Female calls promote song learning in male juvenile zebra finches

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RESEARCH

Their lab intend to explore the neural circuits driving skilled motor learning and orchestrating the coordination of precise movements.

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Mechanisms and Disturbances in Memory Consolidation: From synapses to systems

DFG Deutsche Forschungsgemeinschaft

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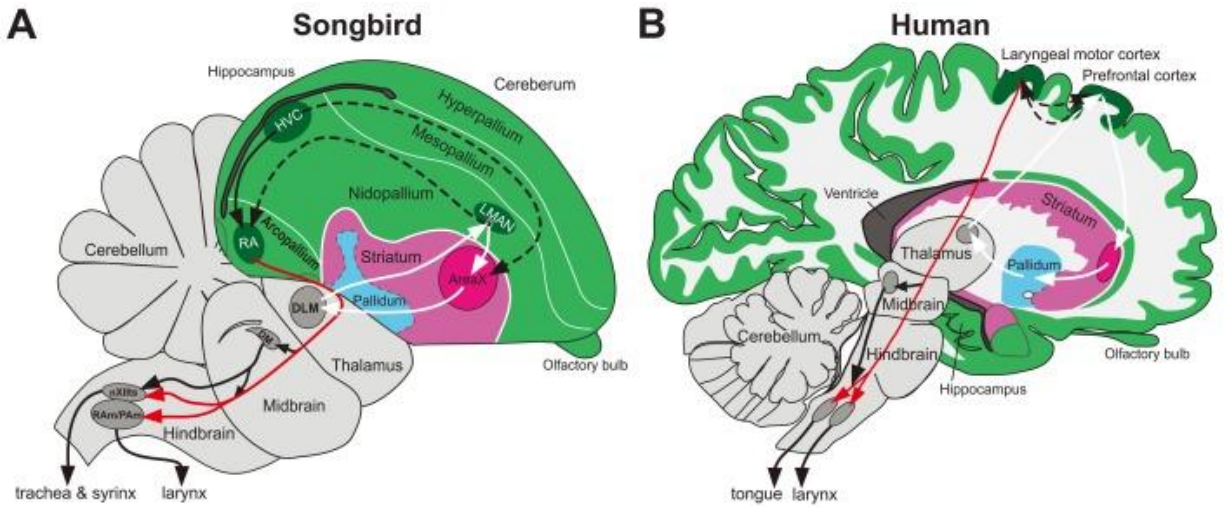
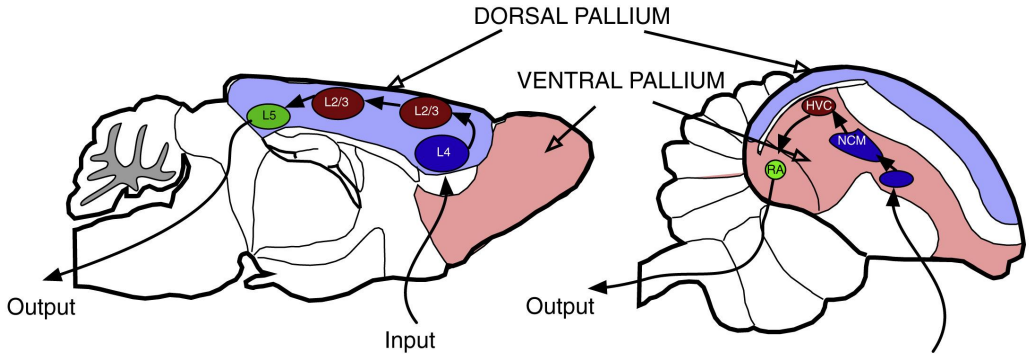
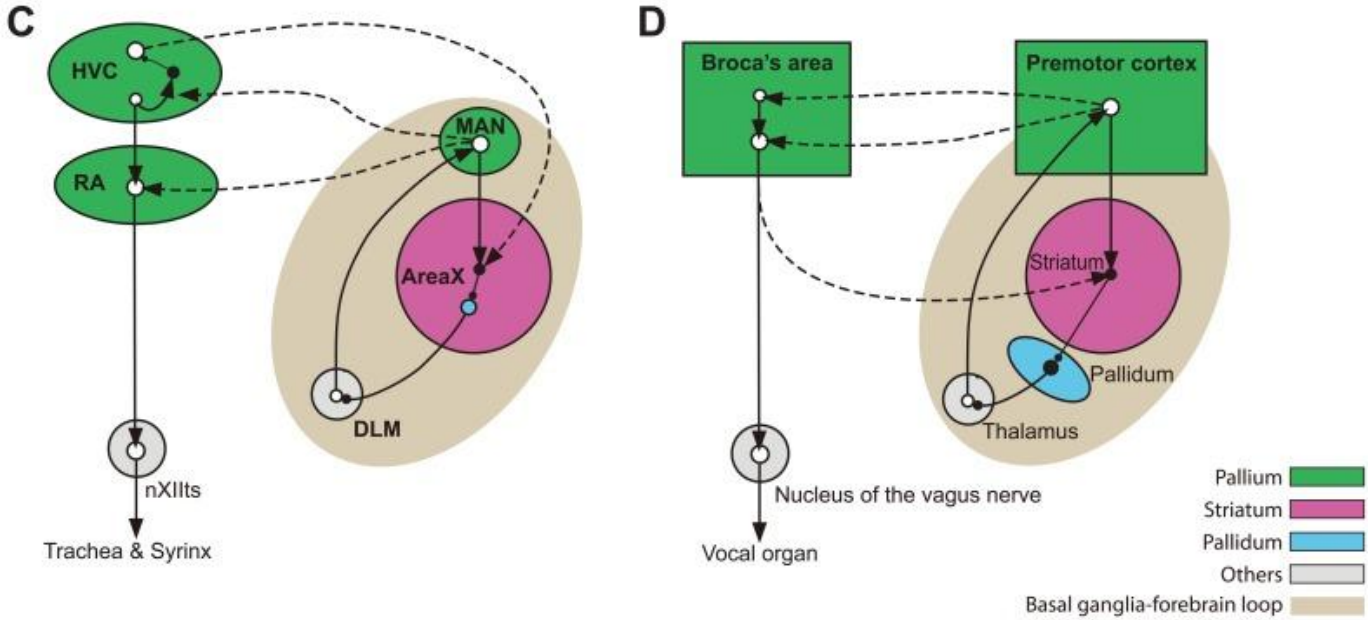
Conserved Neural Circuits: Birds and Mammals





Ball & Balthazart, Curr Biol, 2021

Current Biology



Mori & Wada, Exp Anim, 2015

- Humans and songbirds have specialized neural circuits that support vocal learning and producing.
- Key brain regions involved in vocal behavior are highly conserved across birds and mammals.

Song Learning in Songbirds

Adult male (**tutors -** song model) Social environment (e.g., parental care)

imitate influence

Young male (**tutees**)

tutor - 导师; tutee - 受指导者

Female birds (**unknown - mystery**)

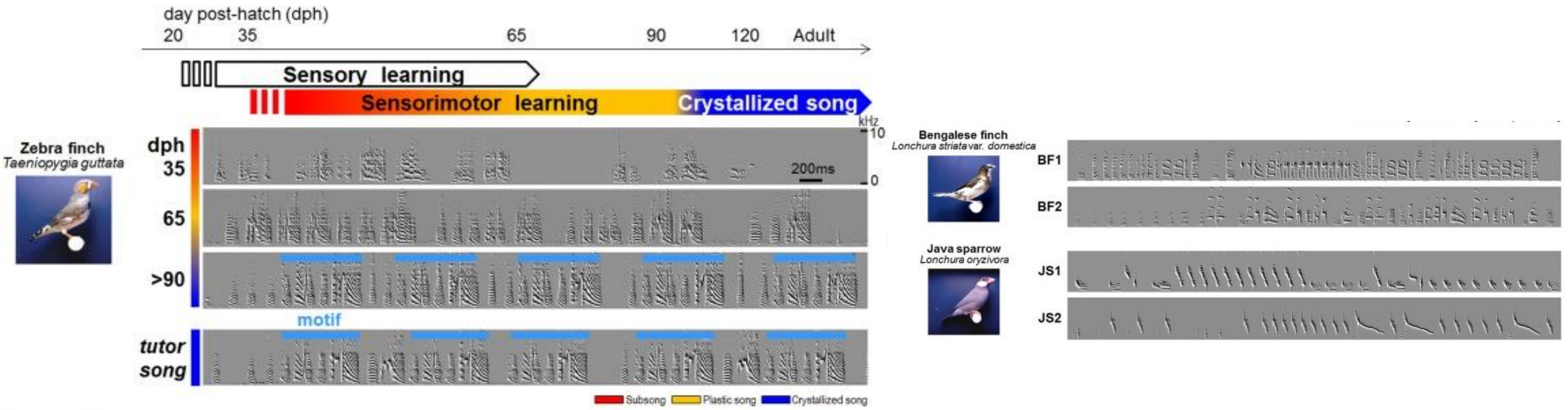
male - courtship song

Model

female - short, innate calls

Model Feedback

Why choose zebra finch?

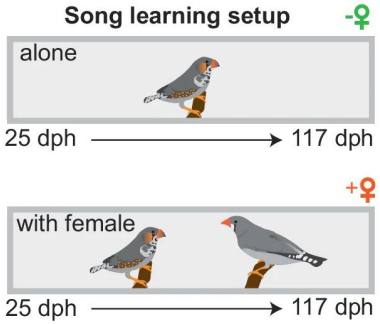


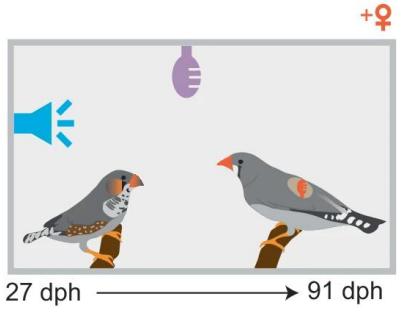
Mori & Wada, Exp Anim, 2015

- Zebra finches are a perfect model for studying how female calls might influence the song learning process in young males.
- The zebra finch is a model organism in *Passeriformes* and is very easy to breed in the laboratory.
- Once Zebra finches develop a stable, species-specific song motif, the song structure remains unchanged throughout their life.

Core Questions Addressed in This Study

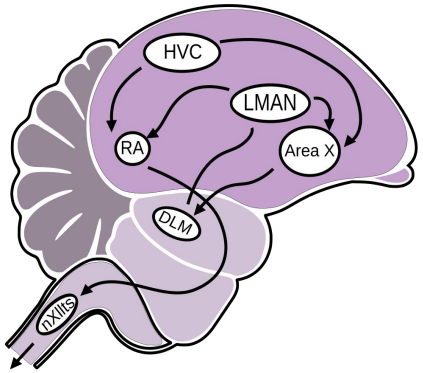
1.How does the presence of female zebra finches enhance song imitation in juvenile males?

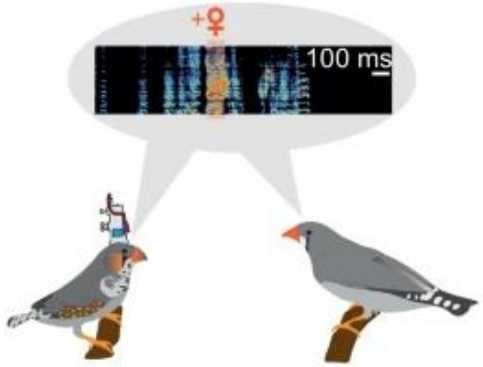




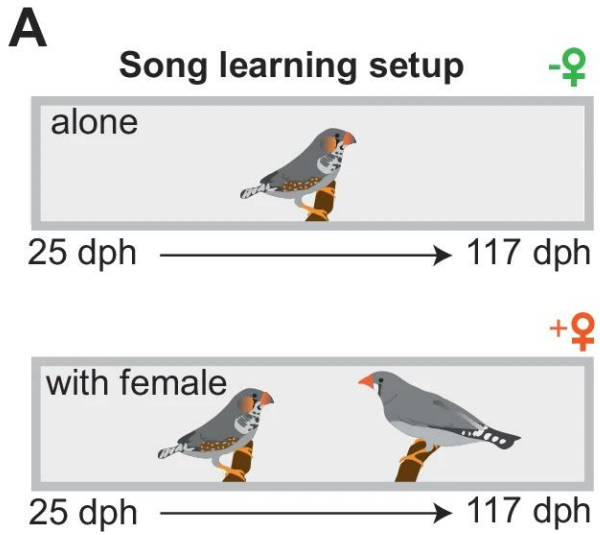
2.What are the neural mechanisms by which female vocal feedback shapes song **learning** plasticity in juveniles versus stable performance in adults?

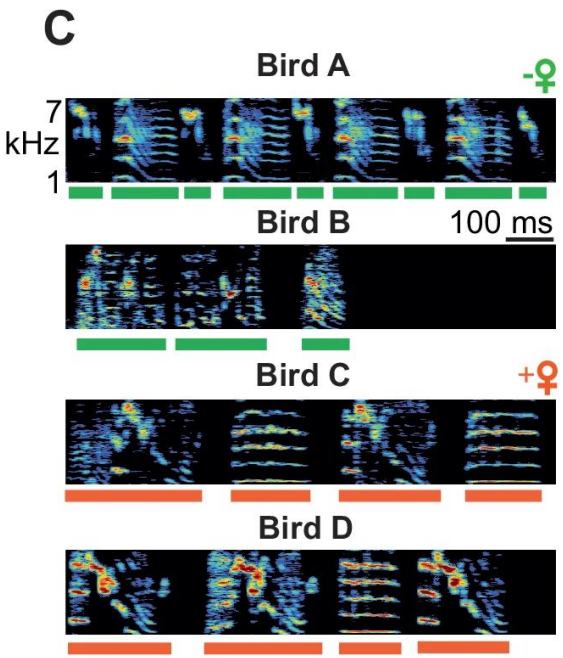
3.How does real-time female vocal feedback modulate **singing** behavior during juvenile practice versus adult performance?





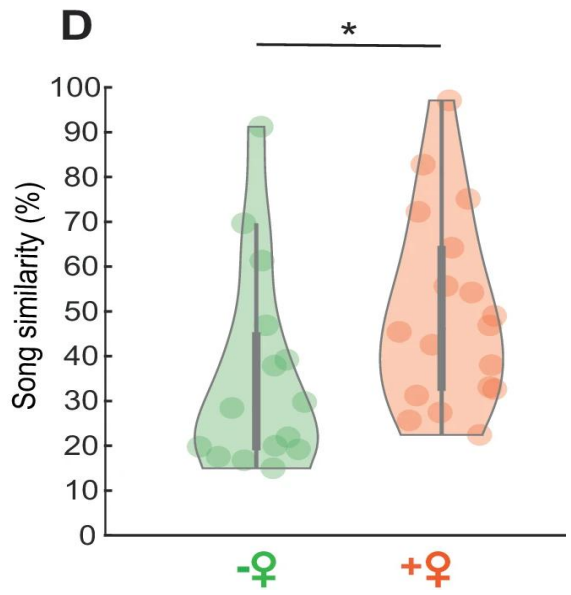
Female Presence Improves Juvenile's Song Learning

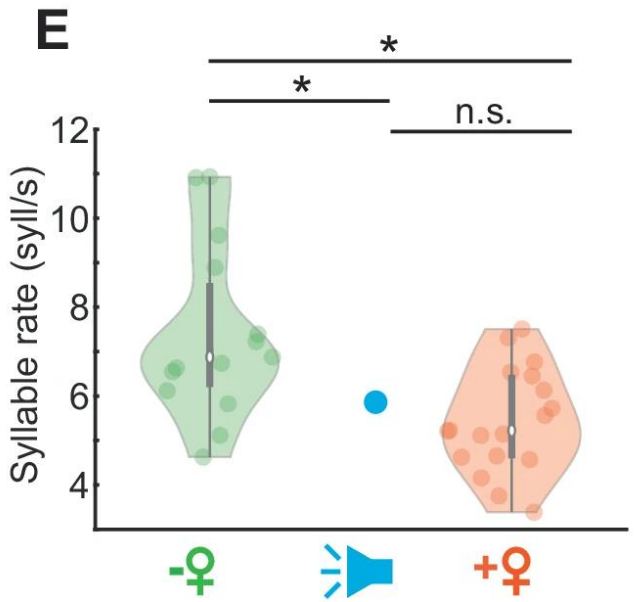


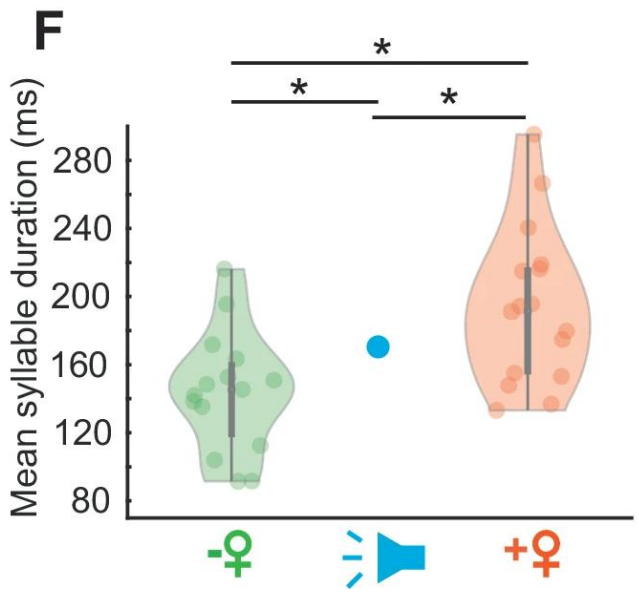


$$\text{Syllable rate (音节速率)} = \frac{\text{Total number of syllables}}{\text{Total duration}}$$

- Juvenile males raised alone or with an adult female.







Conclusion1: Female presence improves juvenile's song learning.

Conclusion2: The presence of a female helps juveniles overcome genetic or early experience biases, allowing them to better learn and imitate the tutor song.

Conclusion3: Female zebra finches actively provide vocal feedback in response to the young male's song practice, and this real-time feedback likely helps guide the learning process, resulting in a better match—both in structure and rhythm—between the learned song and the tutor song.

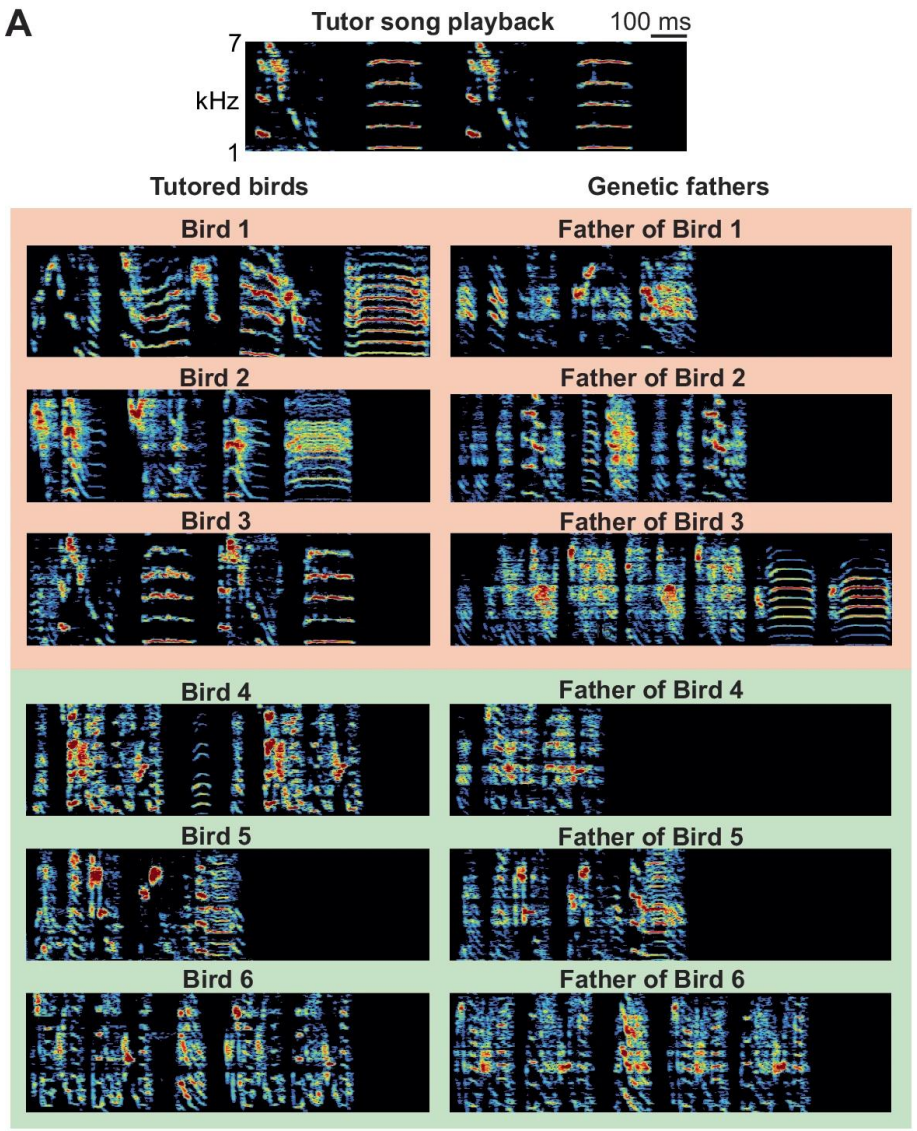
Conclusion4: Female calls During Listening : a salient and meaningful auditory signal

- In juveniles: guide and enhance song learning
- In adults: influence female evaluation of male song performance

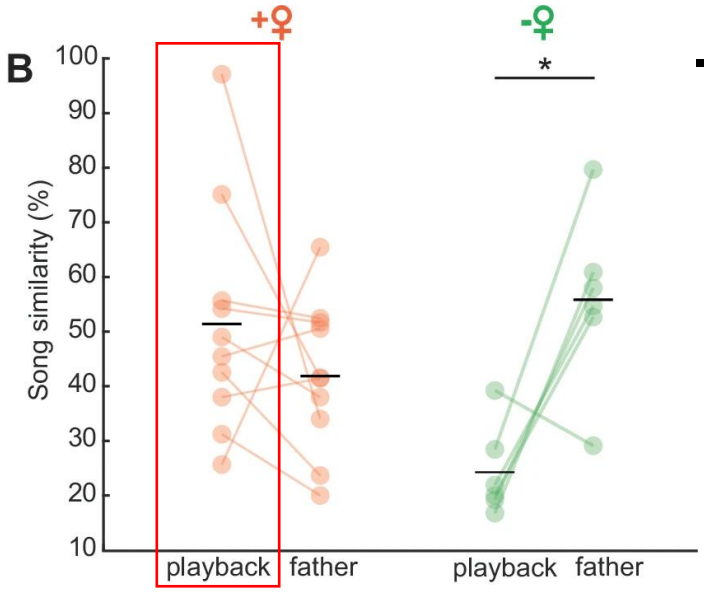
Conclusion5: Female Calls During Singing: modulate neural activity and promote song learning plasticity

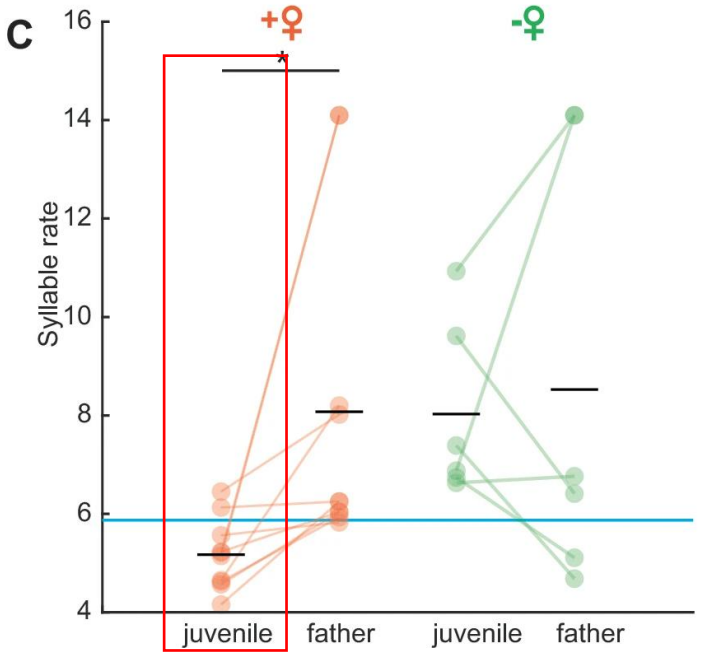
- In juveniles: induce changes in HVC neuron activity—especially subthreshold changes—supporting neural plasticity
- In adults: do not alter HVC neuron activity, maintaining song stability

Controlling for Genetics and Early Experience



Birds 1–3 raised in female presence
Birds 4–6 raised alone





- Birds raised with a female had a much higher similarity to the tutor song playback.
- Birds raised with a female copied the tutor's syllabel rate more accurately.

Blue line - syllable rate of tutor song playback

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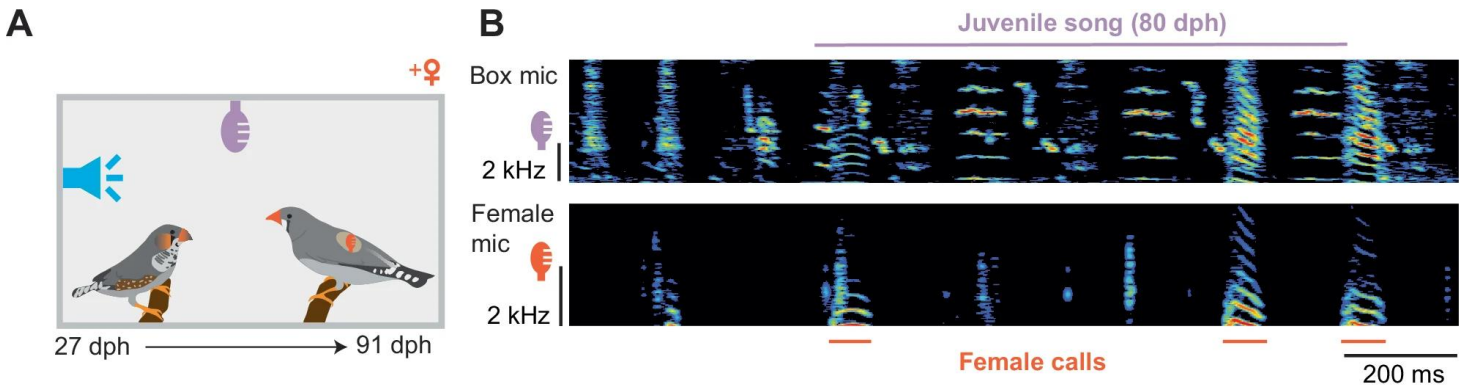
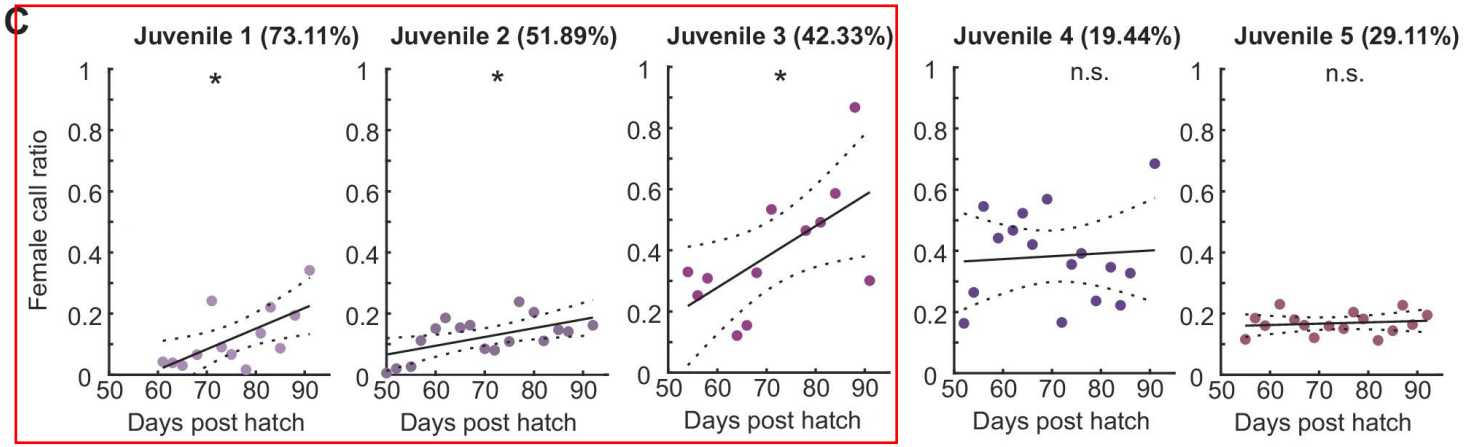
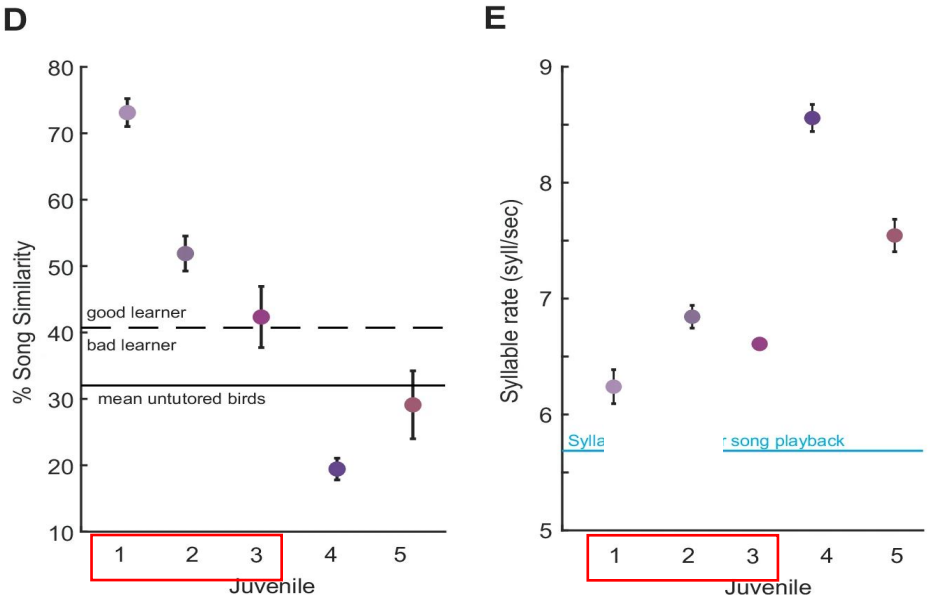
Female Calls as Real-Time Feedback



- Raised six juvenile males, each paired with a different adult female, while still playing the tutor song(purple).



- As the number of days post hatch increased, the ratio of female calls rose significantly, and these juveniles achieved higher song similarity to the tutor song.



- Juveniles 1 to 3 produced songs that were more similar to the tutor song, with syllable rates also closer.

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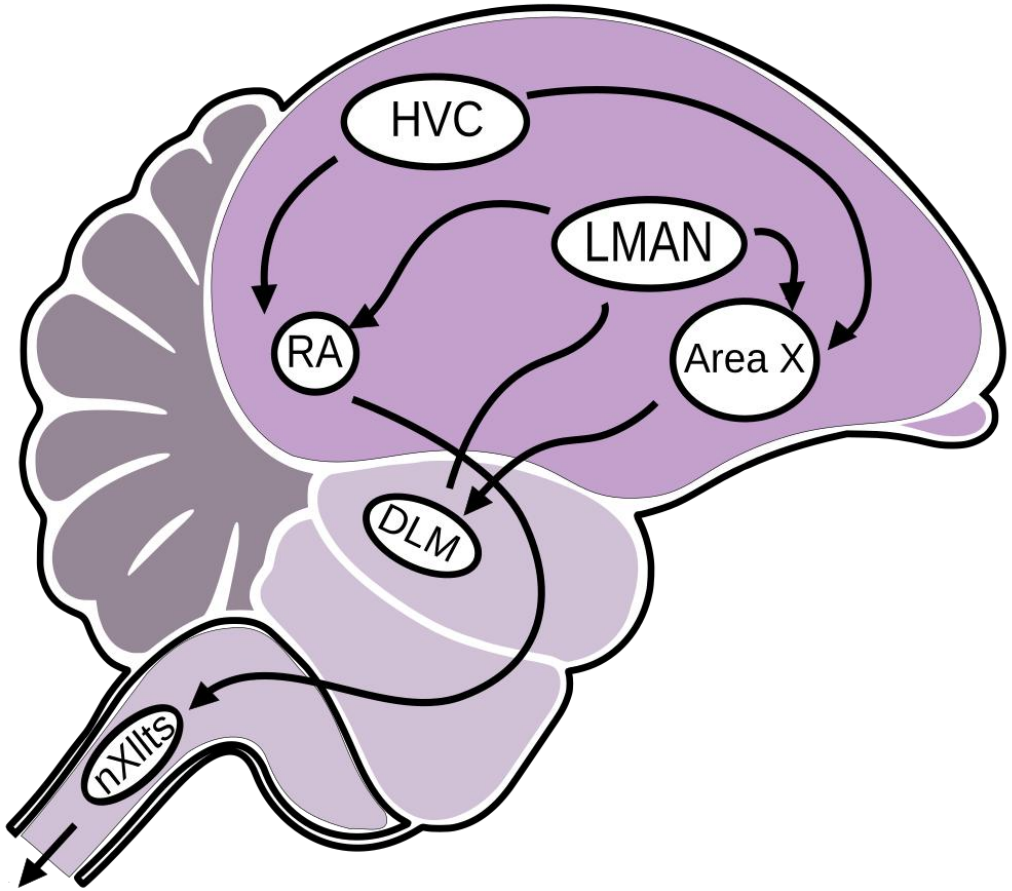
HVC: The Songbird's Song Control Center



Nottebohm & Arnold, Science, 1976

The HVC in the context of the song-learning pathway in birds

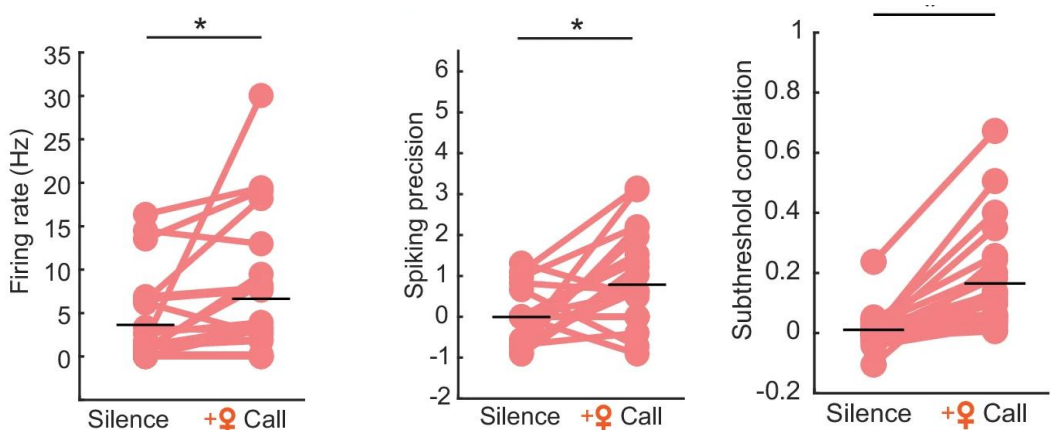
HVC (hyperstriatum ventrale, pars caudalis)

- Key brain region for song learning and producing in songbirds
- Central hub: integrates auditory input and motor output
- Highly plastic during learning—adapts based on experience

Female Calls During Listening – Juveniles vs. Adults

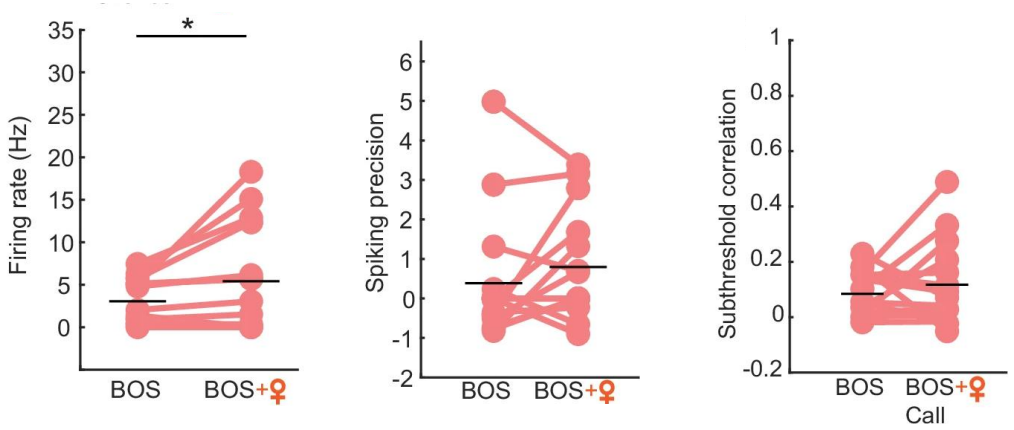
1. Listening to Female Calls

Subthreshold(阈下)



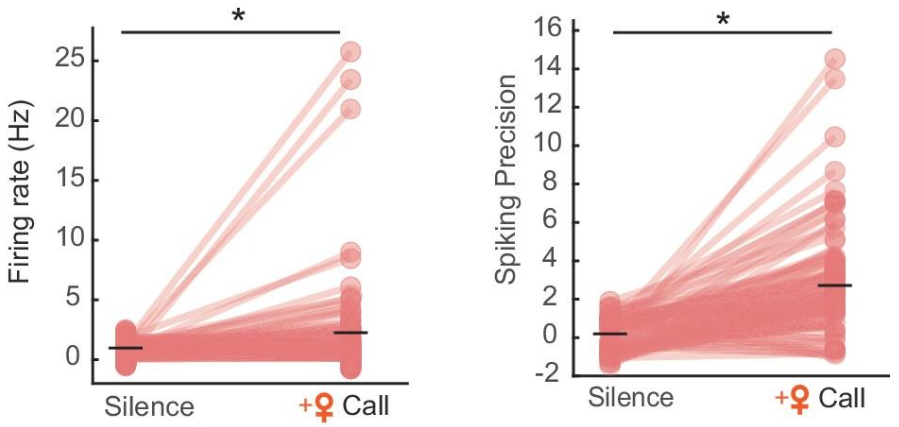
- Female calls directly and specifically activate HVC neurons in juvenile males during listening.

2. Female Calls Combined with Juvenile's Own Song



- In this mixed condition, the neural response to female calls is more variable and less consistent.

3. Adult Males' Response to Female Calls



- This auditory response is maintained even after the song learning.

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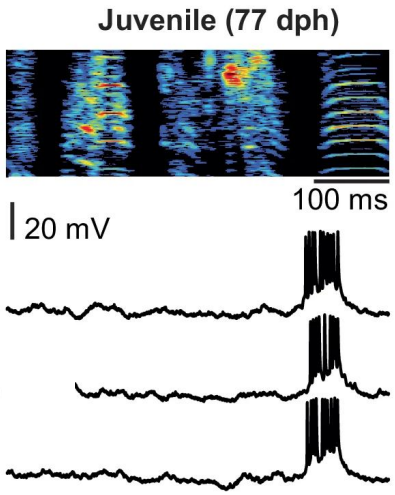
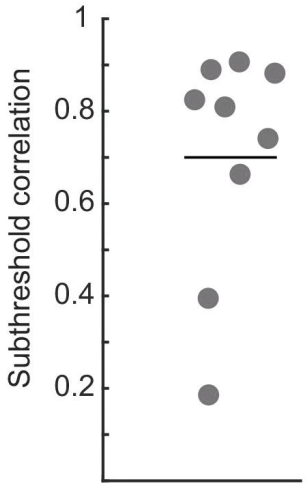
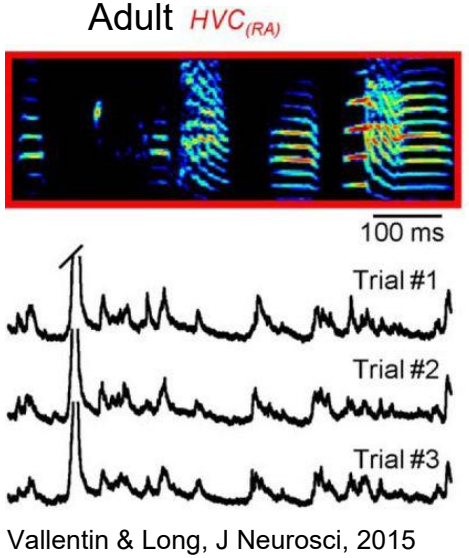
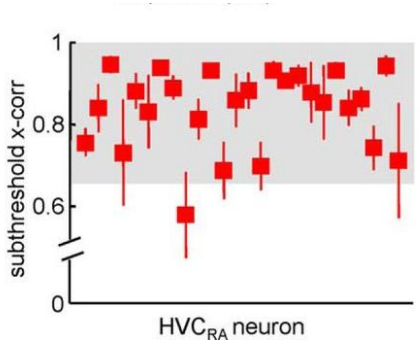




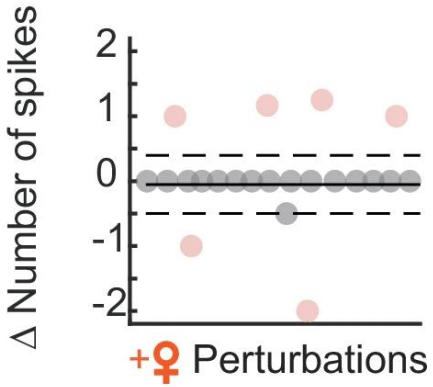


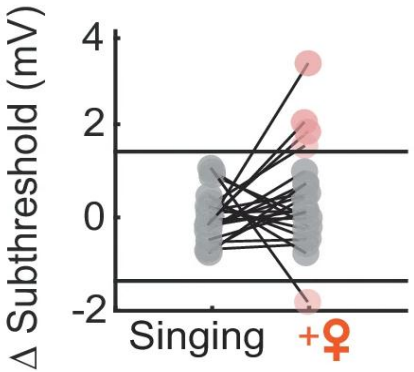
Vallentin & Long, J Neurosci, 2015



median subthreshold correlation:
juveniles = 0.81, adults = 0.80

- The neural activity patterns of juveniles during singing are already as stable and consistent as those seen in adult birds.





black lines - adults
dot - juveniles

- Juvenile neurons are highly sensitive to female feedback.

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Why I Choose This Paper

This highlights a fundamental principle in neuroscience and behavioral biology: social context and feedback are essential for learning complex behaviors—a concept that applies not only to birds, but also to many other species, including humans.

Limitations

- Sample sizes:
  Some key experiments (female call feedback, neural recordings) have small sample sizes, which may limit the generalizability of the findings.

- Causality of feedback:
  The study does not directly test whether female calls act as contingent feedback signals. More controlled experiments (e.g., playback, mute/deaf females) are needed to establish causality.

Thank You & Questions