Investigating the effects of infrasound on the inner ear

Hypothesis:

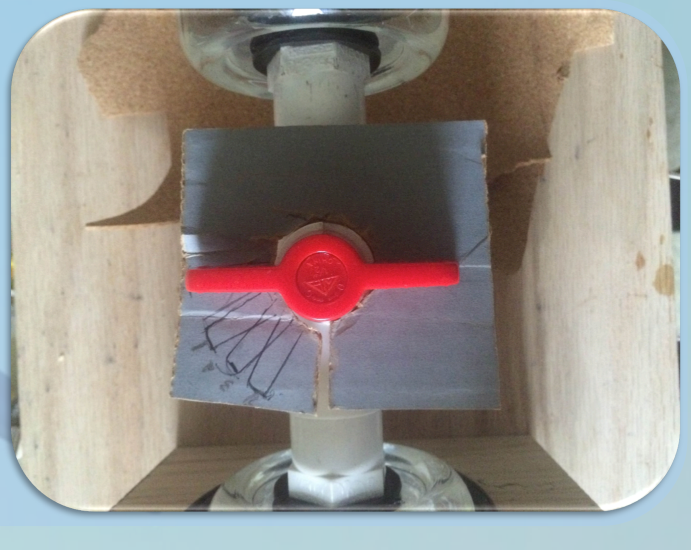
Infrasound has a physiological effect on inner ear fluid pressures.

Background & Significance

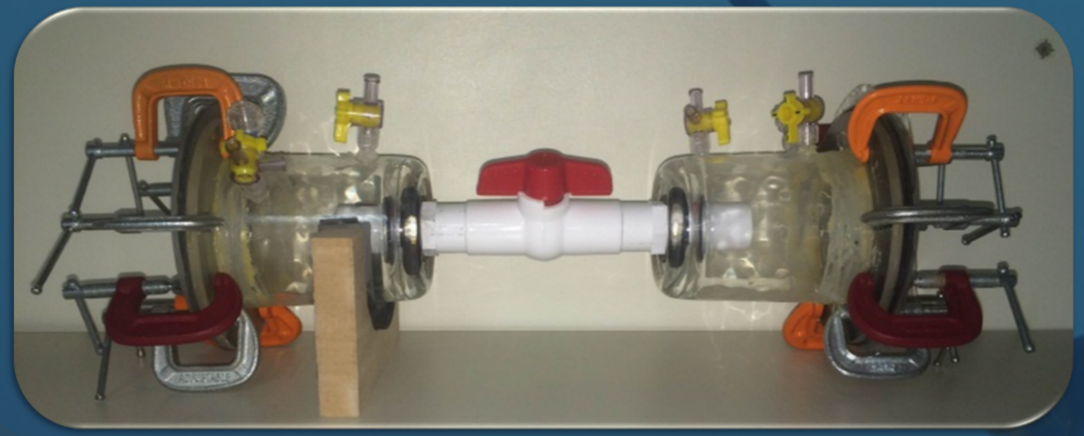
- Wind turbines harvest energy from the earth simultaneously creating infrasound, classified as sound waves with frequencies below twenty hertz.
- According to the American Wind Energy Association, 4,854 megawatts (MW) of wind energy generated from wind turbines were installed in 2014 alone, five times more than the amount of MW installed in 2013.
- Individuals living next to wind turbines have reported "headaches, difficulty concentrating… dizziness, vertigo or tinnitus, and the sensation of aural pain or pressure" (Salt, A. & Hullar, T. 2010).
- Specifically, other studies have documented that infrasound can enter the inner ear and change cochlear processing (Hensel et al. 2007).

Methods

- The mechanical infrasound generator tested on the inner ear model at six different frequencies (300, 440, 900, 1200, and 2150 RPMs)
- Various conditions: valve was open, closed, ¼ open, ½ open, and ¾ of the way open.
- Note that 1200 RPMs is the same as 20 hertz, marking the threshold for hearing.

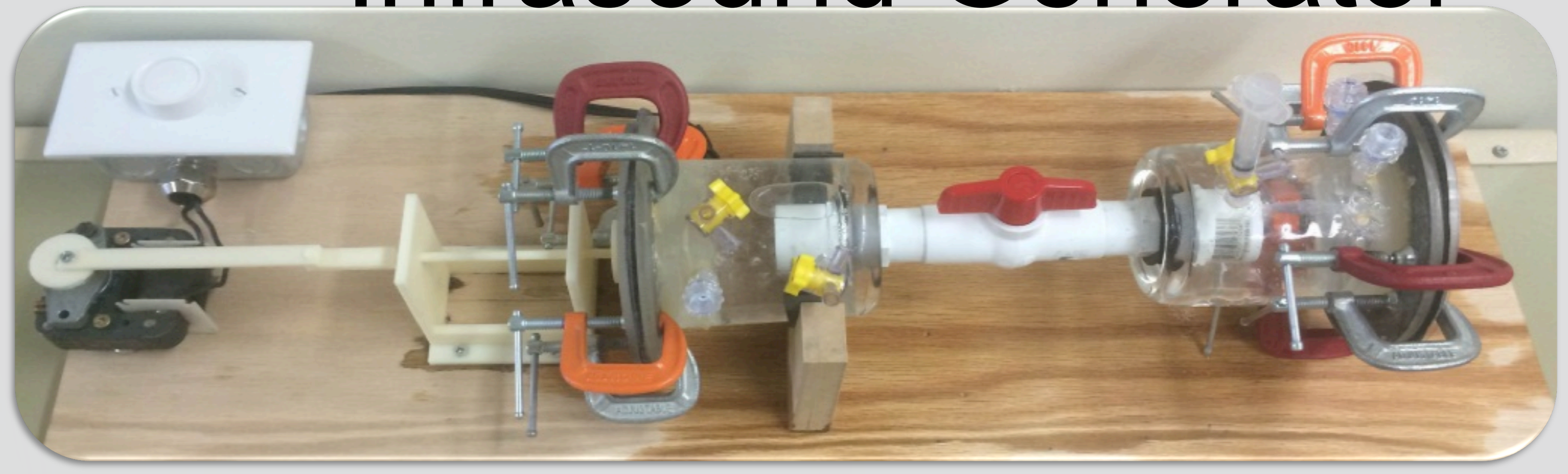


Inner Ear Model

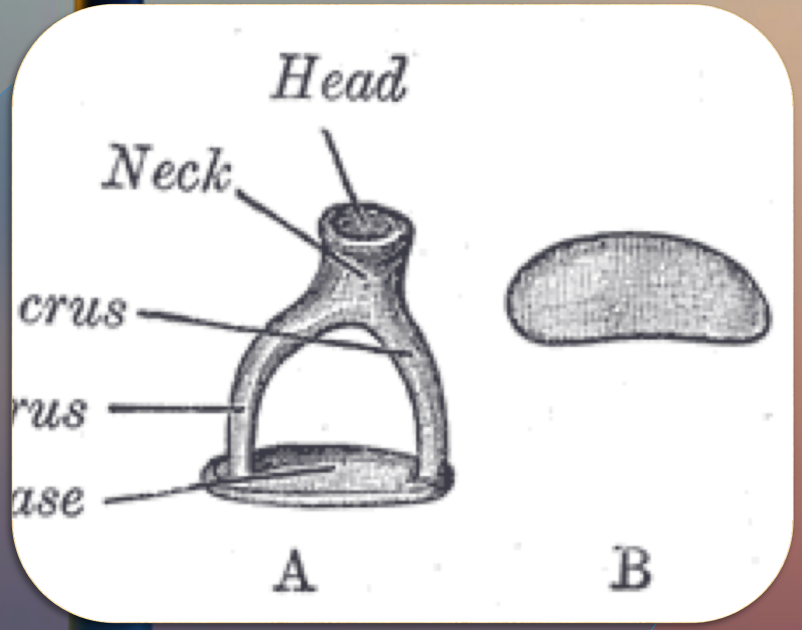


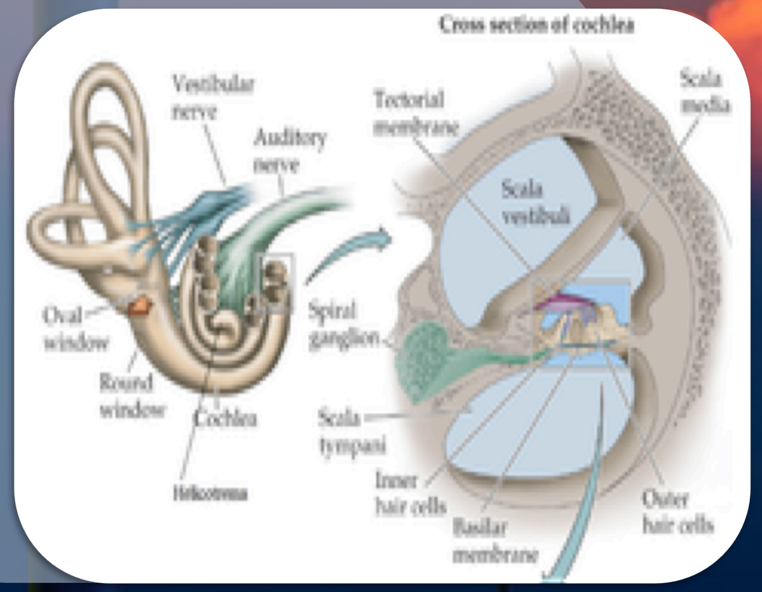
- Outer membrane closest to the infrasound generator models the oval window, the intersection of the middle ear with the inner ear.
- Connection between the compartments contained a valve acting as a resistor, modeling the helicotrema, an opening at the apex of the cochlea through which the vestibular duct (upper bony filled passage) and the tympanic duct (perilymph filled cavities) can communicate (Marquardy and Jurado 2011).
- Membrane farthest from the infrasound generator models the round window, the second intersection of the middle ear with the inner ear.

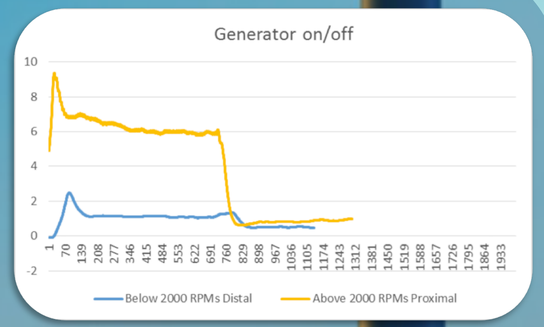
Infrasound Generator

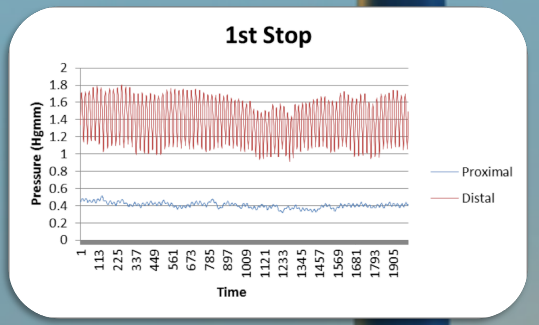


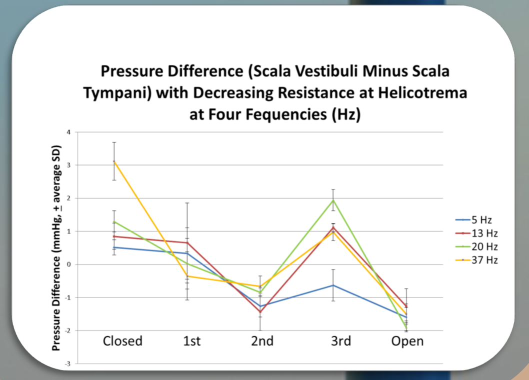
- Designed to mimic the effects of infrasound to replace of an infrasound speaker.
- Cam shaft connected to the plunger designed using SketchUp software and 3D printed.
- Plunger models the stapes bone of the inner ear by hitting the oval window.
- Generator run at frequencies above and below 20 hertz, acting as infrasound and normal sound waves.











Results

- Proximal compartment had higher pressures at all six frequencies and at four of the five different resistances where the distal compartment had lower pressures.
- When the valve was ¾ of the way open, the pressures were almost equal in both compartments.
- Pressures in the proximal compartment was higher when valve was open indicating that there may be some unknown resistance effecting the pressures
- Established that when the generator was turned on, pressure instantly increased and when the generator was turned off, pressure instantly dropped back to zero at all six frequencies.
- A small change in frequency or resistance at 20 hertz may change the outcome of the pressures in each compartment, indicating that resonance or harmonics may also be influencing these pressures.
- Relationship between resonance, harmonics and the pressures within each compartment may be too complicated to define due to the numerous components to the generator.

Future Directions

- Repeat these methods multiple times with an infrasound speaker to show that the patterns are reproducible by changing membrane compliances, amplitudes, frequencies, and resistances.
- 3D print a model of the inner ear and completing similar tests within the 3D printed stapes, oval window, helicotrema, and round window would further show that low frequency noise can change inner ear fluid pressures.
- 3D model would create a better and more realistic visual of the inner ear compared with the current two compartment fluid filled model.

References:

Cross section of cochlea, n. d. photograph, viewed August 28th 2015, https://o.quizlet.com/sX0FcXJHYY5dFgWeE0ejcg_m.png

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Stapes, n. d. photograph, viewed August 28th 2015, https://upload.wikimedia.org/wikipedia/commons/c/c1/Gray918.png

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