A Neurophysiological Investigation of Listening Effort in Normal Hearing Adults using fNIRS and Pupillometry

THE UNIVERSITY of TENNESSEE KNOXVILLE

Jessica Defenderfer[a], Jubin Son[b], Caglar Tas[b], Aaron Buss[b]

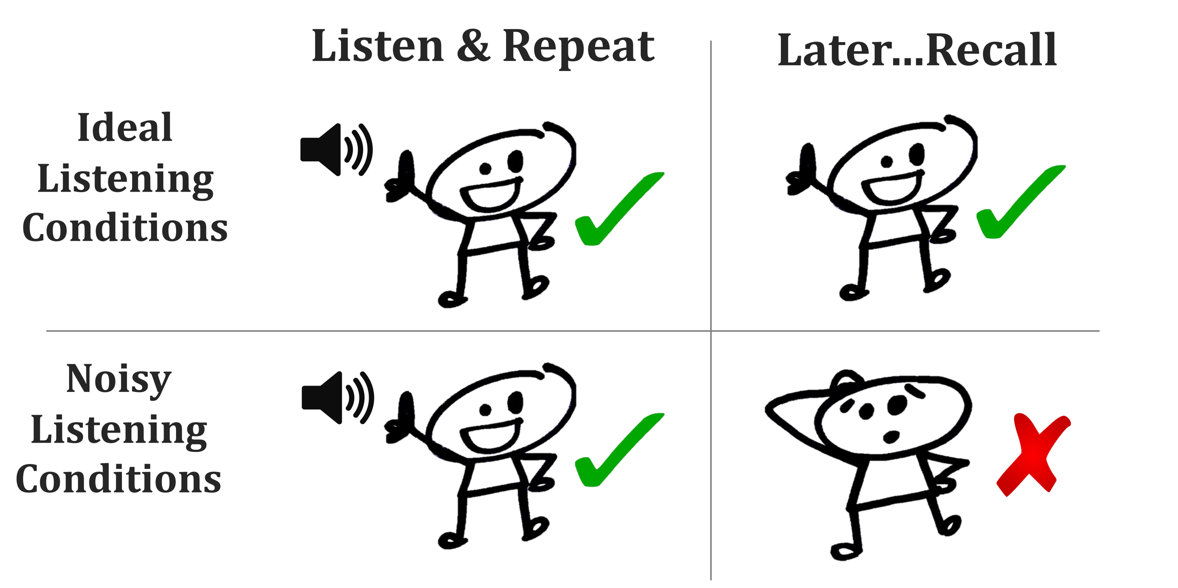
[a]Speech and Hearing Science, University of Tennessee Health Science Center, USA

[b]Department of Psychology, University of Tennessee, USA

Background

Listening Effort

- When listening to speech becomes challenging, people must "try harder" to understand speech.
- Speech recognition ability ≠ Listening Effort[1]



- Sustained, daily listening effort is associated with social withdrawal, higher after-work fatigue, and increased need to take leave from work.[2]
- The neurophysiological mechanisms of listening effort are not fully understood.

Research Aims & Hypotheses

Research Aims

1. Examine the effect of response type (vocalizing vs button-press) has on task difficulty and effort.
2. Investigate how semantic context and spectral degradation (vocoding) interacts with cortical activation and pupillary response.
3. Characterize listening effort by identifying relationships between measures of effort, performance, and neural activation.

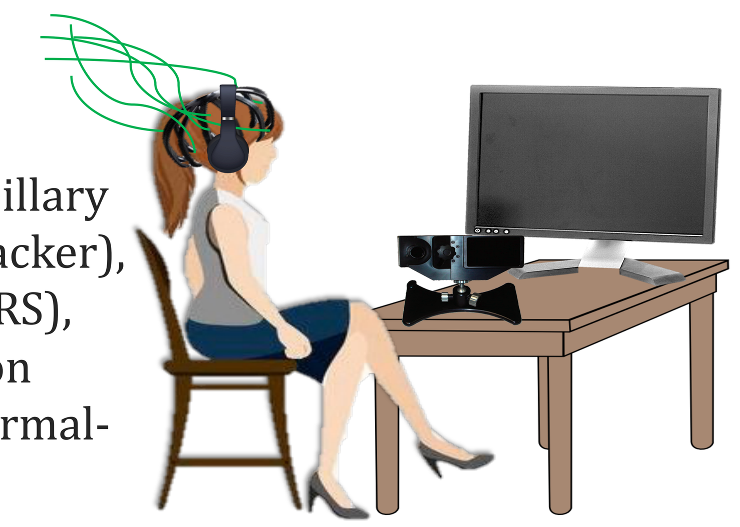
Hypotheses

1. Difficulty of Spoken Response > Button Response task.
2. Frontal cortex Activity : High > Low Semantic Context
3. Effort (pupil size): Low Context, Degraded Speech > High Context, Speech in quiet
4. Speech recognition performance: High > Low Context
5. Hemodynamics in frontal and inferior parietal lobes associated with effortful processing
6. Hemodynamics in the frontal and temporal lobes associated with speech recognition performance.

Methods

Approach

Collect concurrent measurements of pupillary responses (via eye-tracker), brain activity (via fNIRS), and speech recognition performance in 41 normal-hearing adults.



Dependent Measurements

1. Effort: Change in pupil size (ΔPPR)
2. Neural: Brain activity (ΔHbO)
3. Behavioral: Accuracy of participants' answers
   - Recognition Score (% correct)
   - Semantic Gain (% change from Low to High Context)

Task Manipulations

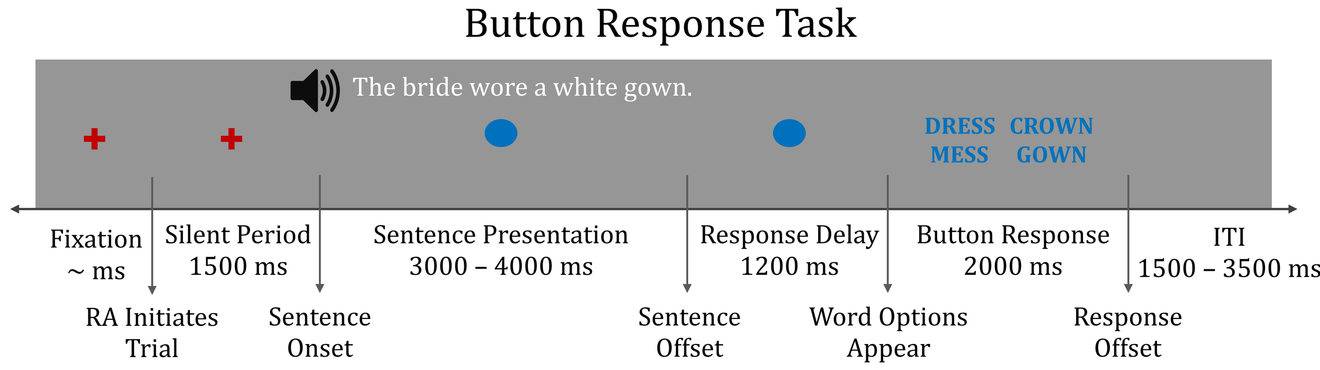
1. **Speech Quality (In-Quiet, Degraded)**
2. **Predictability (High-, Low-Context)**
3. **Response Type (Spoken, Button Response)**

Conditions

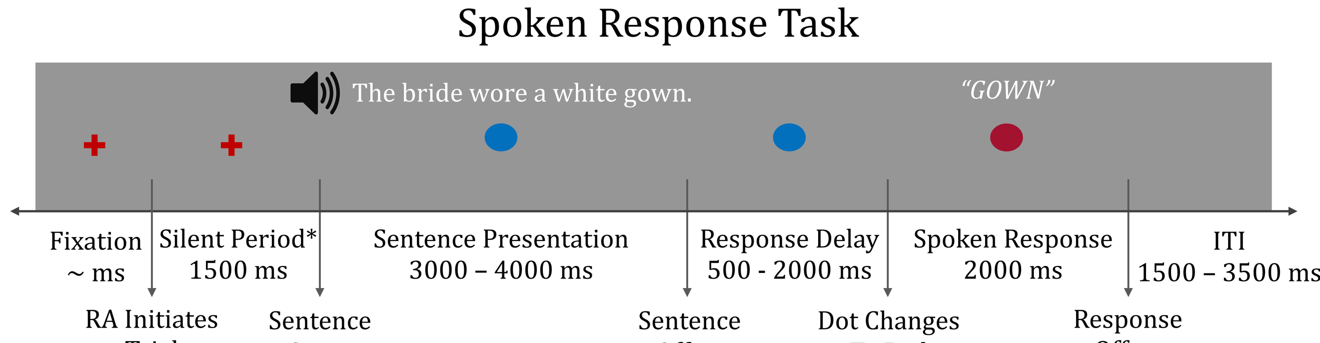
Predictability	Speech Quality: In-Quiet	Speech Quality: Degraded
High Context	"The smoke filled his LUNGS."	"The smoke filled his LUNGS."
Low Context	"He was talking about the LUNGS."	"He was talking about the LUNGS."

Experimental Task

Button Response Task



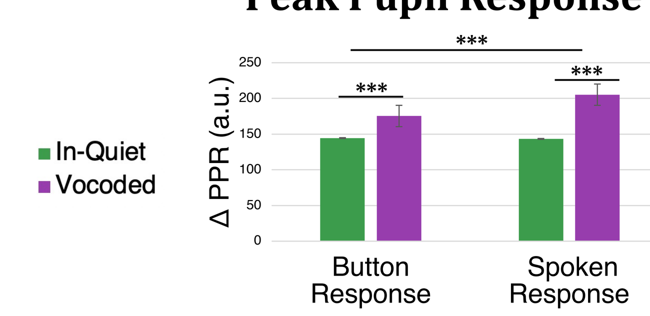
Spoken Response Task



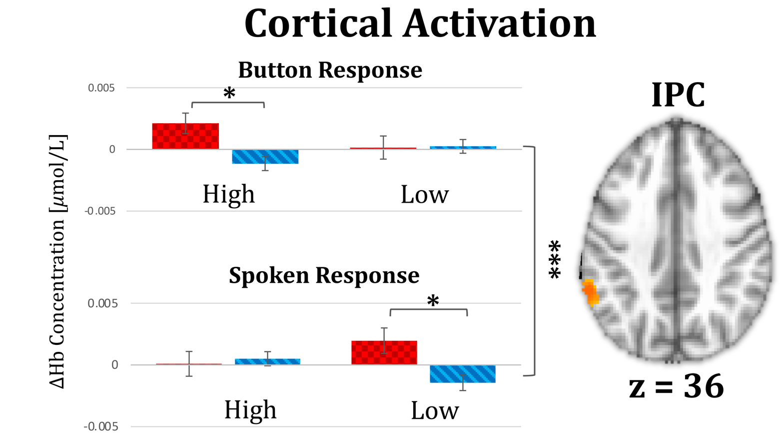
Results & Discussion

Aim 1 – Effect of Response Type

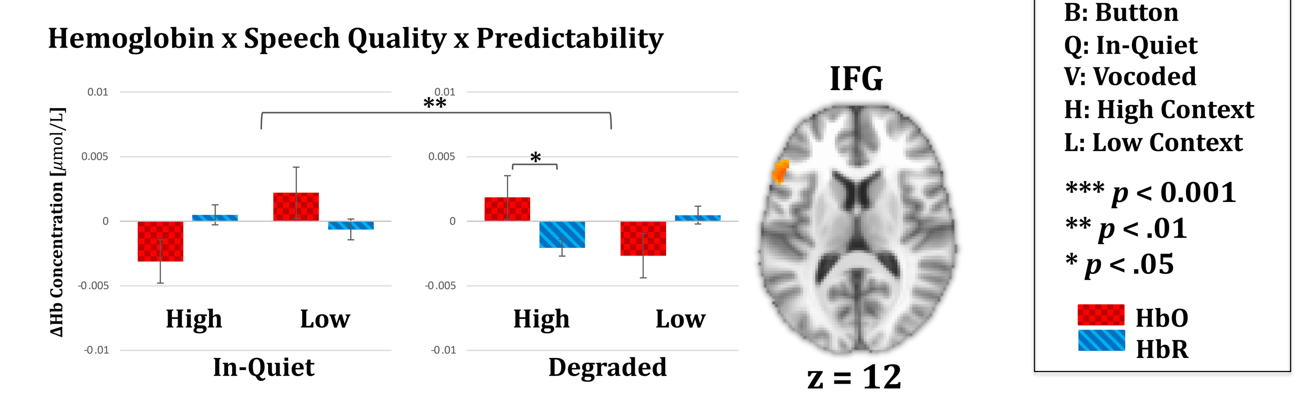
Peak Pupil Response

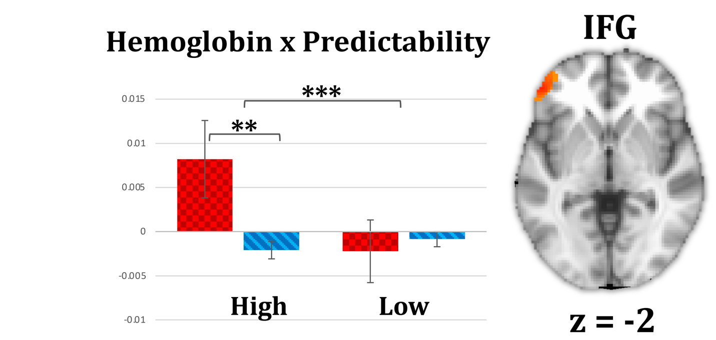


Cortical Activation



Aim 2 – Effect of Semantic Information and Speech Degradation

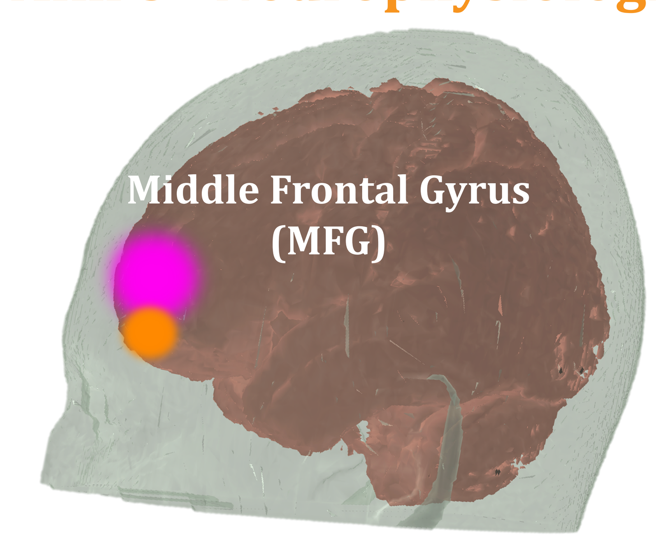




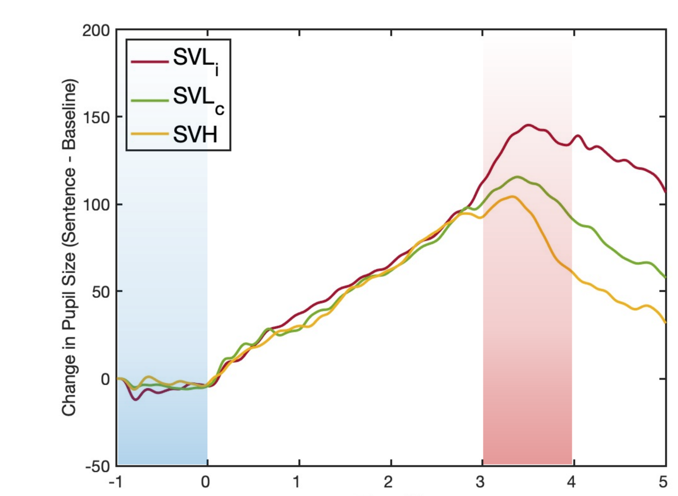
Impact on Performance

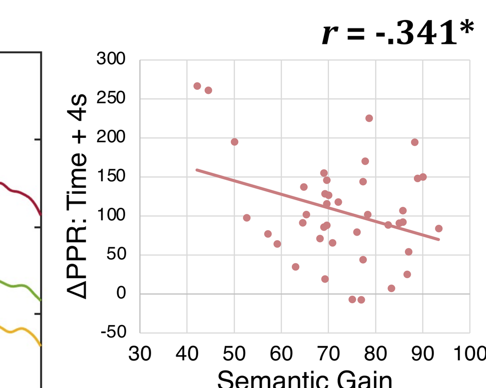
Condition	Mean (Std. Dev. +/-)
SVL	52.4 (8.3)
SVH	87.1 (6.1)
BVL	96.8 (3.4)
BVH	97.9 (3.2)

Aim 3 –Neurophysiological and Behavioral Correlations

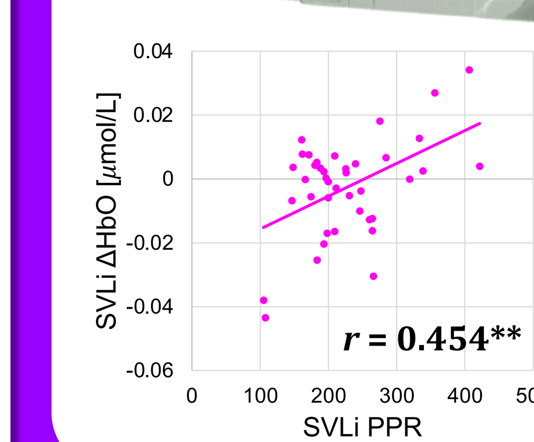


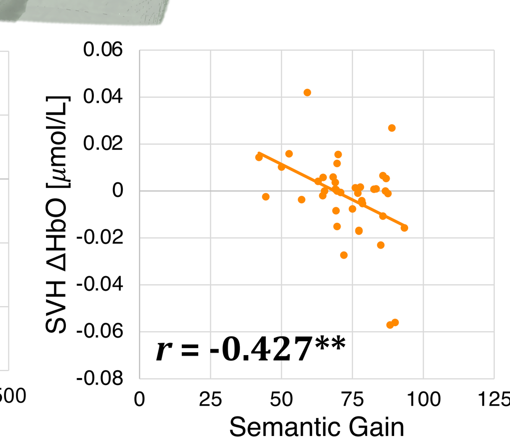
Participants with stronger MFG response had higher levels of effort (larger pupil size) and lower Semantic Gain.

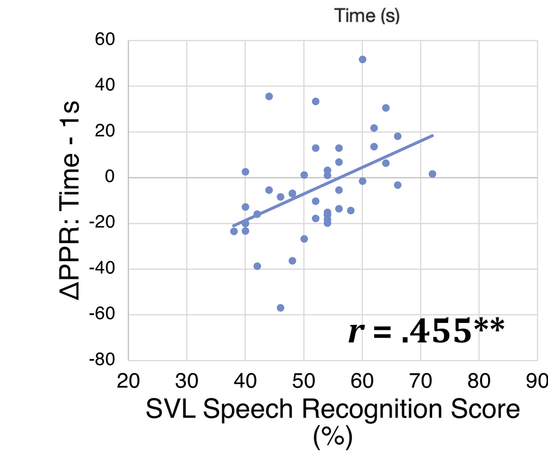




Subject pupil size right *after* sentence onset inversely predicted Semantic Gain.







Subject pupil size right *before* sentence onset predicted speech recognition score.

Conclusions

- Attention mechanisms of the IPC varied as a function of Response Type.
- The effect of listening effort on speech perception (speech recognition score and Semantic Gain) was reflected by the individual neurophysiological response of the listener.
- Listener's readiness or preparedness (pre-stimulus "effort") before the trial was an indicator of speech recognition ability.
- In line with the negative correlation between the MFG response and Semantic Gain, post-stimulus listening effort does not support individual speech perception ability.
- Potential clinical implications: clinicians could use patients' neurophysiological data to formulate targeted rehabilitation strategies for the purpose of improving cortical efficiency amid challenging listening scenarios.

References

[1]Winn, M. B., & Teece, K. H. (2021). Listening Effort Is Not the Same as Speech Intelligibility Score. *Trends in Hearing*, *25*. https://doi.org/10.1177/23312165211027688

[2]Kramer, S. E., Kapteyn, T. S., & Houtgast, T. (2006). Occupational performance: Comparing normally-hearing and hearing-impaired employees using the Amsterdam Checklist for Hearing and Work. *International Journal of Audiology*, *45*(9), 503–512.

[3]Defenderfer, J., Forbes, S., Wijeakumar, S., Hedrick, M., Plyler, P., & Buss, A. T. (2021). Frontotemporal activation differs between perception of simulated cochlear implant speech and speech in background noise : An image-based fNIRS study. *NeuroImage*, *240*(February), 118385. https://doi.org/10.1016/j.neuroimage.2021.118385