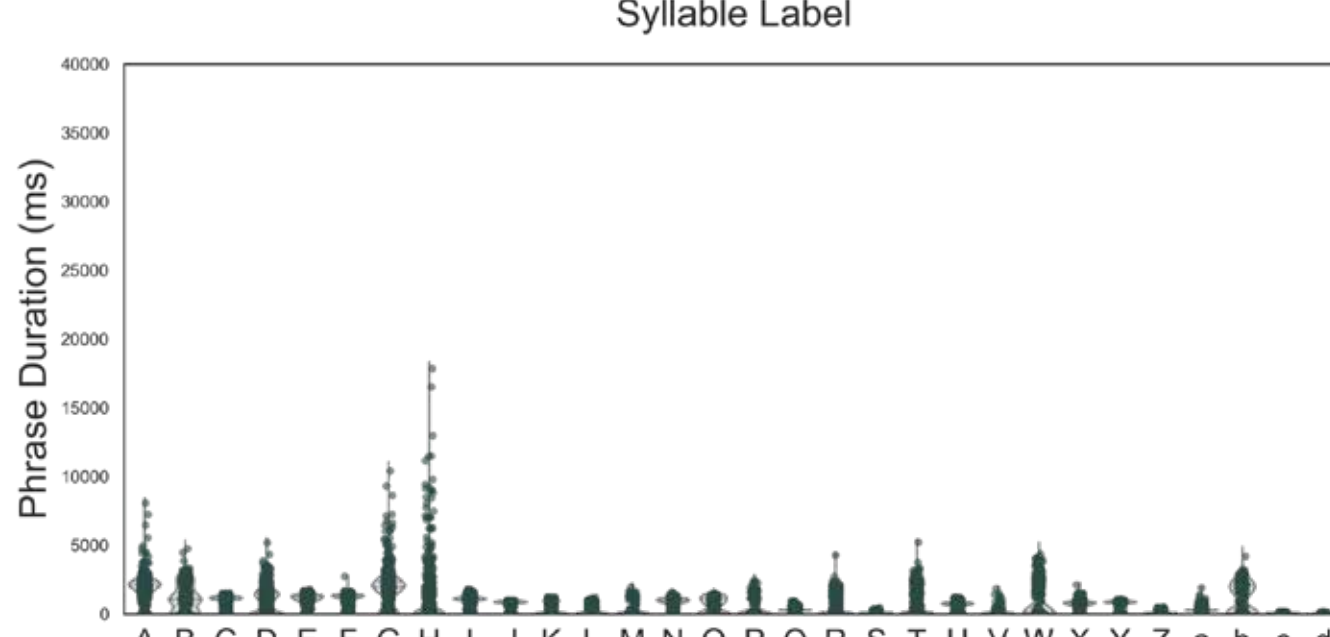
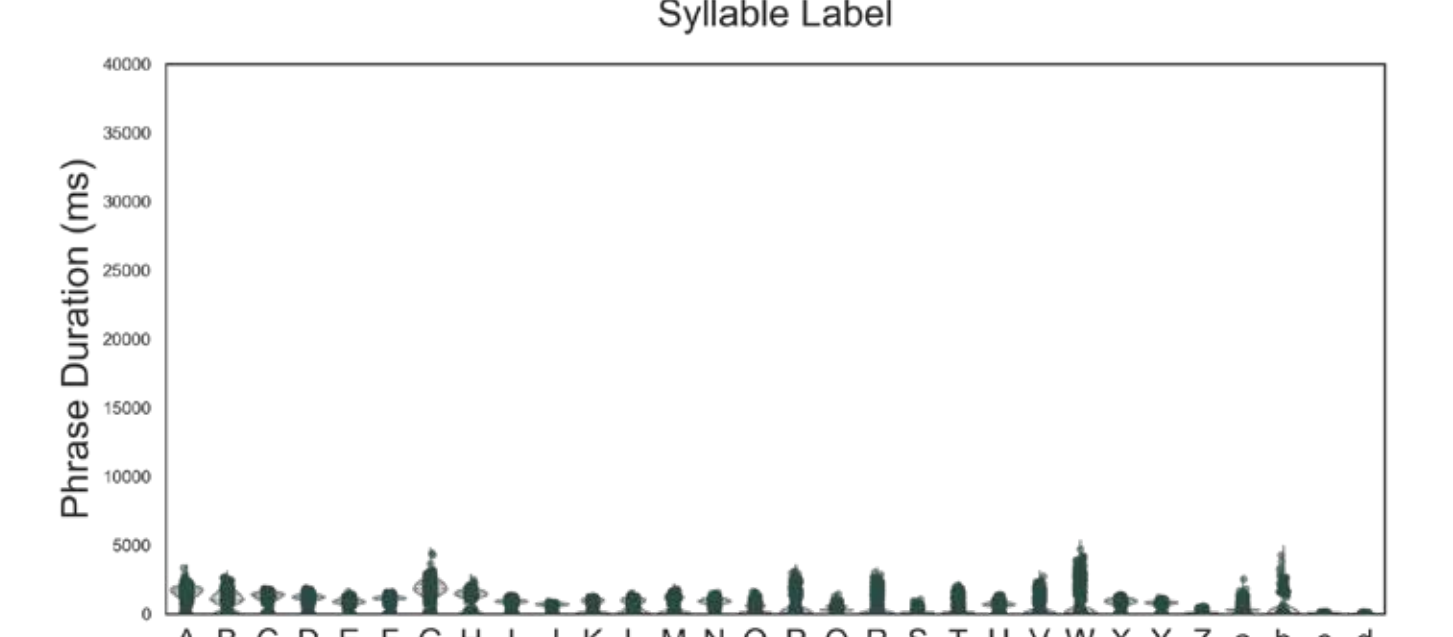
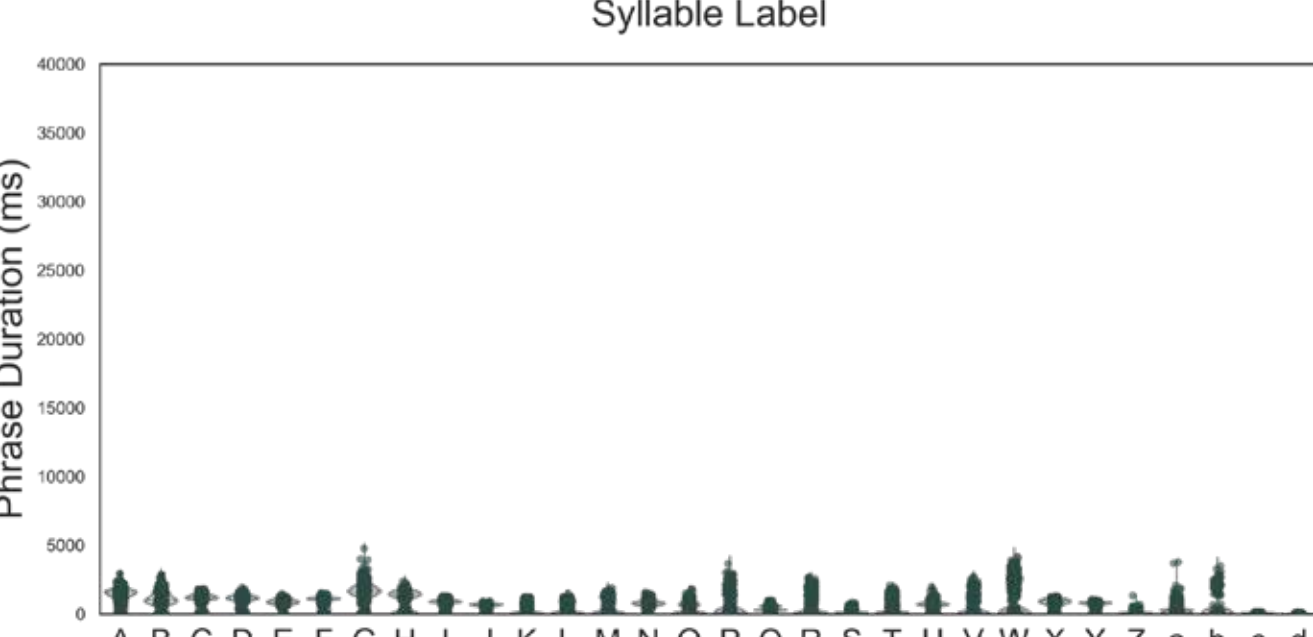
Post-lesion songs



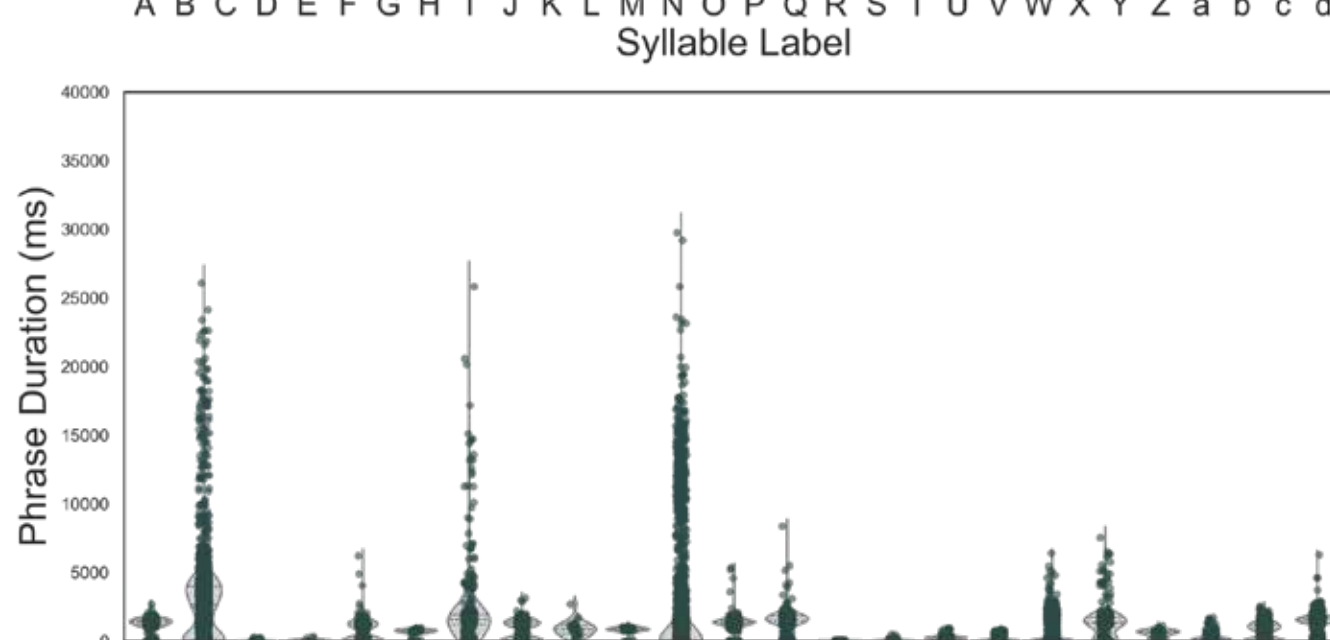
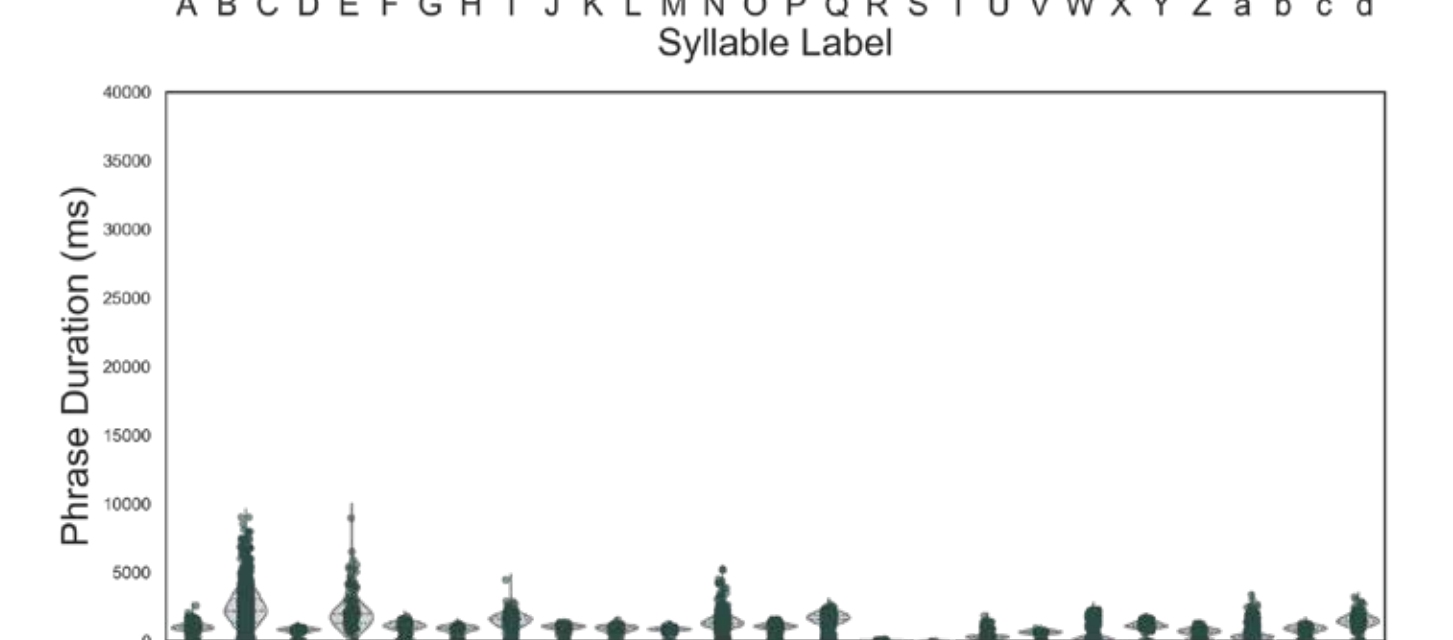
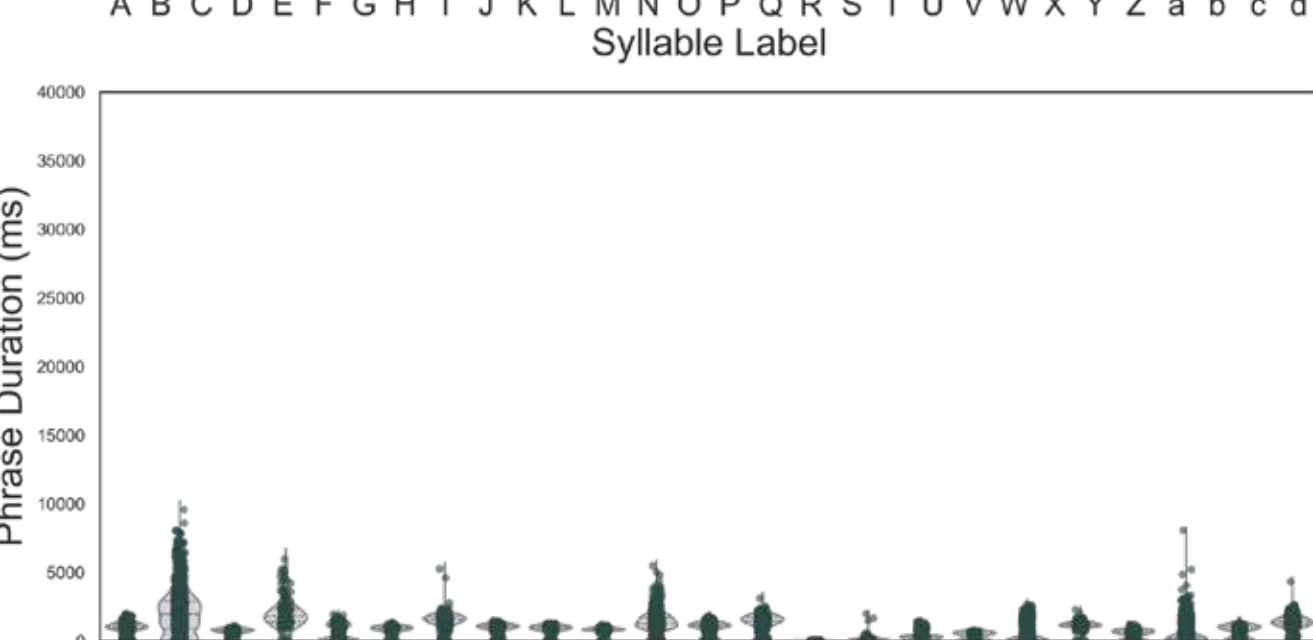
Sham lesion, surgery on Mar. 5, N= 2202 songs/group



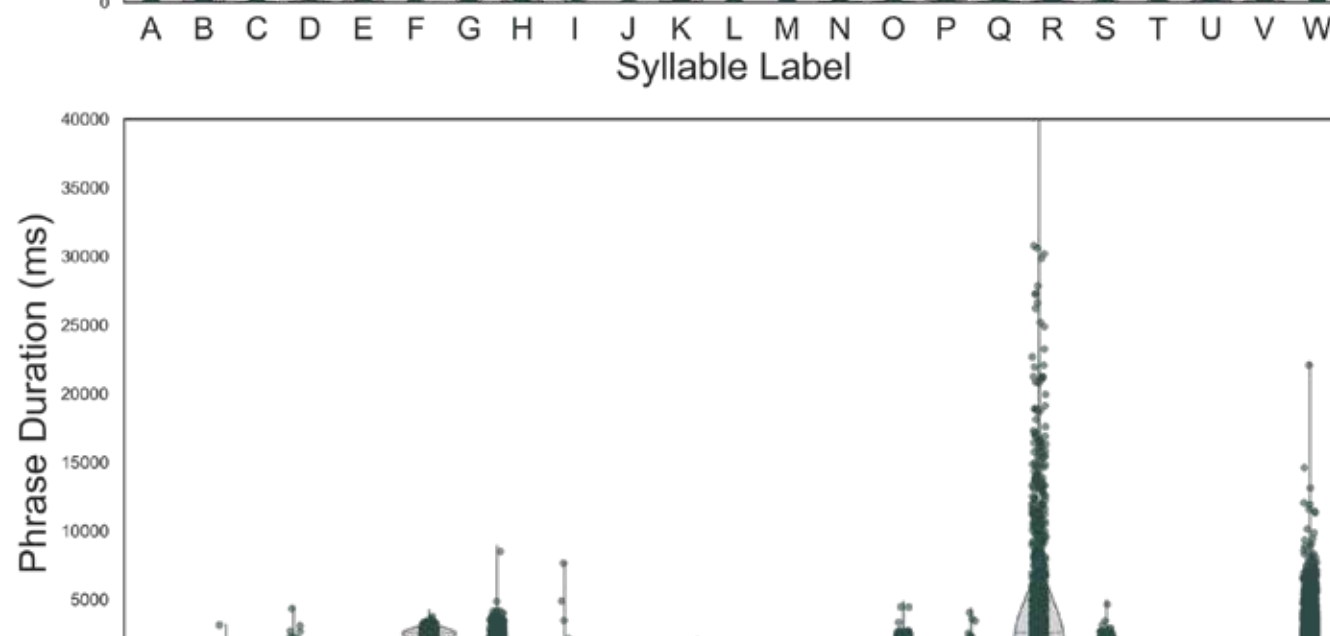
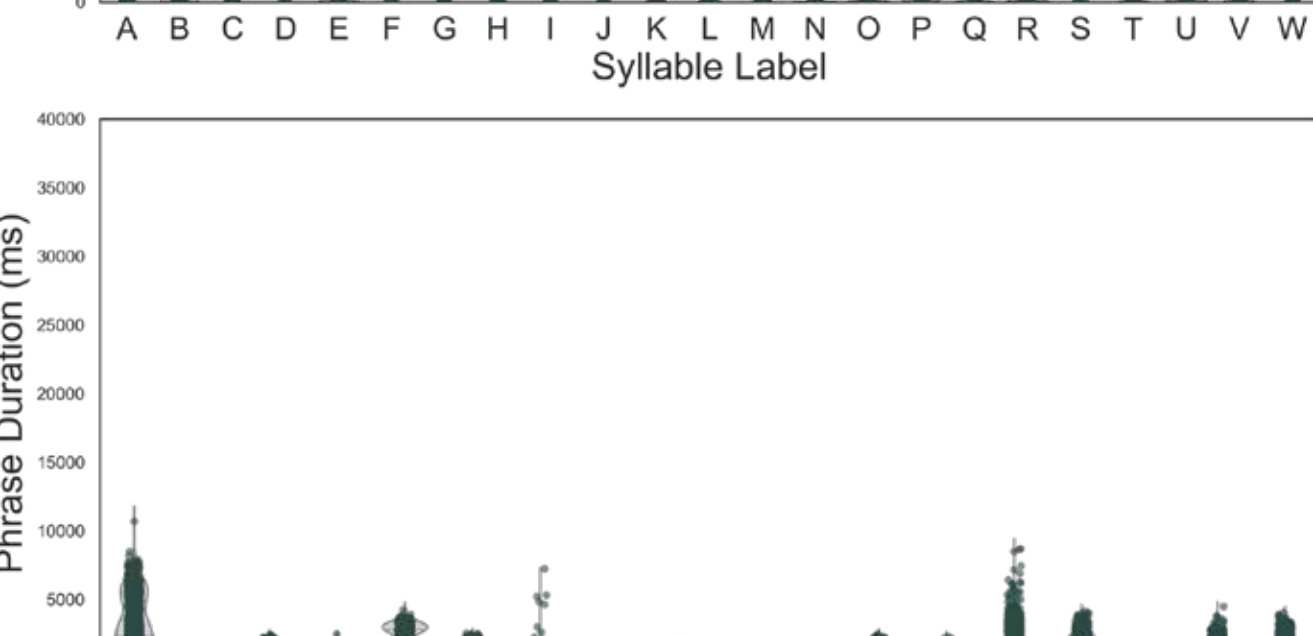
Bird with stutter, lesioned Feb. 20, N= 2212 songs/group



Bird with stutter, lesioned Apr. 10, N=2745 songs/group



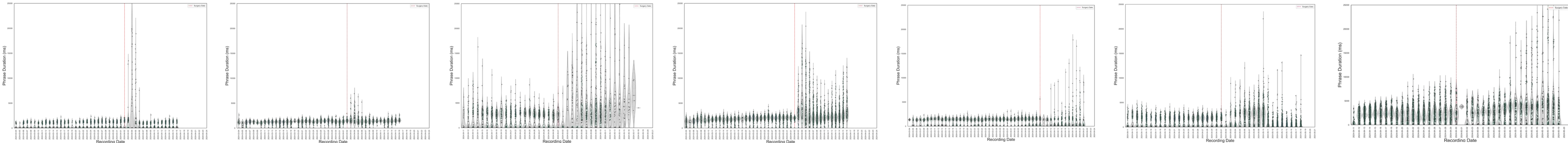
Bird with stutter, lesioned Apr. 30, N= 2096 songs/group



Bird with stutter, lesioned May 1, N= 1848 songs/group



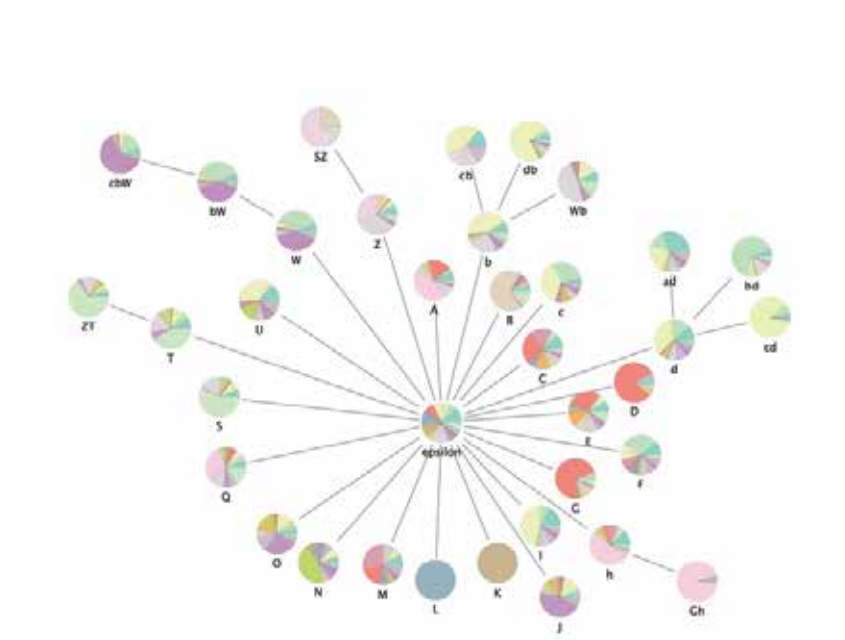
Some impacts to phrase duration and duration variability are transient, but most remain for the duration of the post-lesion recordings.



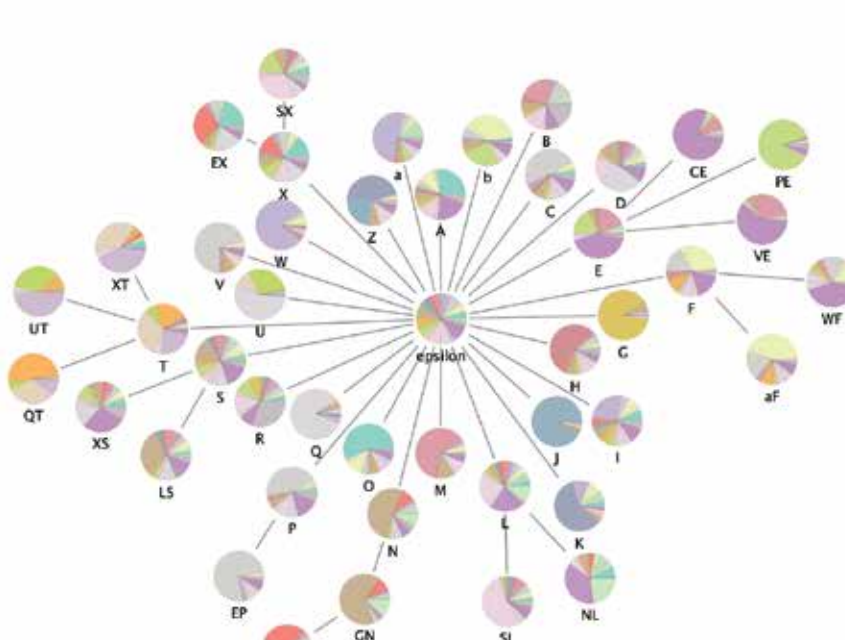
Impact to song syntax. Probabalistic suffix trees.

We generated probabalistic suffix trees (PSTs) to visualize the song syntax, or the ordering of syllables, in each group of songs. Each node corresponds to a subsequence ("suffix") of syllables in the song. The pie charts at each node indicate the likelihood of different syllables following the context at the node. PSTs were calculated with a maximum context length of N=5.

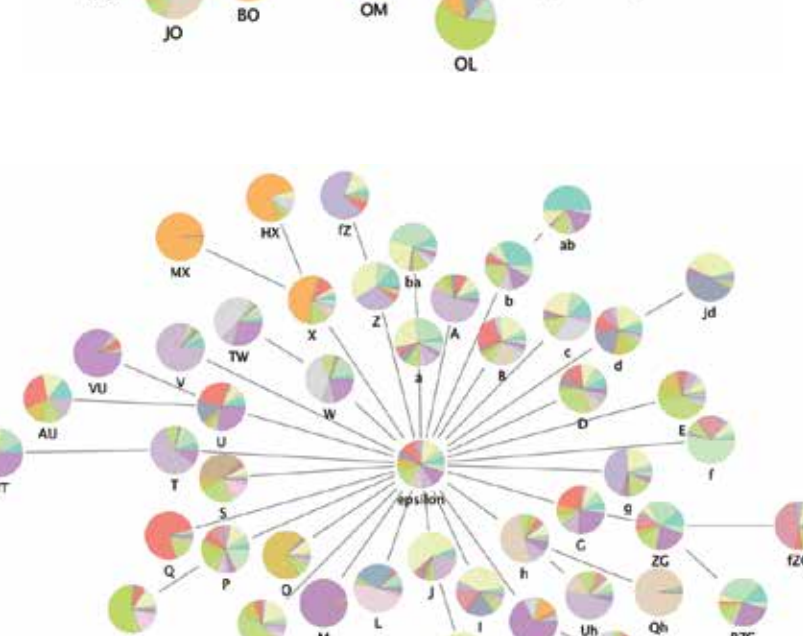
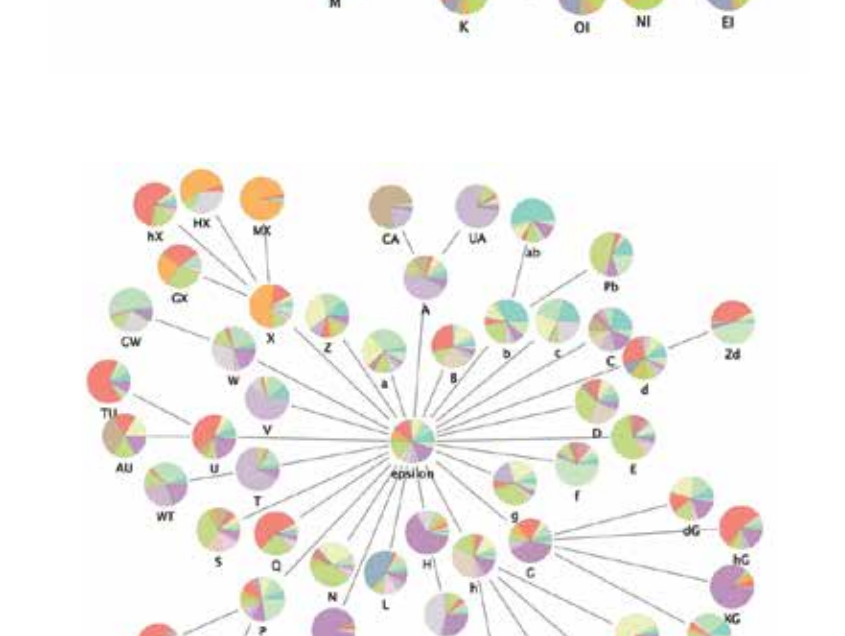
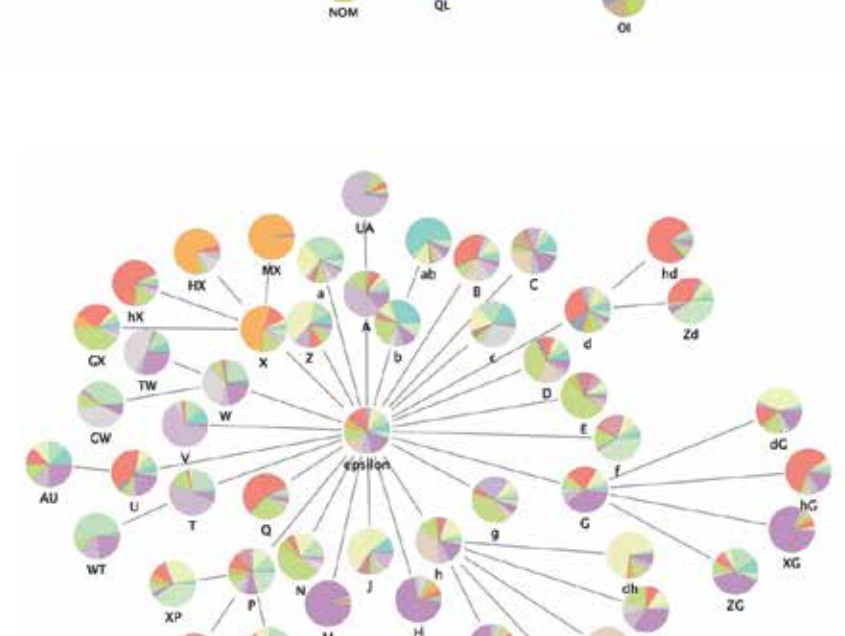
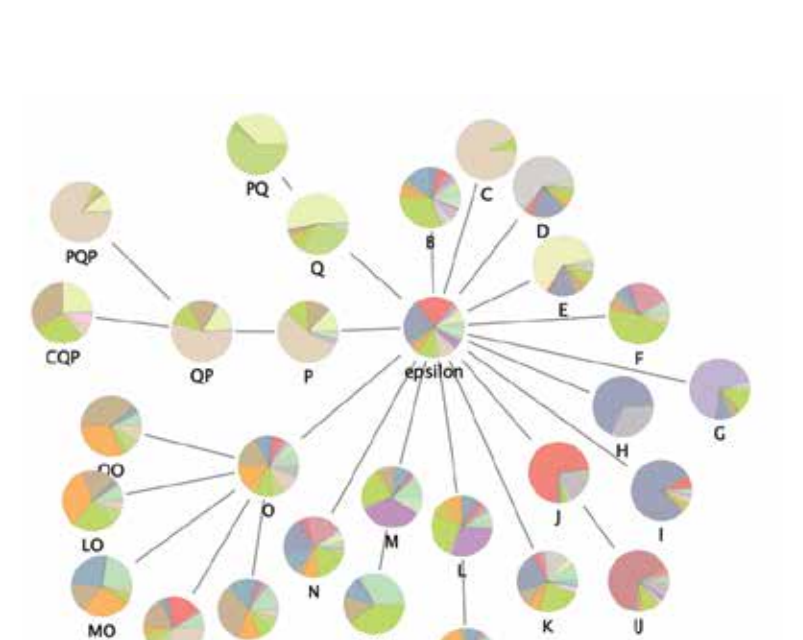
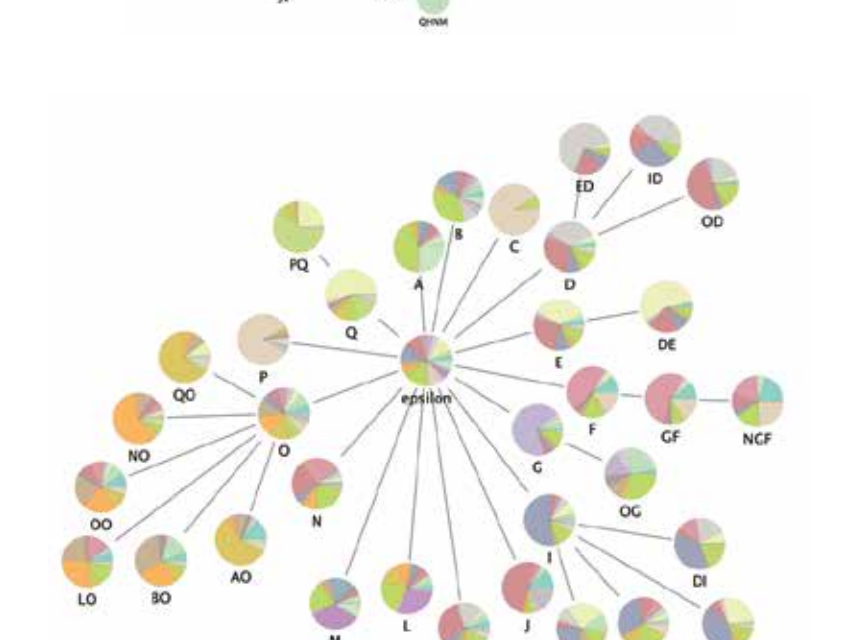
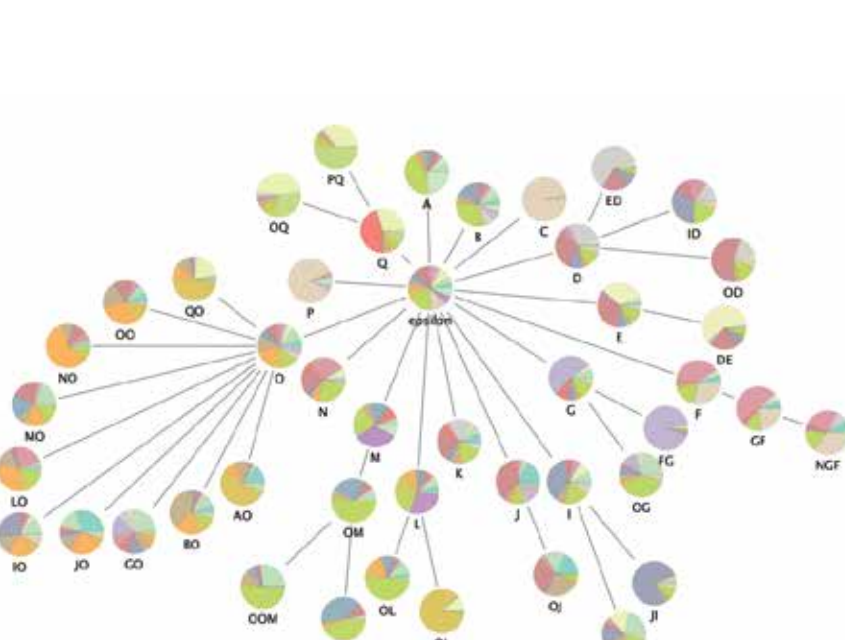
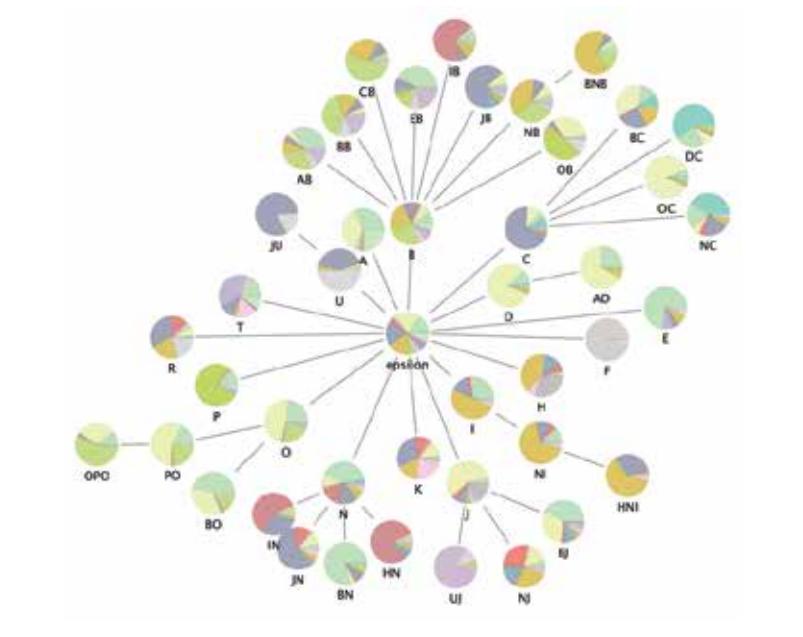
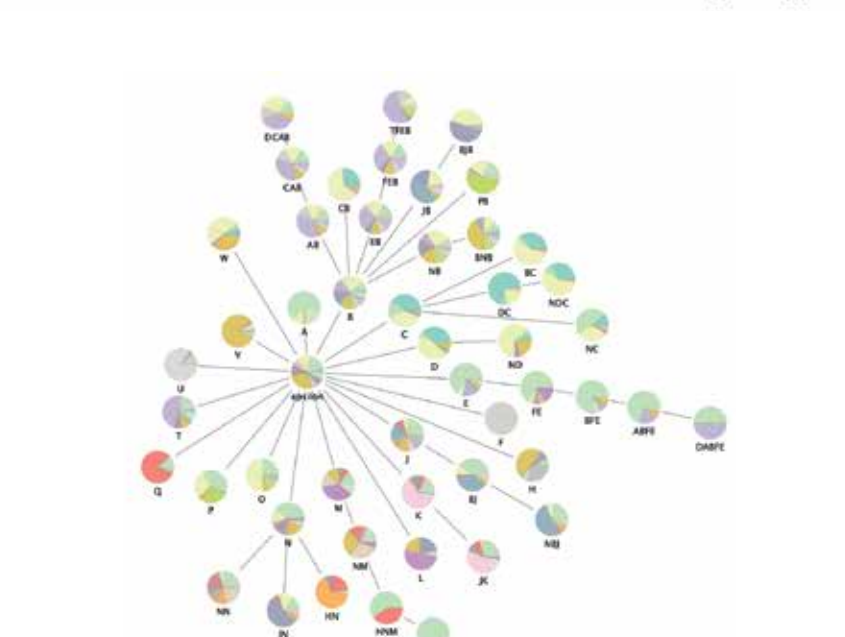
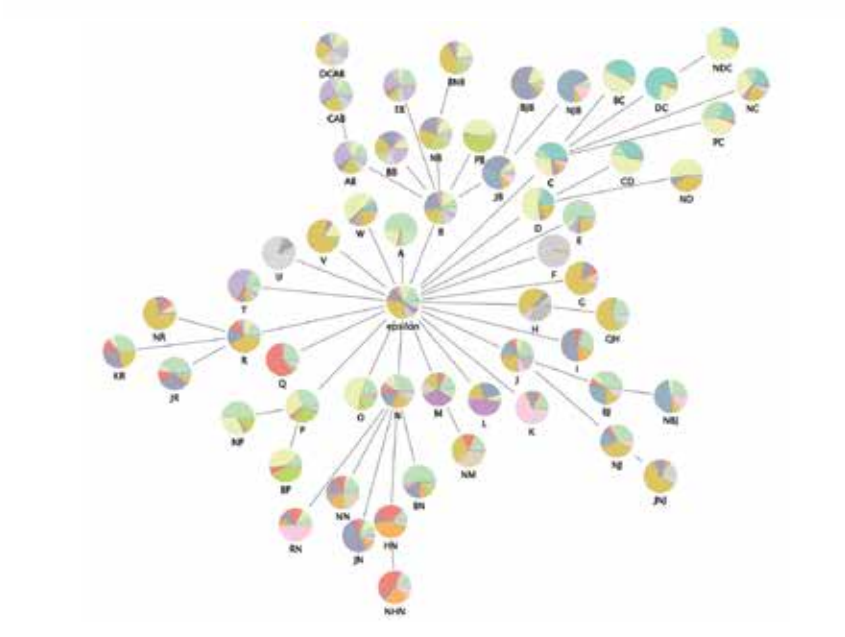
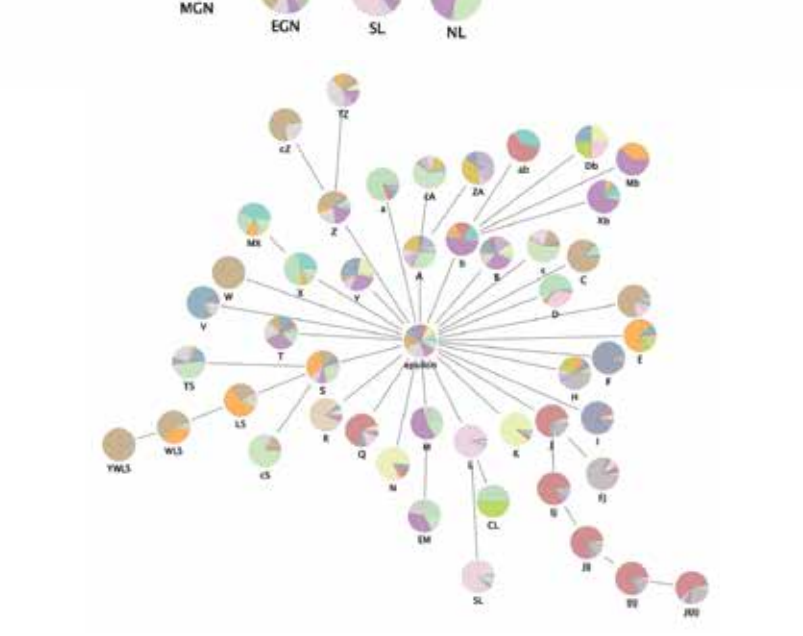
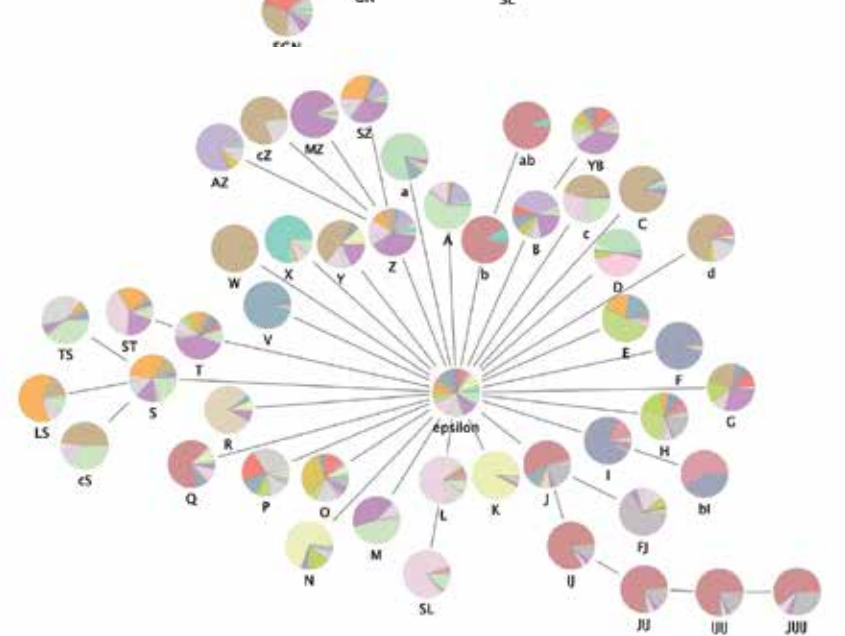
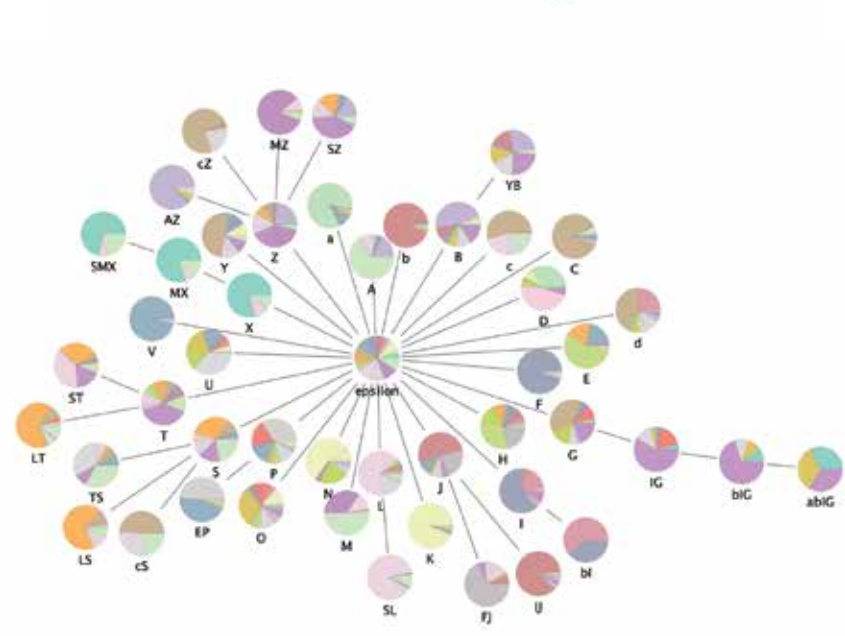
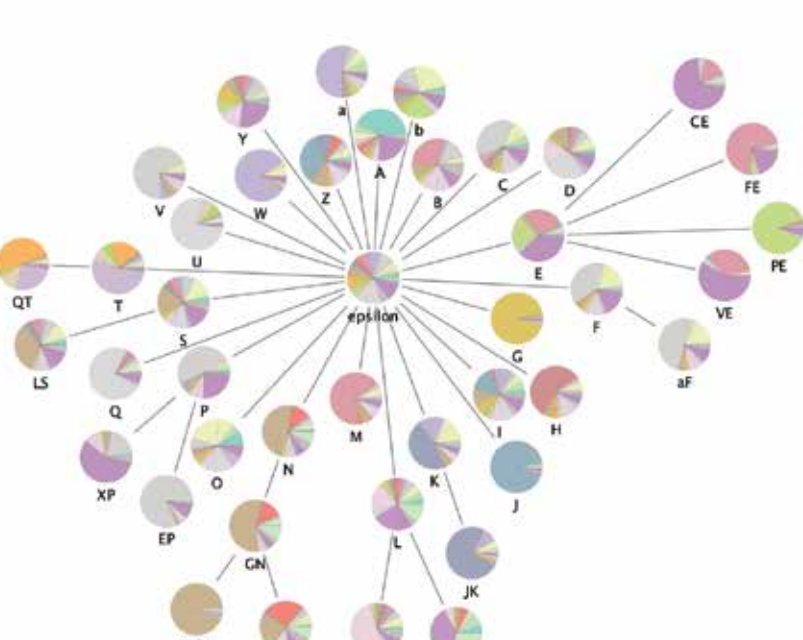
First half of pre-lesion



Second half of pre-lesion



Post-lesion



## Conclusions

- Bilateral basal ganglia (Area X) lesions result in greater duration of certain phrases, indicative of stuttered syllables.
- TweetyBERT can be used to efficiently quantify the structure of thousands of canary songs.
- These findings suggest that the Anterior Forebrain Pathway may impact adult canary song.
- Future directions: Electrolytic lesions will be performed to reduce damage to nearby nuclei from lesioning agent backflow. Increase post-lesion measurement time.

## Acknowledgements

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## References

1. Markowitz et al. (2013). Long-range order in canary song. PLoS Computational Biology, 9(5), e1003052.
2. Kobayashi et al. (2001). Partial lesions in the anterior forebrain pathway affect song production in adult Bengalese finches. Neuroreport, 12(2), 353-358.
3. Koparkar et al. (2024). Lesions in a songbird vocal circuit increase variability in song syntax. eLife, 13.