Change in Pupil Size Reveals Impact of Simulated-Cochlear Implant (CI) Speech on Listening Effort

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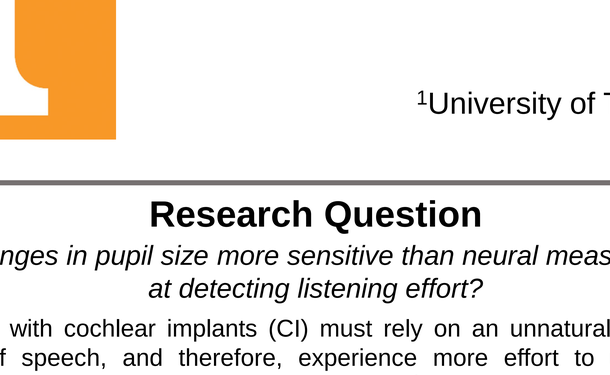
Research Question

Are changes in pupil size more sensitive than neural measurements at detecting listening effort?

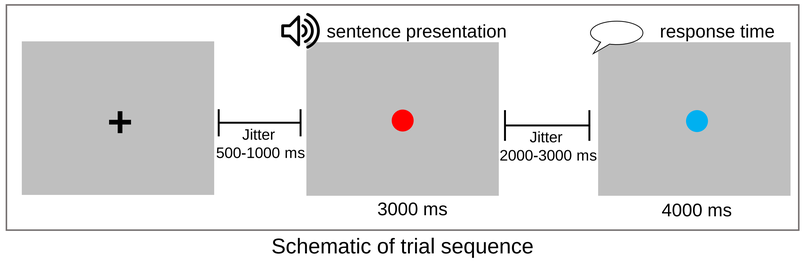
Listeners with cochlear implants (CI) must rely on an unnatural, degraded quality of speech, and therefore, experience more effort to understand speech than people with normal hearing (NH).[1] Changes in pupil size have been shown to reflect the amount of cognitive resources required to carry out a task.[2] While we previously showed increased neural response as a function of speech intelligibility,[3] we did not observe neural differences between normal speech and CI speech.

Methods

Young NH adults performed a speech recognition task while changes in pupil size and brain activity were measured concurrently. Neural activation was measured with functional near infrared spectroscopy (fNIRS) from left frontal, temporal, and parietal regions while participants listened to sentences at ~65 dB SPL either in speech-in-quiet (SIQ), simulated CI speech/vocoded (VOC), or speech-in-noise (SIN) in a randomized order. During the sentence presentation, participants were instructed to fixate on a red dot. At the end of each sentence, the fixation dot changed to blue, cueing participants to repeat back the sentence.



Layout of the experiment room



Schematic of trial sequence

References:

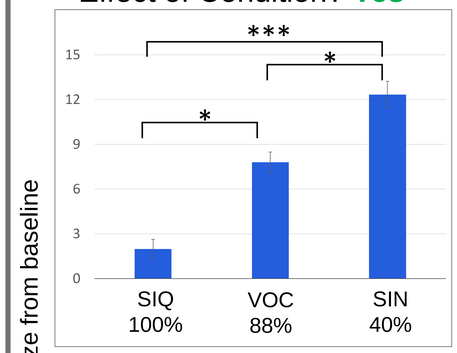
1. Wang, Y., Naylor, G., Kramer, S., (2018). Relations Between Self-Reported Daily-Life Fatigue, Hearing Status, and Pupil Dilation During a Speech Perception in Noise Task. *Ear and Hearing, 39, 573-582.*
2. Zekveld AA, Kramer SE. Cognitive processing load across a wide range of listening conditions: insights from pupillometry. *Psychophysiology 2014, 51:277–284.*
3. Defenderfer, J., Kerr-German, A., Hedrick, M., & Buss, A. T. (2017). Investigating the role of temporal lobe activation in speech recognition accuracy with normal hearing adults: An event-related fNIRS study. *Neuropsychologia*, *106*, 31-41.

Results

Pupil and fNIRS data were analyzed with repeated measures ANOVAs. Cross-measure correlations performed via two-tailed bivariate correlational analyses using Pearson coefficient.

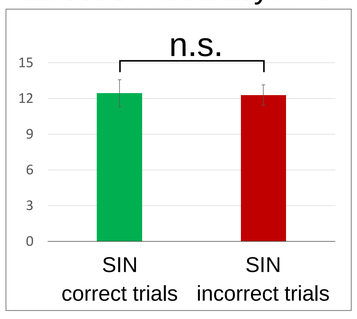
Pupil Data

Effect of Condition? **Yes**



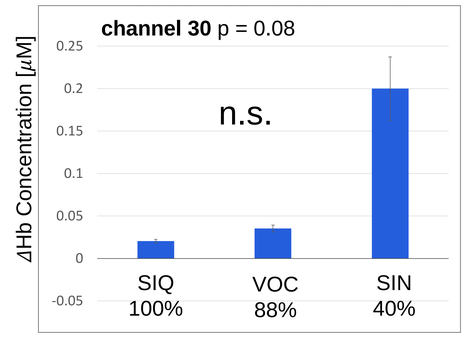
- Changes in pupil size revealed a **Condition effect:** Pupil size significantly increased as cognitive demand increased.
- However, the pupillary response was not sensitive to differences in recognition accuracy in the most difficult (SIN) condition where accuracy was 40% on average.

Effect of Accuracy? **No**

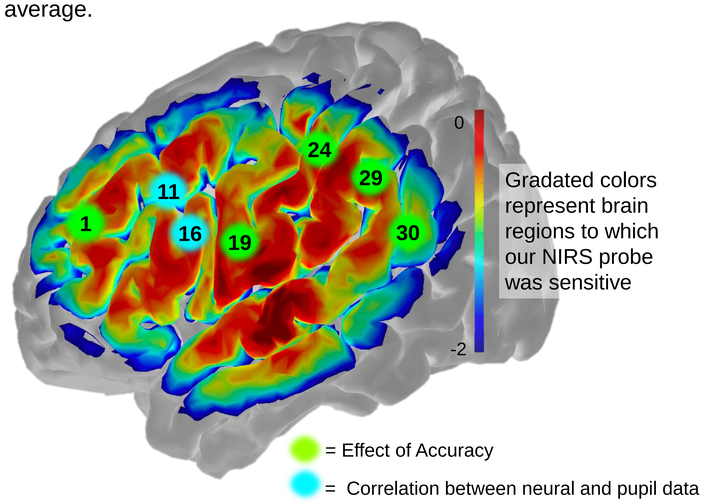


fNIRS Data

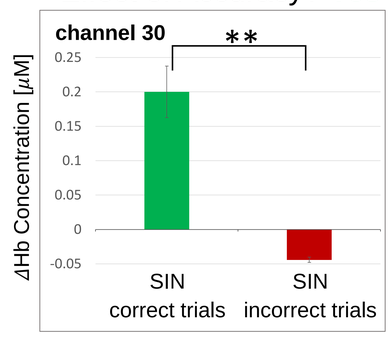
Effect of Condition? **No**



- We found a marginal effect of condition on neural activation for correct trials on channel 30 (posterior temporal region).
- We found a significant effect of **recognition accuracy:** Significantly higher activity during correct speech trials compared to incorrect trials on channels overlaying frontal and posterior temporal regions.



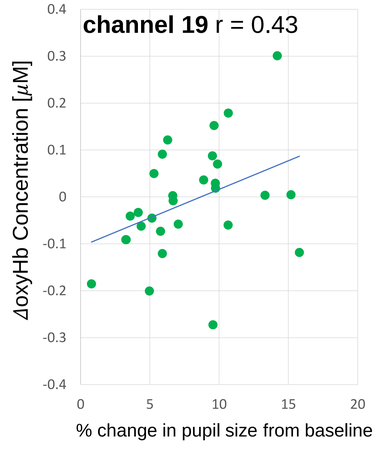
Effect of Accuracy? **Yes**



* p < .05
** p < .01
*** p < .001

Cross-measure Correlations

- We found a significant positive correlation between pupillary response and neural activity in the neural regions related to effortful processing (i.e., frontal and sensorimotor) during the VOC trials.



Summary

The results presented here indicate:

1. The pupillary response is a more sensitive measure of listening effort compared to neural measurements via fNIRS.
   - VOC trials demanded more cognitive resources than SIQ, and further, that SIN trials required greater effort than both VOC and SIQ.
2. Neural activation, on the other hand, is a more sensitive measure of performance accuracy.
   - The frontal and posterior temporal regions reveal significantly higher activation during correct responses relative to incorrect responses.
3. Finally, activity in regions of the frontal lobe correlate with changes in pupil size for the VOC trials, indicating these regions may be involved in the effortful processing of simulated CI speech.