Seasonal-like growth and regression of the avian song control system: Neural and behavioral plasticity in adult male Gambel's white-crowned sparrows

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- Undergraduate Studies:
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- Worked with Eliot Brenowitz, as did Meitzen, while at the University of Washington; received his Ph.D.
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Discussion Overview
- Hormone Receptors and Photoperiods
- Meitzen and Nottebohm
- Neurogenesis as a mechanism of growth
- Regression of HVC and RA nuclei
- Take home messages
- Questions
Avian song control system

- Review showed the distribution of sexual hormone receptors within the AFP and motor system of the brain
- Stimulation of testosterone (T) production in gonads of young male birds through long day photoperiods

Why estrogen receptors in HVC?

Response: Question 1

- Similar in relative spatial arrangement of nuclei, internuclear connections
- Dichotomy of receptor types among nuclei; HVC possesses both T and E2
- Reviewed literature discussed that AR immunoreactivity of other nuclei not ascertained in white-crowned sparrows
- Assumptions drawn from other species (i.e. canaries)

Breeding conditions and associated physiological changes

Short Day (SD) photoperiod

Characterized by:
- 8 h light / 16 h dark; non-breeding season conditions
- Decreased system testosterone (T) levels; (correlated?)
- Regression of HVC and RA nuclei volume and cell population

Long Day (LD) photoperiod

Characterized by:
- 20 h light / 4 h dark; breeding season conditions
- Increased system testosterone (T) levels
- Increased volume and cell population in RA and HVC nuclei

Physiological changes observed in HVC and RA nuclei

- Increased cell population after LD photoperiod
- Minimal change in cell population; marginal increase in volume of nucleus

What causes an increase in cell population?
**Discussion Question 2**

Where is the data from originally?

How is it presented here?

Are there any potential drawbacks to analyzing data in this manner?

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**Response: Question 2**

- The figure description states that the represented data is a set of average values from results of two different experiments in two different journal references; extrapolated?
  - Brenowitz authored in both papers

- Other differences? Observed assumptions?

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**Neurogenesis: new nerves from neural stem cells**

Meitzen et al.:

- Compiled data on physiological changes in nuclei volume determined that new neurons were generated in HVC in males; correlated with T exposure
  - Maximized cell/nuclei growth observed to T and estrogen exposure, evidenced by introduction of aromatase inhibitors

Nottebohm:

- Conducted experiments in the late 1980s on T effects in female canaries; results reflected presence of receptors essential for growth of HVC and RA nuclei
- Female birds with systemic T present will sing male-like song; they possess fewer syllables than male canaries
- No studies on the cause of nuclei volume change

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**Nottebohm’s exploration of neurogenesis**

**Table 1**

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Timepoint</th>
<th>Treated</th>
<th>Control</th>
<th>Timepoint</th>
<th>Treated</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>RA</td>
<td>1 month</td>
<td>10.5</td>
<td>8.5</td>
<td>2 months</td>
<td>10.0</td>
<td>8.0</td>
</tr>
<tr>
<td>HVC</td>
<td>1 month</td>
<td>11.0</td>
<td>9.5</td>
<td>2 months</td>
<td>11.5</td>
<td>10.0</td>
</tr>
</tbody>
</table>

**Hypothesized mechanisms of HVC and RA morphological changes**

- No evidence of what could drive adult neurogenesis in HVC

**Neurotrophin regulated activity:**

- HVC grows after changes in RA and other AFP nuclei; trophic signal generated from HVC

- Neurotrophins act to differentiate progenitor cells into neurons
  - Increased cell numbers in the HVC

- Neurotrophin is essential for nerve cell growth, maintenance and survival
  - Induced apoptosis if absent

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**Nottebohm suggested mechanisms for nuclei growth in canaries as research was being conducted on adult neurogenesis**

- Tritium-thymidine injections for labeling HVC neurons; seasonal incidence of cell death

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**End of breeding season**

**Beginning of breeding season**
Transition to non-breeding conditions

Photorefractoriness:
The desensitization of photoreceptively-driven pathways; in this example, male Gambel’s white-crowned sparrows in the non-breeding season saw decreased T levels despite the LD photoperiod exposure (prior to summer solstice)

Underlying mechanism?

Regression of nuclei

Time differential in regression rates:
- HVC regresses rapidly, showing increased apoptosis
  - Regression time of no more than 72 hours
- Downstream, RA and Area X regress within 7 to 20 days of initial transition to non-breeding conditions
  - Change in soma volume and neuron density, not cell population

Suggests that the underlying neural mechanism of regression is the same as that of growth in RA nucleus

Systemic T levels

Testosterone drives HVC nucleus growth, removal induces apoptosis; neuroprotective
Reduced by luteinizing hormone and FSH
  - Regressed gonadal production of T
Lack of systemic T
  - Cessation of bird song production
End of breeding season

Future Questions

What underlying factors contribute to physiological changes in HVC (i.e. with proliferation, migration of new neurons)?
What electrophysiological affects are observed in the growth and regression of song control nuclei?
Why is estrogen necessary for growth of song nuclei and maintenance?
What affects do the androgen receptors have on the motor nuclei and syrinx between breeding and non-breeding seasons?

Final Summary

1. Plasticity in bird song neural pathway is partly regulated by photoperiods and systemic hormonal levels of sexual steroids
2. Testosterone and estrogen are essential to maximizing growth in HVC and RA nuclei, and testosterone is implicated in maintaining the integrity of these nuclei during the breeding season
3. HVC is the first nuclei to respond to systemic testosterone, to grow and project to other regions
4. There is still a great deal of work to be done on various components of the song neural system

Discussion Questions

After reading this review, what conclusions intrigued you?
Were you able to identify any parallels between this neurobiological review, and the ethological papers we have read previously about bird song research?
Response: Question 3

- Provided reductionist view of underlying neurobiological mechanisms of stereotyped behavior

- Complemented other literature previously studied:
  - Lesioning of LMAN and disrupted growth of HVC; reflects interconnected pathway between the nuclei of the brain essential for behavior
  - Contextualizes the singing behavior relative to breeding behavior

Other Questions?