Cortical hemodynamic responses to degraded speech shows activation in right fronto-temporal cortex and Broca's area

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BACKGROUND

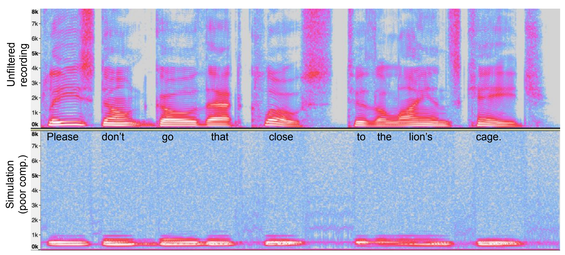
The transient nature of spoken language can render the task of comprehending language into a daunting task for individuals with typical hearing. For individuals with hearing loss, this task may become difficult or even impossible. Most deaf children in developed countries, as well as many post-lingually deafened adults, are now able to receive benefits to their hearing through the intervention of cochlear implants (CI). However, speech perception outcomes show widely varying outcomes, independent of audiological and demographic background.

To improve the outcomes of poor CI users, a better understanding of cortical processing of CI-produced speech, the underlying cognitive framework, and possible compensatory neuroplasticity is required. Speech processing in CI users has traditionally been modeled using vocoded speech (Shannon et al, 1995). More recent work (Dorman et al., 2017) has provided evidence that bandpass filtering and spectral smearing may produce a more accurate representation. The effect of this signal distortion on comprehension is not well understood.

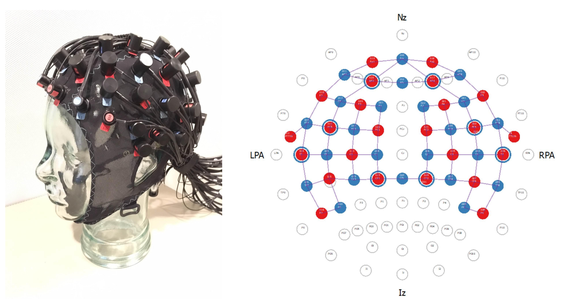
METHODS

17 healthy, typical hearing adults (ages 18-40):

- 60 CUNY sentences (Boothroyd et al., 1985), with 20 interleaved fillers.
- Unfiltered Recording vs. Simulated input of a Cochlear Implant user with either moderate or poor oral language comprehension.
- CI simulation based on Dorman, et al. (2017)



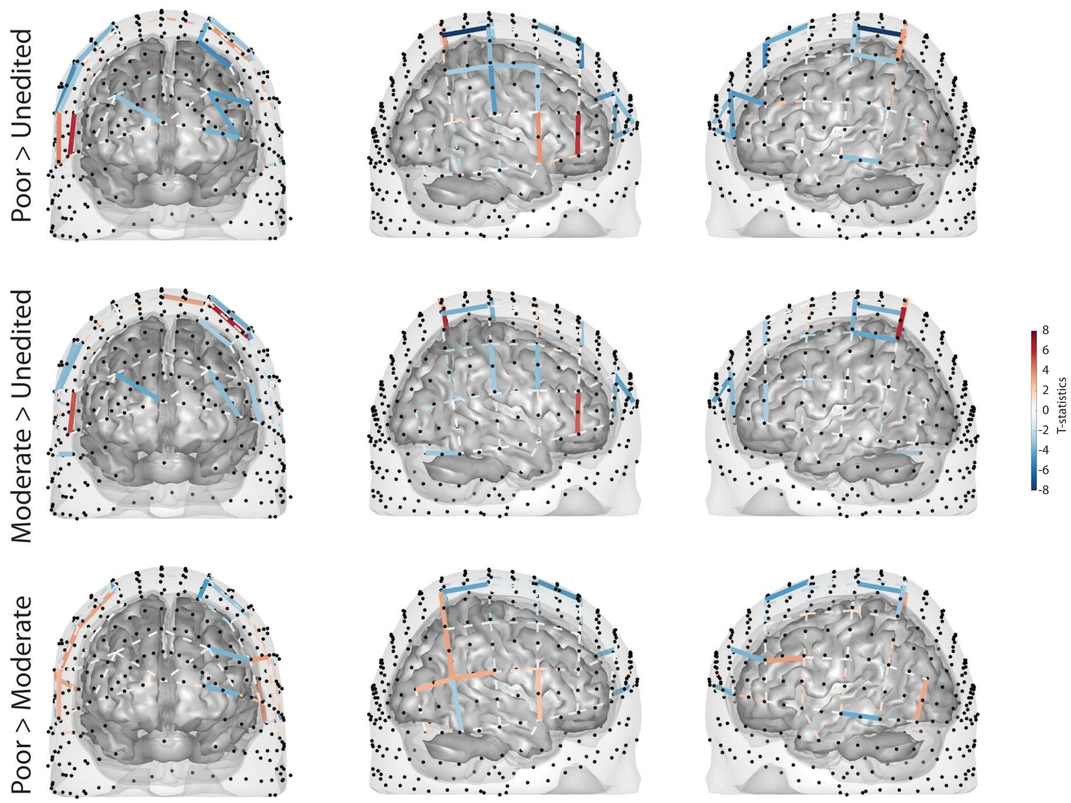
Hemodynamic responses were recorded using a NIRx NIRScout fNIRS system, with 24x 24 optodes and 8 short channels, with the layout below:



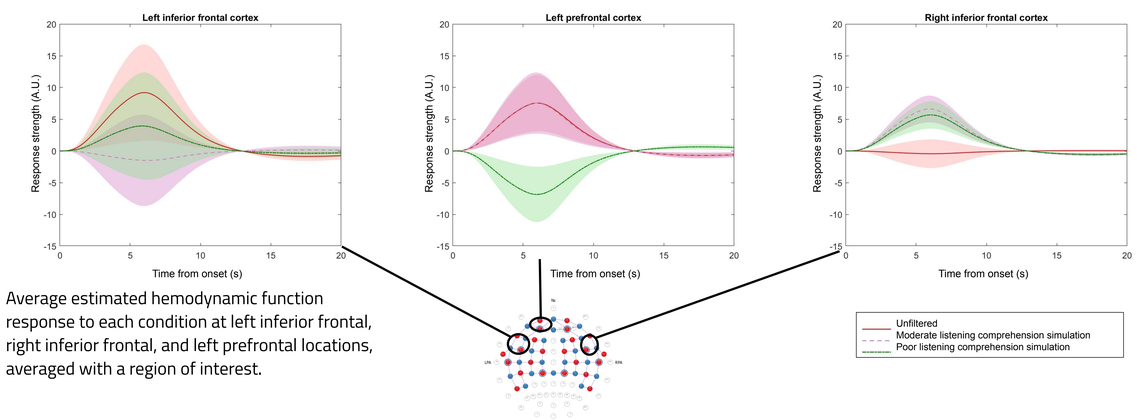
Analysis with +NIRS Toolbox (Santosa et al, 2018), an open-source analysis software built in MATLAB.

RESULTS

HbO concentration changes: differences between the conditions



Colored bars represent the t-values of for the differences between conditions, with solid lines representing channels which survived multiple comparison correction using FDR.



Average estimated hemodynamic function response to each condition at left inferior frontal, right inferior frontal, and left prefrontal locations, averaged with a region of interest.

CONCLUSION

In response to the unfiltered sentences, we found that there were many perisylvian language areas showing activation. This is as one might expect given the nature of the stimuli. Further, unfiltered speech produced stronger activation than unintelligible speech in both left and right prefrontal cortices.

When the speech stimuli were filtered to simulate the experience of a moderately successful user of a CI, we found an increased activation around right inferior frontal area. This could be caused by an increased reliance on spectral cues. It should be noted that participants reported that these sentences were only marginally harder to understand than the unfiltered speech.

For the sentences filtered to simulate the experience of a poor user of a CI, participants reported after listening that these sentences were nearly unintelligible. Right inferior fronto-temporal area was more activated than during normal speech, and the left inferior-middle frontal area (near Broca's area) showed stronger activation than during moderately modified speech.

The majority of the language areas were significantly less activated than when the stimulus was more intelligible. This could be caused by an increased reliance on porosity, periodicity, and phonetic cues. However, we also propose the possibility that this effect may be an up-regulation of cognitive control mechanisms related to effortful listening.

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