The Role of Auditory Experience in the Neural Systems for Effortful Listening

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INTRODUCTION

Everyday conversation frequently occurs under a wide range of suboptimal and adverse listening conditions.[1] Behavioral and neuroimaging research suggest that processing degraded acoustic information creates a cascading effect on the mechanisms underlying speech comprehension, indicating that our cognitive resources are limited and causing a trade-off between effort and comprehension.[2,3] Here, using a plausibility judgment task and functional near-infrared spectroscopy (fNIRS), we aim to dissociate motivated listening and its modulation of language processing in response to increased demands on executive functioning in listeners with typical hearing acuity and experienced, early-deafened hearing aid and cochlear implant users.

QUESTION AND HYPOTHESES

Does early, chronic exposure to acoustically degraded speech modulate language processing in response to increased demands on cognitive executive functions (e.g., short-term verbal working memory, attention)?

H1. Early, chronic exposure yields adapted language systems.
P1. Increased demands will yield comparable behavioral and neural patterns.
H2. Early, chronic exposure yields constraints on language systems.
P2. Increased demands will yield dissimilar behavioral and neural patterns.

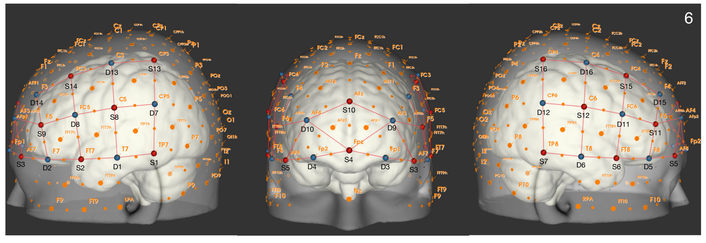
METHODOLOGY

Participants. Healthy, monolingual, English-speaking adults (N=24).
*Cochlear Implant Users** (N=4, F=0, Age range=18;0 to 19;7, Mean age=18;8)
*Hearing Aid Users** (N=5, F=1, Age range=18;1 to 20;10, Mean age=19;2)
Typical hearing (N=15, F=11, Age range=19;1 to 37;9; Mean age=28;6)
*Used since before age 5;0

Task. English sentence plausibility judgment task.[4,5]

Stimuli. 288 sentences presented at various speech rates and with or without distortions. Equal number of plausible and implausible sentences.

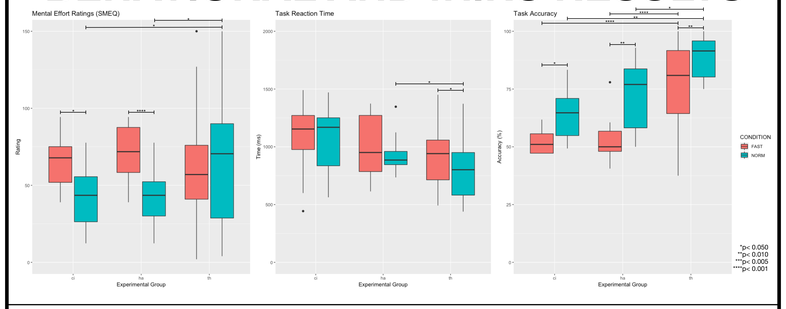
Simple (subject-relative clause): e.g., *Boys that help girls are nice.*
Complex (object-relative clause): e.g., *Boys that girls help are nice.*

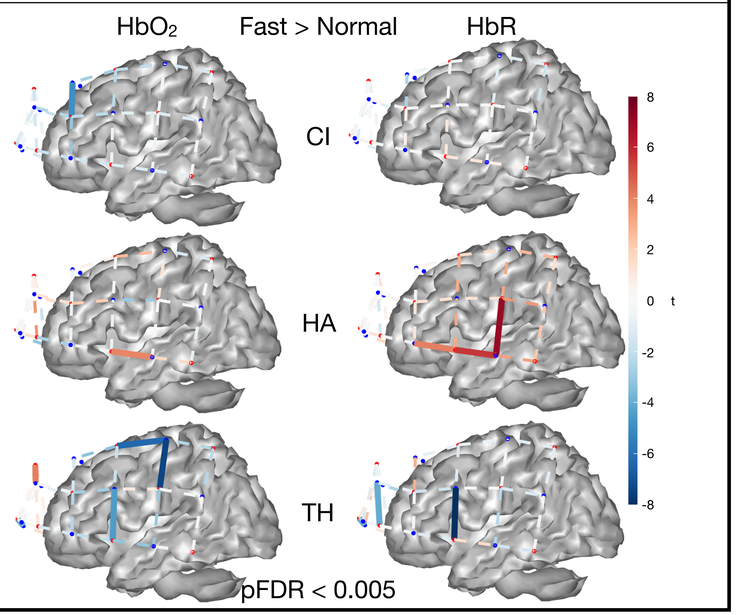


ANALYSES

Behavioral analyses were conducted using R and Welch t-tests. **Functional NIRS data** were preprocessed and analyzed using the NIRS Brain AnalyzIR Toolbox.[7] *Individual Analysis***:** We used linear regression modeling with an autoregressive iterative re-weighted least squares (AR-IRLS)[8] pre-whitening method. *Group Analysis***:** Group-level comparisons were made using mixed-effects statistical models.

BEHAVIORAL AND fNIRS RESULTS





Behavioral. We observed statistically significant differences between normal and fast speech presentations for participants' ratings of mental effort and task performance. **fNIRS.** We observed increased HbO_2 and HbR activity in the left hemisphere for normal compared to fast speech in TH listeners. This pattern is similar for CI listeners, but to a lesser extent. We observe the opposite pattern (increased HbO_2 and HbR activity in the left hemisphere for fast compared to normal normal speech) in HA listeners.

DISCUSSION

CI. Behavioral results indicate that the task is and remains difficult for fast and normal conditions. However, the task does not appear to be so difficult that participants disengage from the task. Neuroimaging results support this, as the two conditions do not significantly recruit activation relative to each other.
HA. Behavioral and neuroimaging results indicate that increased demands on cognitive executive functions modulate systems for language processing.
TH. Behavioral results indicate that fast speech is marginally more difficult than normal speech. Neuroimaging results support this and indicate greater left hemisphere involvement for normal compared to fast speech.

H2 Language Processing: Here, we find that auditory experience does in fact modulate the neural systems for language processing. Crucially, the nature of one's listening experience may predict this modulation.

We identify relationships between different listening experiences and demands on executive functioning in listeners with typical and reduced hearing acuity. As a whole, this work tests hypotheses surrounding the effect of auditory experience on the neurobiological systems for effortful listening.[3,5,9,10, 11]

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