APA citation of journal article: Gruters, K. G., Murphy, D. L. K., Jenson, C. D., Smith, D. W., Shera, C. A., & Groh, J. M. (2018). The eardrums move when the eyes move: A multisensory effect on the mechanics of hearing. Proceedings of the National Academy of Sciences, 115(6), E1309–E1318. https://doi.org/10.1073/pnas.1717948115.

The Basics:

1. What was the broad question being asked by this research project? What was the specific question being asked by this research project?
    a. Summarize the background information on the research topic in three sentences.
    b. What is the gap in the literature identified by the researchers? What question(s) are they trying to answer? What is their hypothesis and what should happen if the author's hypothesis is true?
    c. What are alternative hypotheses?

How are the visual and auditory systems integrated in real time? Where in the auditory pathway do eye movements impact auditory processing? Specific: *Does the brain send signals to the auditory periphery about eye movements*?
Hypothesis: Eye movements are first integrated in the auditory periphery.
Alternate: Eye movements aren't first integrated in the auditory periphery; they're integrated somewhere else first (e.g., inferior colliculus, auditory cortex, superior colliculus, etc.)
Background: Previous work has found some evidence that eye movements modulate auditory processing, but this is much later in the process than Gruters and colleagues speculate happens. Gruters and colleagues suggest two possible ways that the auditory pathway could be modulated by descending neural pathways in the brain (presumably a mechanism for why the auditory periphery is a good candidate).

2. What experiments were done to test the hypothesis or investigate the research question?
    a. Explain the task design – what are participants instructed to do and what is being measured? Think about the independent and dependent variables.

16 participants had a microphone placed in their ear canal and moved their eyes to visual targets varying in horizontal position on the screen. Sometimes there were noises before, during, or at timepoints when participants made saccades so the researchers could compare neural signals in silence and during sound.

Fig 2: Dependent variables are microphone signals and eye positions, per independent variable of time relative to when they moved their eyes.

Fig 3: regression is between saccade amplitude and direction and microphone voltage (compared against the scrambled data); most subjects show the effect

Usually thinking about the amplitude and direction of the eye movement as it related to inferred ear drum movement (sound pressure, mm, microphone voltage)

3. What evidence supports each of the conclusions?
    a. Before you read the discussion, summarize the main findings and link each one back to the research question(s). How does each result inform the hypothesis?

- Eardrums move with saccades
    - Change in ear canal pressure abt 10 ms before eye movement onset (in prep?)
    - Significant slope of line between amplitude of saccade and voltage, and the direction of the saccade and voltage (visual: 2F, 2g, Fig 3)
    - Direction of gaze relative to recorded ear determines phase
- Eye movement-related eardrum oscillation (EMREO) is related to relative, not absolute, saccade direction
    - Phase relation: for a given moment during a given saccade, eardrums bulge inward in one ear while bulging outward in the other ear (Fig 4 a & b)
- Relating the EMREO Signal to Eardrum Displacement
    - They converted the microphone voltage signal to calculate around how many mm the eardrum moves for different saccade types and the sound pressure (Fig 5c)
    - Inferred initial deflection opposite direction of saccade: when eyes moved left, eardrums moved right, & vice versa
- EMREOs in Monkeys
    - Characterizes the time pattern in monkeys (4b-e – probably typo? Meant fig 6?)
- Controls for Electrical Artifact
    - Maybe electrical signals in the eyes, due to eye movements, causes this, and that's what the microphone is picking up
        - Acoustically occlude the microphone; effects no longer present. Can't be that mike is just picking up on that (fig 7).
- EMREOs and Click Stimuli
    - Occur in silence and when sound is presented
    - Subtracted out signal when clicks presented; EMREO not changed (Fig 8). Peak-to-peak amplitude doesn't correspond either

4. What are the major conclusions?
    a. What do the results add to the field? How do the researchers interpret their findings? Summarize any limitations identified by the researchers.

"When the eyes move left, both eardrums initially move right and then oscillate for three to four cycles, with another one to two cycles occurring after the eye movement is complete. Eye movements in the opposite direction produce an oscillatory pattern in the opposite direction. This EMREO is present in both human and nonhuman primates and appears similar across both ears within individual subjects." Pg. E1315

The biggest limitation is that the researchers doesn't really identify why this happens. They speculate a lot on why it could be important and other things they want to look at.

The Critique:

1. Is the paper well written? How do you know? For week 2 & later, use this space to practice headlines & summaries of the articles via tweets.

Sometimes a bit too technical; I got why they wanted to use EMREO, but a couple of times I had to flip back. It has a few good summary sentences that help with the technical language. The headlines of the science news articles do a good job summarizing the Big Idea of this paper.

2. Do the conclusions seem logical given the data processed? Why or why not? Another way of thinking about this: do the results adequately support the conclusions that are drawn? Are there alternative explanations for the findings? What inferences about the hypotheses and questions can be made based on these results?

Makes sense that if the eye movements are causing the eardrum to move (at least in preparation), it's related to the amplitude and direction of the movement. This is indirect evidence, but I'm not sure how you could see it happening live. The authors don't have data to show why this occurs or how it could impact other processing (e.g., what if they had these microphones in the ears, but were also recording from neurons in key auditory processing areas? Especially on silent trials). They replicate the results in 2 human samples, looked at humans individually, and looked at monkeys, so it's likely a real effect (most sensory processing effects are considered more reliable, because they are more basic properties of cognition. Sensory processing generally has fewer individual differences.).

3. Are the conclusions important? How do you think this relates to everyday behavior?

I think it's interesting to consider how vision/auditory signals are integrated, but it's hard to know what it means if our eardrum moves when we move our eyes. The authors also suggest that this is an example of multisensory information in peripheral processing and that the brain is controlling information early in sensory processing (comment on top-down processing) to make best-informed decisions.

4. What were the best aspects of the research presented, and how could the research be improved? Name at least one way to improve the experiment.

See comment above: I would like to know what this means. The authors say that these signals could have value for disorders where there are auditory or visual-auditory deficits, but don't show us anything to suggest why. They mention why the oscillations could be important. The authors suggest that a copy of a motor command to generate the eye movement could cause the signal. But all of these possibilities are not explicitly tested.

5. How would you follow-up this experiment or study?

Wrote about this in four and two.

Additional Resources: What are the basic concepts that you need to know to understand the science presented in your paper? What other information or resources would help you better understand the paper? This is helpful to consider for your science communication pieces. *Possibly about how textbooks teach auditory & visual processing (see slides).*

Further Questions:
Write at least five comments or questions about the article to discuss with the class.

1. Is this interesting? It's such a new and bizarre effect, but I do wonder if it's important.
2. What could they have done to make this more meaningful?
3. Do you like the convergence across species? Is this a basic property of primate or all cognition? Is it possible to do in other species? Probably not?

4. It seems like the lab's future experiments are on oscillations (based on the extensive discussion). Is that the most exciting next new avenue of research?
5. Simple idea, simple design; maybe that made it a good article to cover for SciComm?