Development of Precocious Avian Hearing: Frequency Specificity and Cross Species Comparison

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Abstract

- The development of hearing can provide important insight into frequency specific encoding.
- Neuron physiology and tonotopy determine how spectral and temporal stimulus features are encoded.
- The embryonic and hatchling chicken are excellent models for development because of the chicken's precocious nature.
- The hatchling chicken click ABR is quite similar to other avian species, but frequency thresholds improve in adulthood.
- Embryonic ion channel currents suggest low frequency hearing development extends beyond hatch.

Background

The ABR in hatchling chickens measures auditory neural synchrony and hearing sensitivity. It also represents an *in-vivo* methodology comparable to *in-vitro* molecular and developmental research. The ABR has also been characterized in animal models across classes.

Both mammals and birds have an auditory nerve that provides excitatory, glutamatergic input to distinct cochlear nucleus structures. The avian nucleus magnocellularis (NM) is analogous to the mammalian anterior ventral cochlear nucleus (AVCN) and encodes temporal information. NM is critical to encode the temporal aspects of sound localization.

Method

- Chicken hatchlings 1-2 days old were anesthetized with 20 mg/kg ketamine and xylazine. Feathers on the head were removed and subdermal electrodes implanted.
- Click and tone burst stimuli were presented at a 100 µs and 5 ms durations, respectively.
- Literature sources for other avian species and mouse were referenced. All sources used a click stimulus, but age, temperature, speaker position, and click rate varied.
- Patch clamp electrophysiology was performed in embryos at three developmental stages.
- The lowest frequency NM neurons in the caudolateral region (NMc) were sampled for physiology data.
- All data were analyzed and visualized in GraphPad Prism.

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Click ABR Latency Across Species

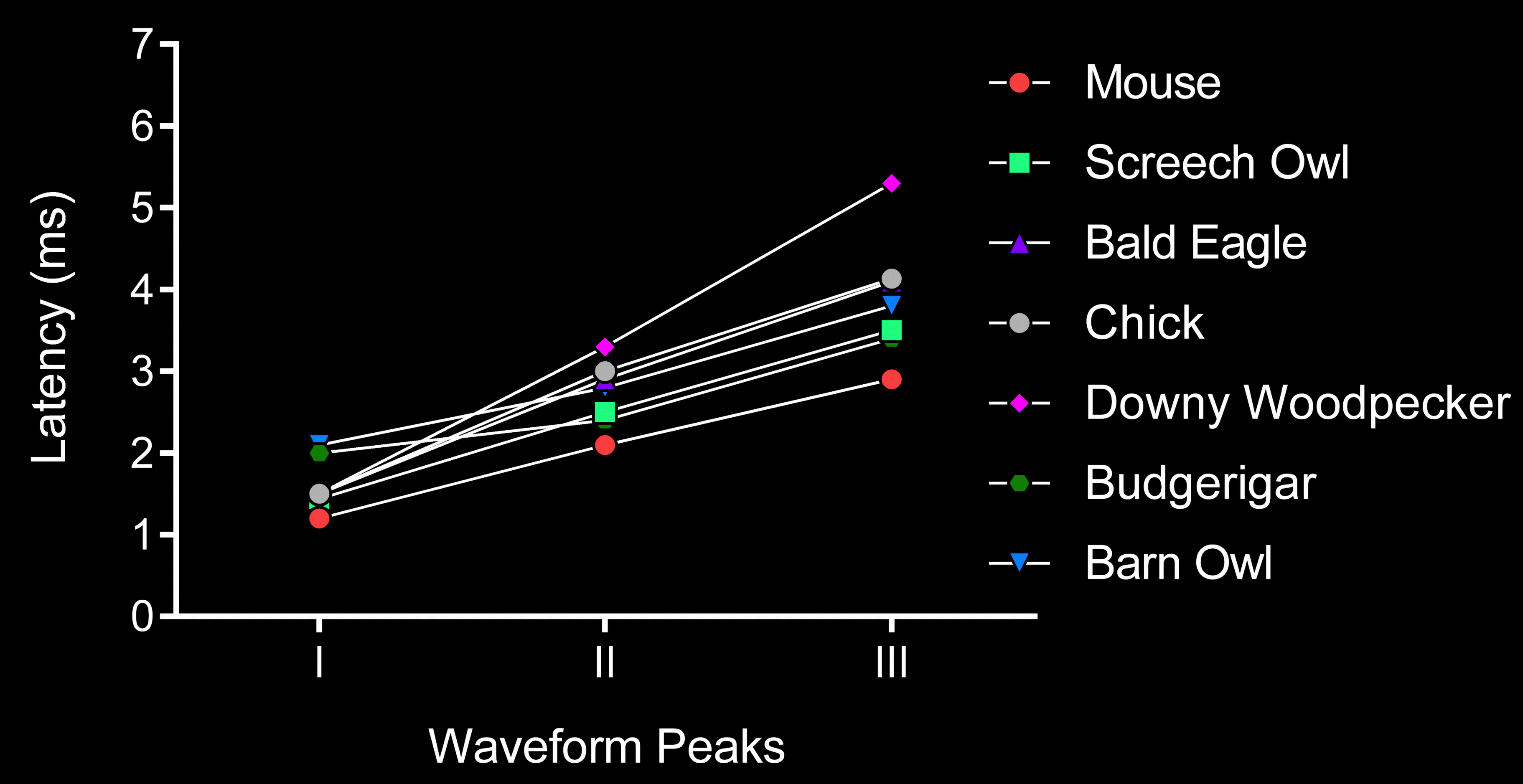

Figure 1: Waveform peaks in response to a click stimulus. All species were adult animals except the chick. All recording set-ups were non-invasive, but the distance between the speaker and animal differed. Click intensity ranged from 50-90 dBSPL.

Hatchling vs. Adult Frequency Thresholds

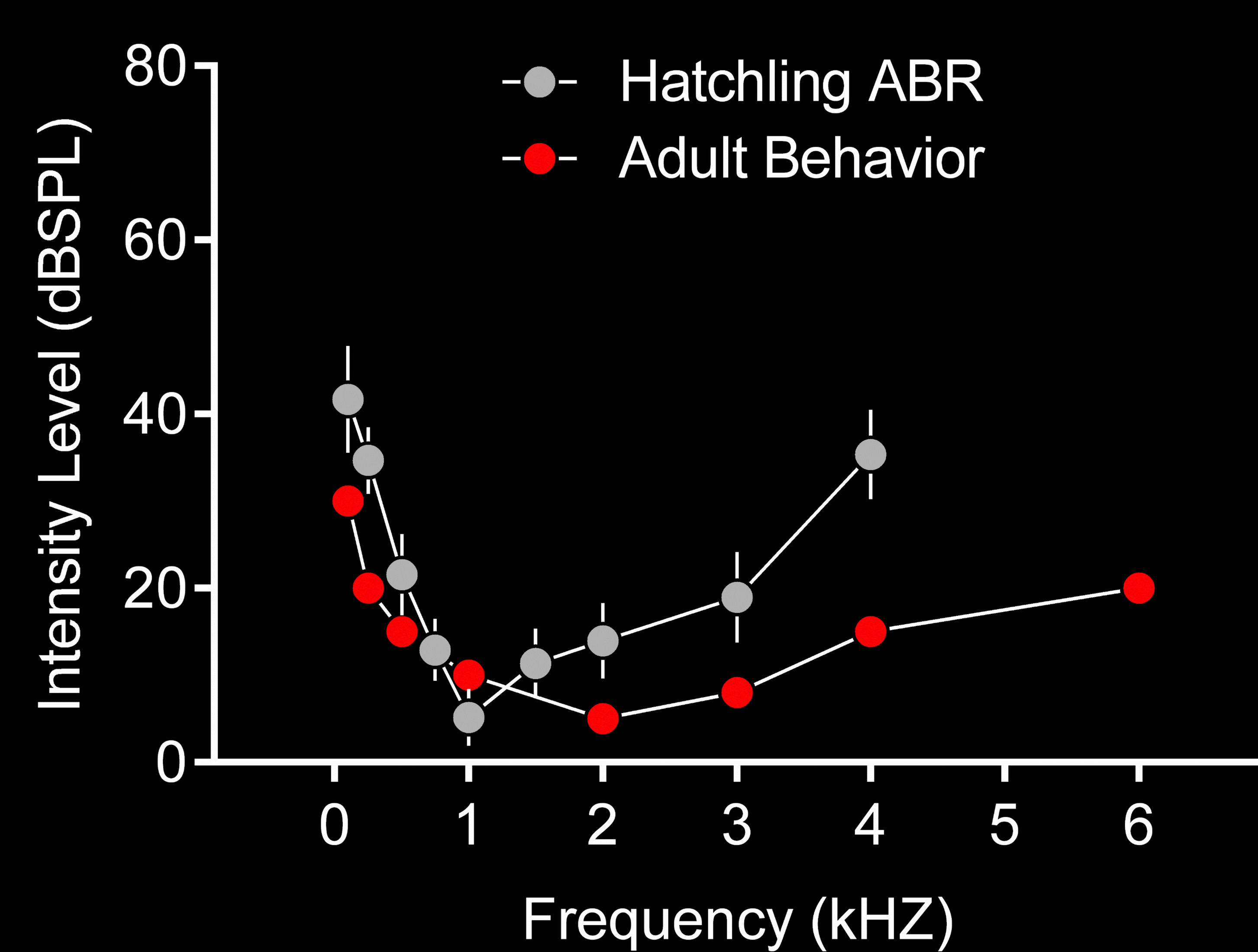

Figure 2: Hatchling ABR thresholds and adult behavioral audiogram. Hatchling ABR thresholds for nine frequencies tested showed a best sensitivity at 1000 Hz. Adult behavioral data (Hill 2014) showed the best sensitivity around 2000 Hz. ABR Thresholds shown with 95% Confidence Interval.

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Embryonic Variability in NMc

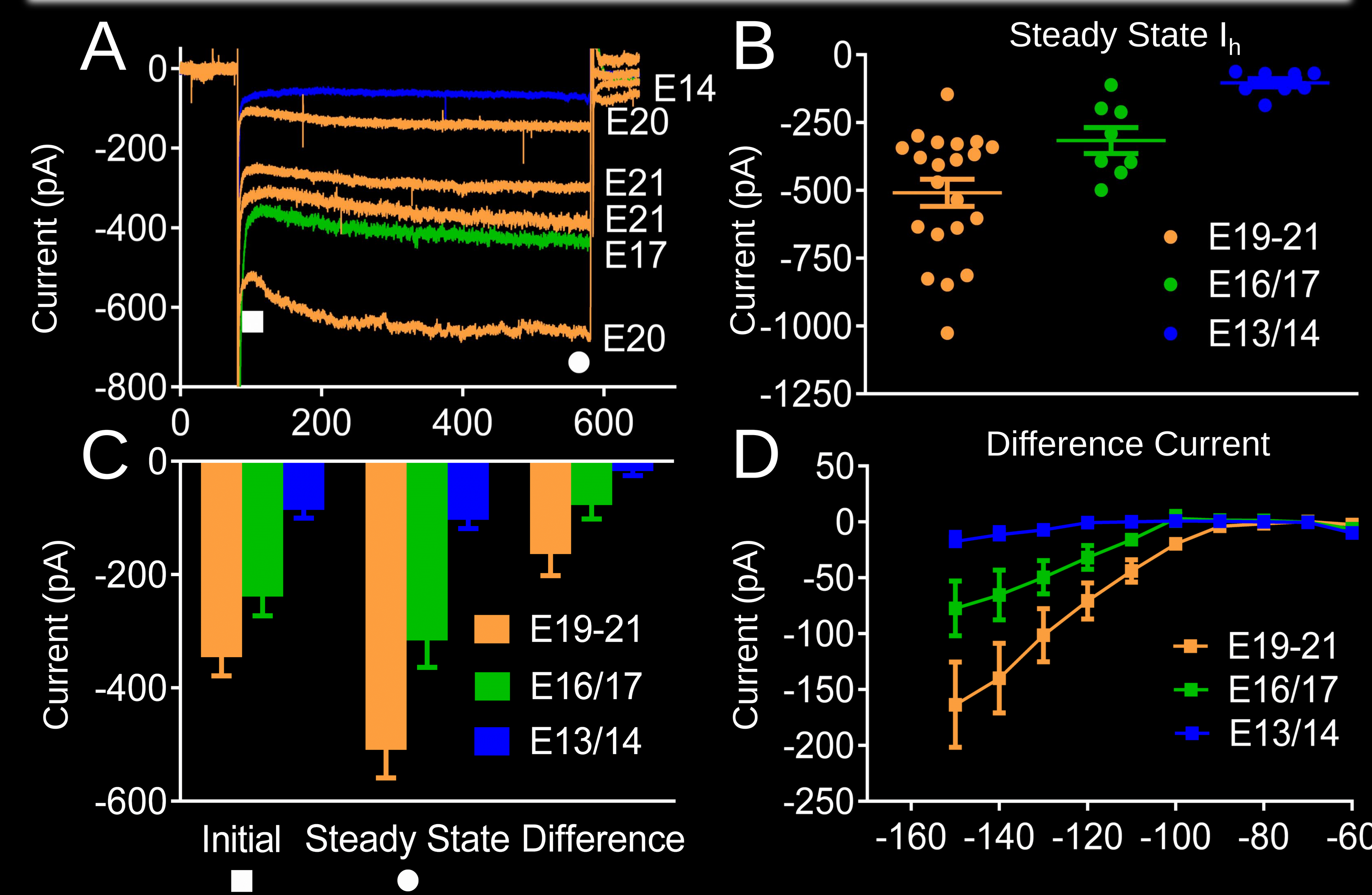

Figure 3: I_h current throughout NMc development. (A) Individual current traces at -140 mV. (B) Strip chart of steady state current. (C) Steady state initial and difference currents. (D) Difference current at multiple voltages. Error bars denote SEM.

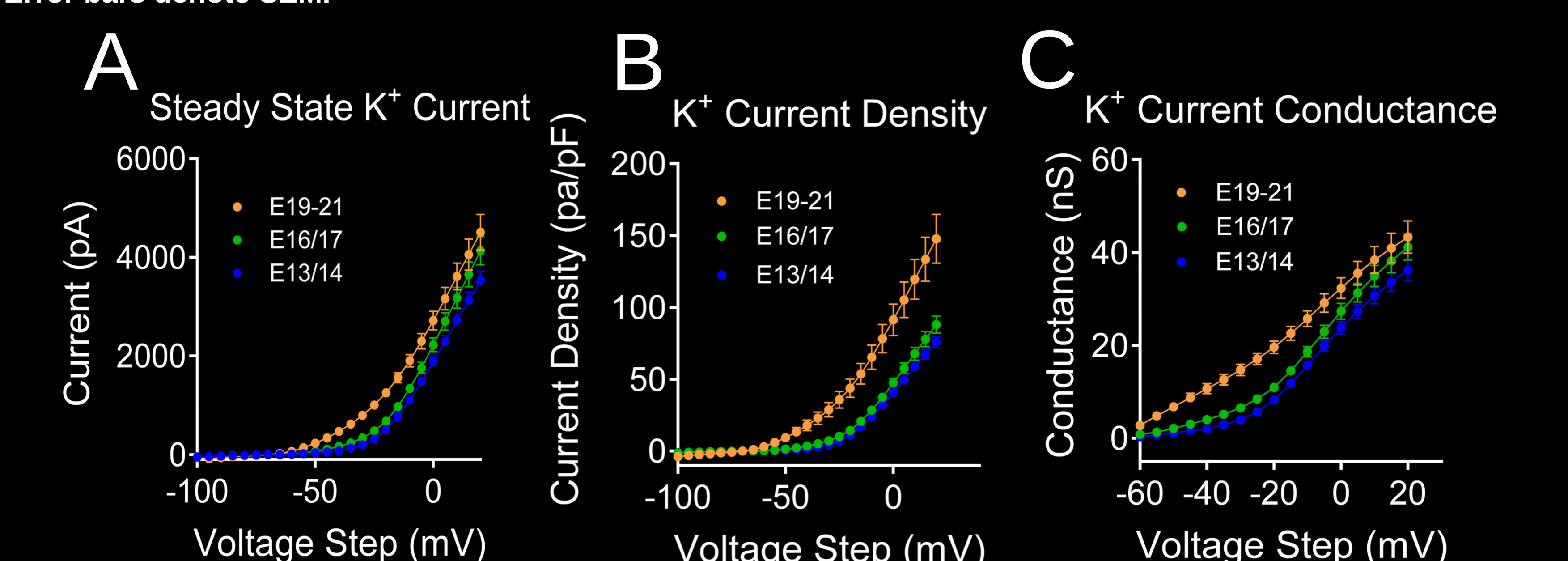

Figure 4: K^+ current properties in NMc development. (A) I/V curve from -100 to +20 mV. (B) K^+ current divided by cell capacitance. (C) Current conductance based on reversal potential of -85 mV. Error bars denote SEM.

Conclusions

1. Comparative ABR analysis can assist research in auditory development.
   - Similar subcortical encoding would suggest cortical selectivity.
2. The precocious chicken has near mature hearing at hatch, but further frequency specific refinement likely occurs.
3. Embryonic data confirm high variability in low frequency cochlear nucleus neurons.
   - How is tonotopy established? Disrupt neurotrophin development.

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