Understanding the Golden Eagle sensory world to enhance detection and response to wind turbines

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- **Co-PI1**: Jeff Lucas, Purdue University.
- **Co-PI2**: Todd Katzner, USGS.

PURDUE UNIVERSITY

USGS science for a changing world

Birds are visually-oriented organisms

Why would they collide with wind turbines?

Hodos. 2003. Report No. NREL/SR-500-33249
Martin. 2011. Ibis 153: 239-254.

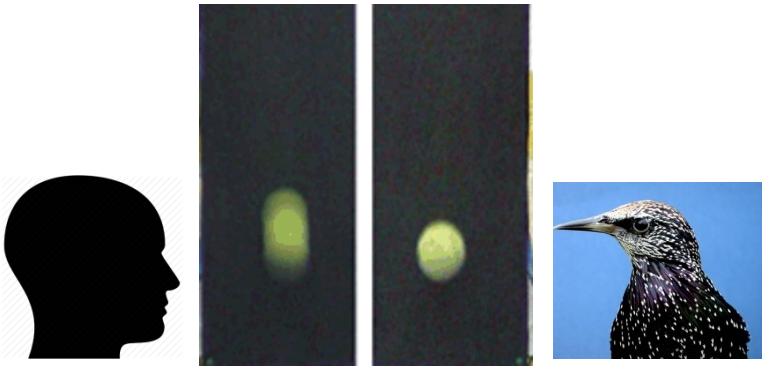
→ issue with their visual perception

Birds see their world **very** differently from humans

Lateral vision

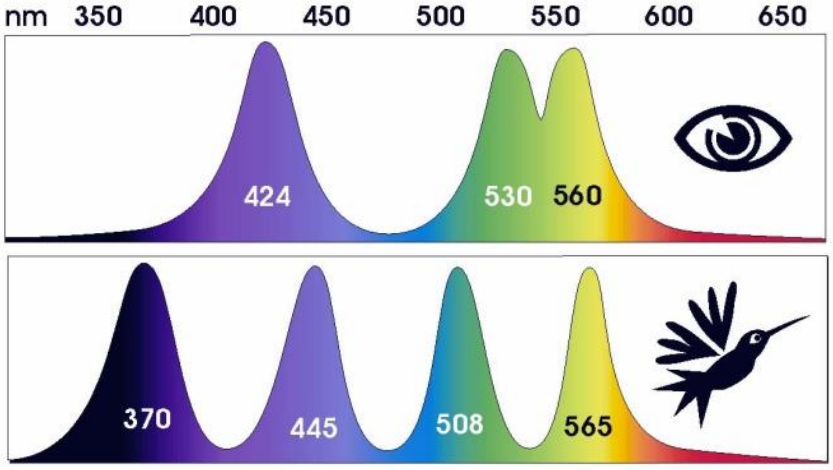
High visual acuity

High temporal visual resolution

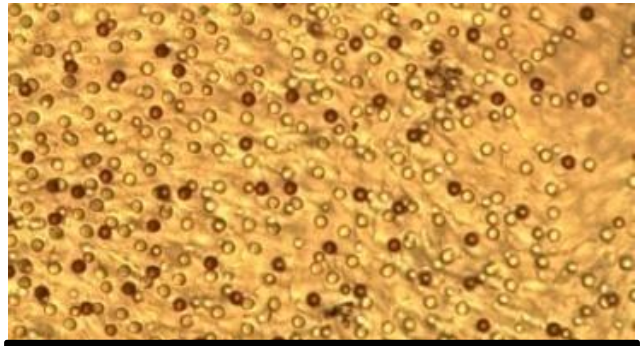


https://www.computer.org/csdl/trans/tp/2005/04/i0531.html

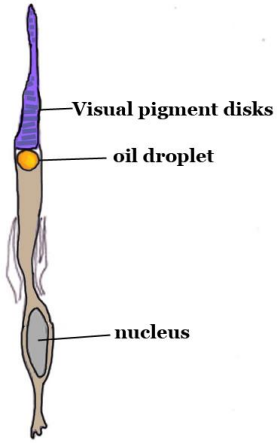
Wide color space



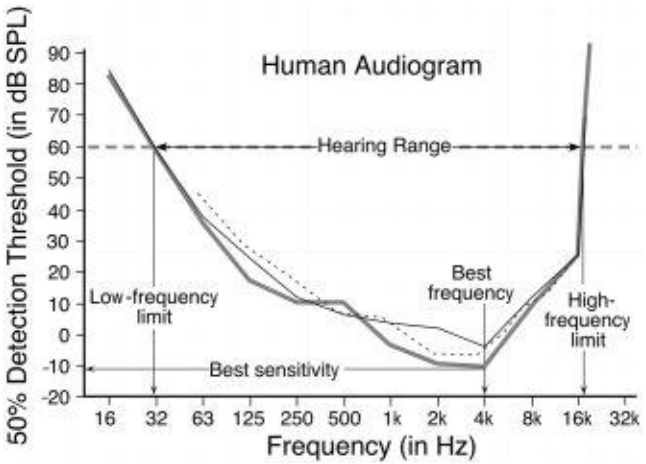
https://fieldguidetohummingbirds.wordpress.com/2008/11/11/do-we-see-what-bees-see/

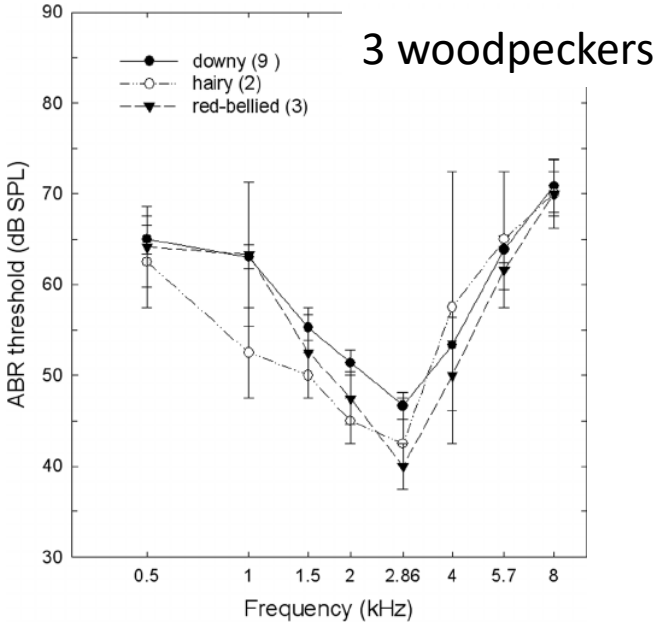


Cone oil droplets (filters)
= better color discrimination



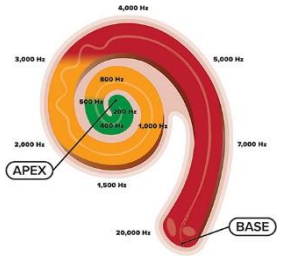
Bird's hearing is different too



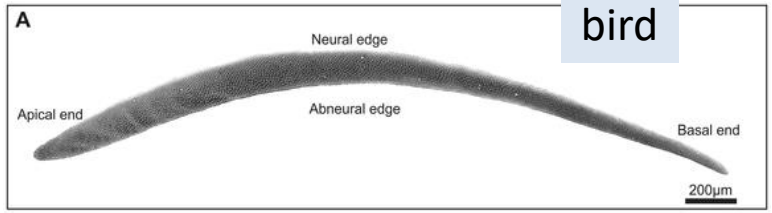


For example, humans hear a broader range of frequencies than birds, but birds have better temporal resolution than humans

-- in part because the membrane that dissects sounds into frequencies in the inner ear is 33 mm long and coiled in humans, but only 2.5-4.5 mm long and straight in birds.



human



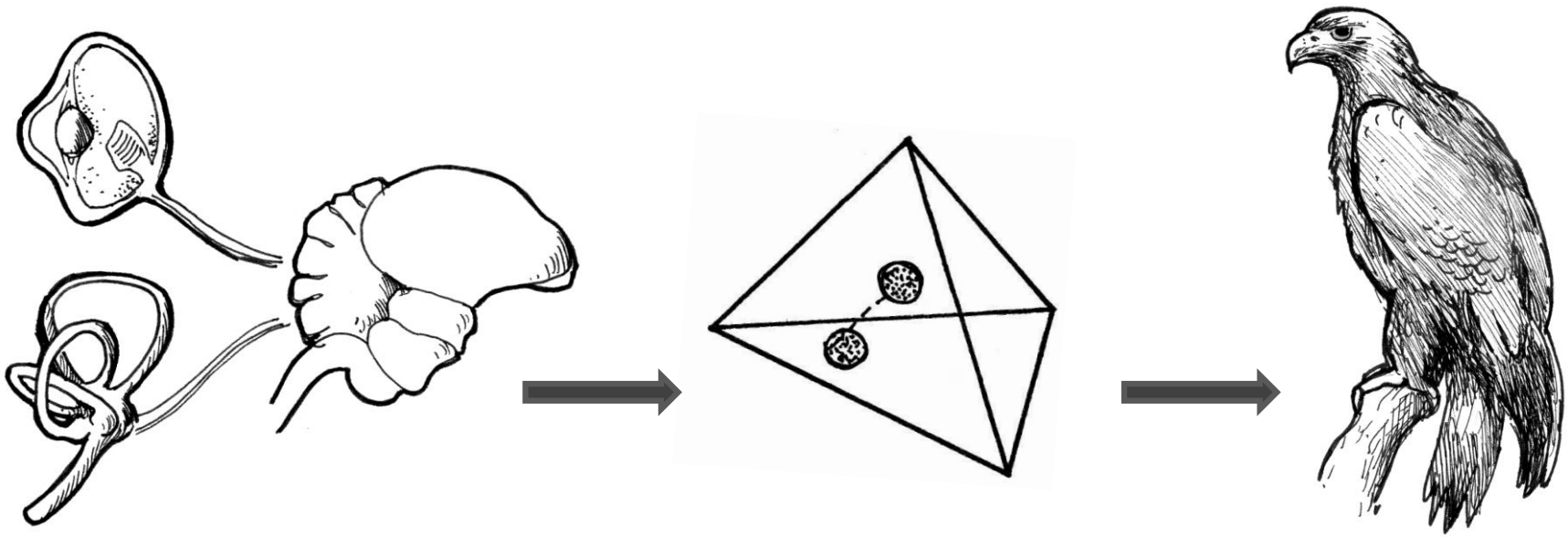
bird

Our Research Program

Make wind turbines more conspicuous for eagles by understanding how eagles respond to visual and auditory stimuli from the sensory system up

https://www.allaboutbirds.org/guide/Golden_Eagle/id

Given the particular avian sensory world, we will characterize the visual and auditory systems of eagles (sensory sweet spots) from which a combo of visual and acoustic stimuli will be used to establish increased attention or avoidance responses.



Sensory physiology

Perception

Behavior

Specific goals

1. Measure key components of the visual and auditory systems of eagles.
2. Model sensory perception to pinpoint stimuli with highest sensory stimulation.
3. Run simple behavioral tests in wildlife rehabilitation centers to determine the responses of eagles (attraction, avoidance, neutral) to combinations of conspicuous visual and acoustic stimuli.

Study species

https://www.thinglink.com/scene/764180391568343042

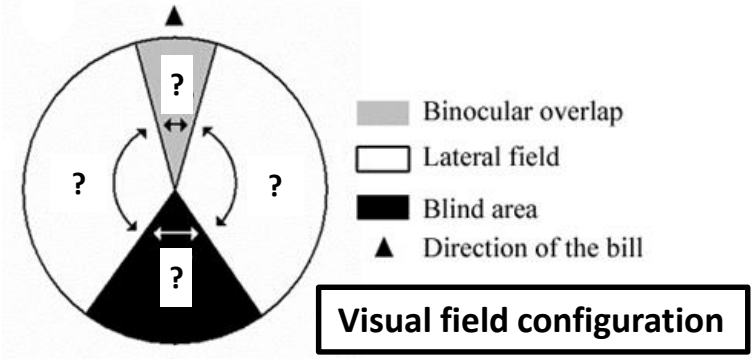
Golden Eagle

https://www.fws.gov/refuge/Umatilla/Wildlife_Habitats/Bald_Eagle.html

Bald Eagle

How can eagle visual configuration inform the design of the lights?

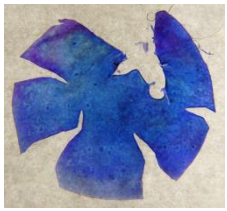
Visual system



Visual field configuration

Light properties

Light viewing angle



Density of retinal ganglion cells = projection of center of acute vision in the visual field

Position of the light in the wind turbine that enhances detection

+

Sensitivity and density of photoreceptors

Perceptual modeling

$$\Delta f_i = \ln\left(\frac{Q_{iA}}{Q_{iB}}\right) = \ln\left(\frac{\int_{300}^{700} R_A(\lambda) I(\lambda) S_i(\lambda)\, d\lambda}{\int_{300}^{700} R_B(\lambda) I(\lambda) S_i(\lambda)\, d\lambda}\right)$$

Light color with the highest conspicuousness in different ambient light conditions

Can eagle auditory physiology inform the design of altering sounds?

- Sounds to be tested that are most likely to be salient:
  - Range of tones used in their vocalizations
  - Range of simple tone sweeps somewhat faster than used in their vocalizations (i.e. unusual)
  - Range of periodic frequency-modulated tones somewhat faster than used in their vocalizations (i.e. unusual)
  - Range of amplitude modulation rates used in their vocalizations
- Auditory responses that are most likely to be useful indices of sound detection
  - Processing of sounds at intensity levels similar to those heard in the field
  - Processing of these sounds both with and without background noise

Aviary behavioral tests

https://www.zoochat.com/community/media/bald-eagle-golden-eagle-aviary.269491/

Measure responses to 2 choices of perches each associated with a different combination of light and sound

Testing will be done in 3 stages

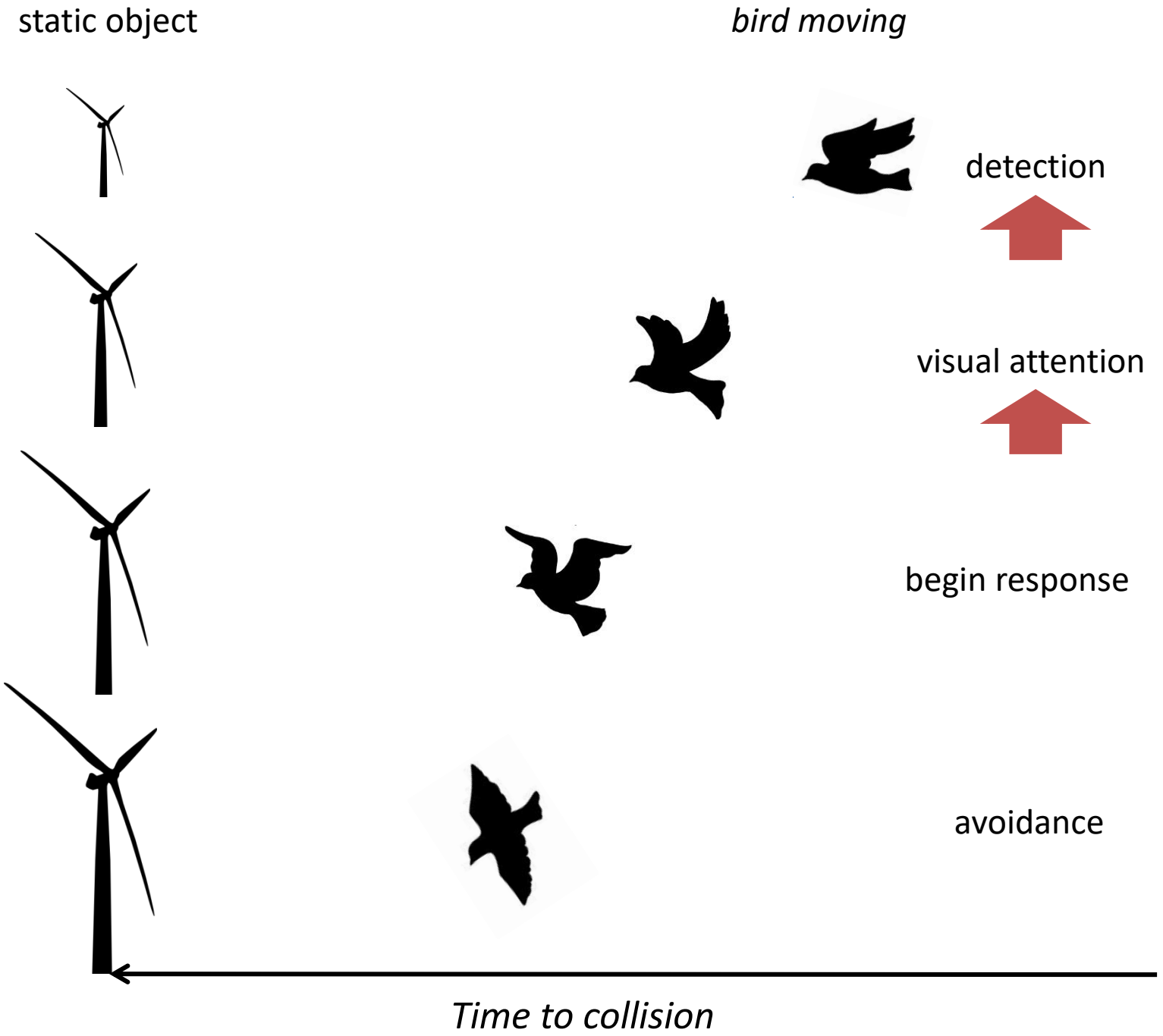
Two relevant parts: stimulus choice and behavior tests of stimuli

Stimulus

- Stage 1: Light
  - Use visual traits to identify 9 light stimuli most likely to alert eagles
- Stage 2: Sound
  - Use auditory traits to identify 9 sound stimuli most likely to alert eagles
- Stage 3: Light+Sound
  - Use 2 strongest light and 2 strongest sound stimuli to make 4 multimodal stimuli

Behavior

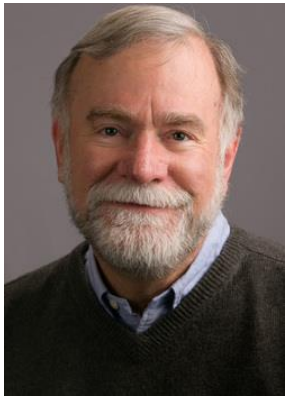
- Stage 1-2: Behavior in 2-choice tests of light or sound
  - Have a LED light (stage 1) or sound (stage 2) above one perch and no light above the other
  - Record body movements while perched and subsequent flight pattern after light or sound turns on for all 9 stimuli (presented at random)
- Stage 3: Light+Sound
  - Use 2 strongest light and 2 strongest sound stimuli to make 4 multimodal stimuli
  - Broadcast a light/sound stimulus above each perch such that all combinations of each pair of light/sound stimuli are tested against each other
  - Run tests with 2 replicates of each stimulus pairing


static object
bird moving
detection
visual attention
begin response
avoidance
Time to collision

The research team

Esteban Fernandez-Juricic:

- Avian Visual Physiology
- Visual Ecology
- Animal Behavior
- Human-Wildlife Interactions



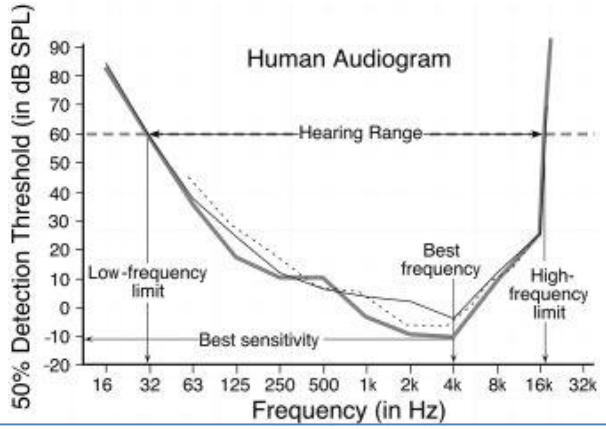
Jeff Lucas:

- Animal Communication
- Sensory Ecology
- Hearing in Birds
- Dynamic Game Theory

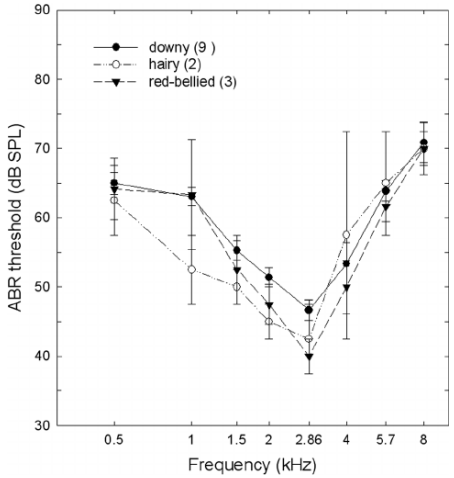
Todd Katzner:

- Conservation Ecology and Monitoring of Raptors
- Bird Movement and Migration
- Interaction between Energy Development and Raptors

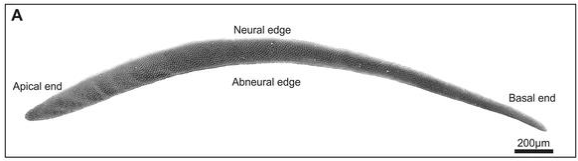
Slide 4 figure Sources



https://www.researchgate.net/figure/8242696_fig8_Figure-1-Average-audiogram-of-seven-humans-tested-in-a-soundproof-chamber-with-sounds



Lohr et al. 2013. J Acoust Soc Amer 133:337-342



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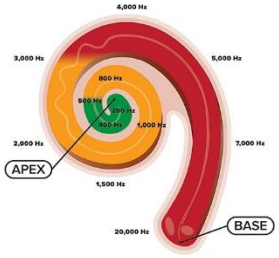

Lahav & Skoe. 2014. Front. Neurosci. 8:381