Listening Experience and Syntactic Complexity Modulate Neural Networks for Speech and Language: A Functional Near-Infrared Spectroscopy Study

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INTRODUCTION

- **Effects of listening experience.** Experience listening to acoustically-degraded speech modulates how the brain perceives and processes speech and language information.[1–11]
- **Predicting brain function at rest.** Investigations of long-term, experienced hearing aid (HA) and cochlear implant (CI) users suggest that the type of developmental listening experience may predict how the brain functions at rest.[2,9]
- **Early life sensitive periods.** The effects of early, life-long exposure to acoustically-degraded speech on *functional* speech and language networks (especially in the presence of increased cognitive demand) are still elusive.

QUESTION AND HYPOTHESES

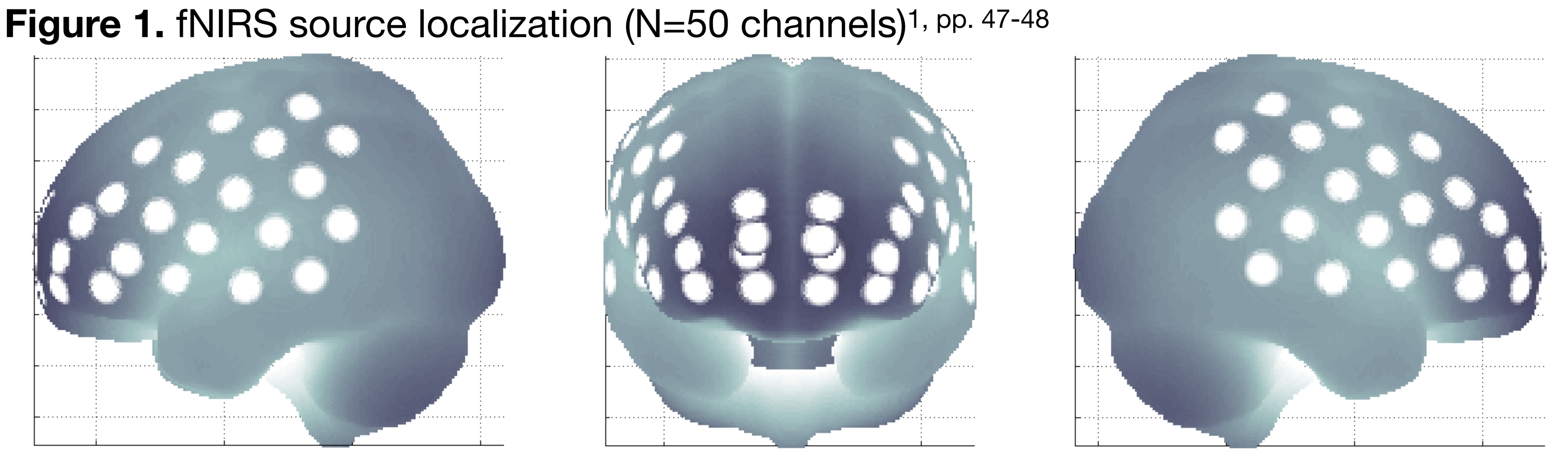
Do variations in early-life auditory experience modulate functional connectivity (FC) networks in the prefrontal and bilateral temporal-parietal cortices during online processing of speech and language (i.e., task-based FC neural networks)?

H1	H2
H1. Early, life-long exposure to acoustically degraded speech results in compensatory neuroplasticity **H1 Predictions:** Behavioral performance TH = HA = CI Mental effort ratings TH = HA = CI tbFC networks TH = HA = CI	**H2**. Effortful listening resources are limited, and may modulate the speech and language network **H2 Predictions:** Behavioral performance TH > HA or CI Mental effort ratings TH < HA or CI tbFC networks TH ≠ HA or CI

METHODOLOGY

Participants. Young, right-handed, healthy, monolingual English-speaking adults (N=39) participated in this study.[1] Participants were divided into three groups: TH listeners and early, long-term HA and CI users.* Participants were matched based on a battery of language and cognitive assessments.[16-20] **Received and used since age ≤ 5;0*. **Task.** English sentence plausibility judgment task[12] and rating scale of perceived expended mental effort[13]. **Stimuli.** 192 sentences presented at 205 wpm. Sentences varied linguistically (i.e., simple subject- [*Boys that help girls are* nice] and complex object- [*Boys that girls help are nice*] relative clause structures) for all participants and, for TH listeners only, acoustically (i.e., undegraded, HA simulated/wide-band, and CI simulated/narrow-band). **Apparatus.** Functional near-infrared spectroscopy[14,15] (fNIRS; see Figure 1 for probe source localization).

Figure 1. fNIRS source localization (N=50 channels)[1, pp. 47-48]



ANALYSES

Behavioral performance was modeled using restricted maximum likelihood (ReML) linear mixed-effects statistical modeling[21] with Welch-Satterthwaite approximation[22]. **fNIRS** data were preprocessed and analyzed using the NIRS Brain AnalyzIR Toolbox. *Individual Analysis*. We used robust general linear regression modeling with an auto-regressive iterative re-weighted least squares (AR-IRLS) pre-whitening method and a max model order of four times the sampling rate (acquired: 7.812 Hz, downsampled: 1 Hz). *Group Analysis*. Group-level comparisons were made using mixed-effects statistical models. Each channel was compared to all other channels for each condition using Pearson's Product-Moment Correlation. Conditions were compared using *t*-tests.

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RESULTS

Figure 2. Behavioral results (Index. ***, p<0.001; **, p<0.005; *, p<0.01; •, p<0.05)

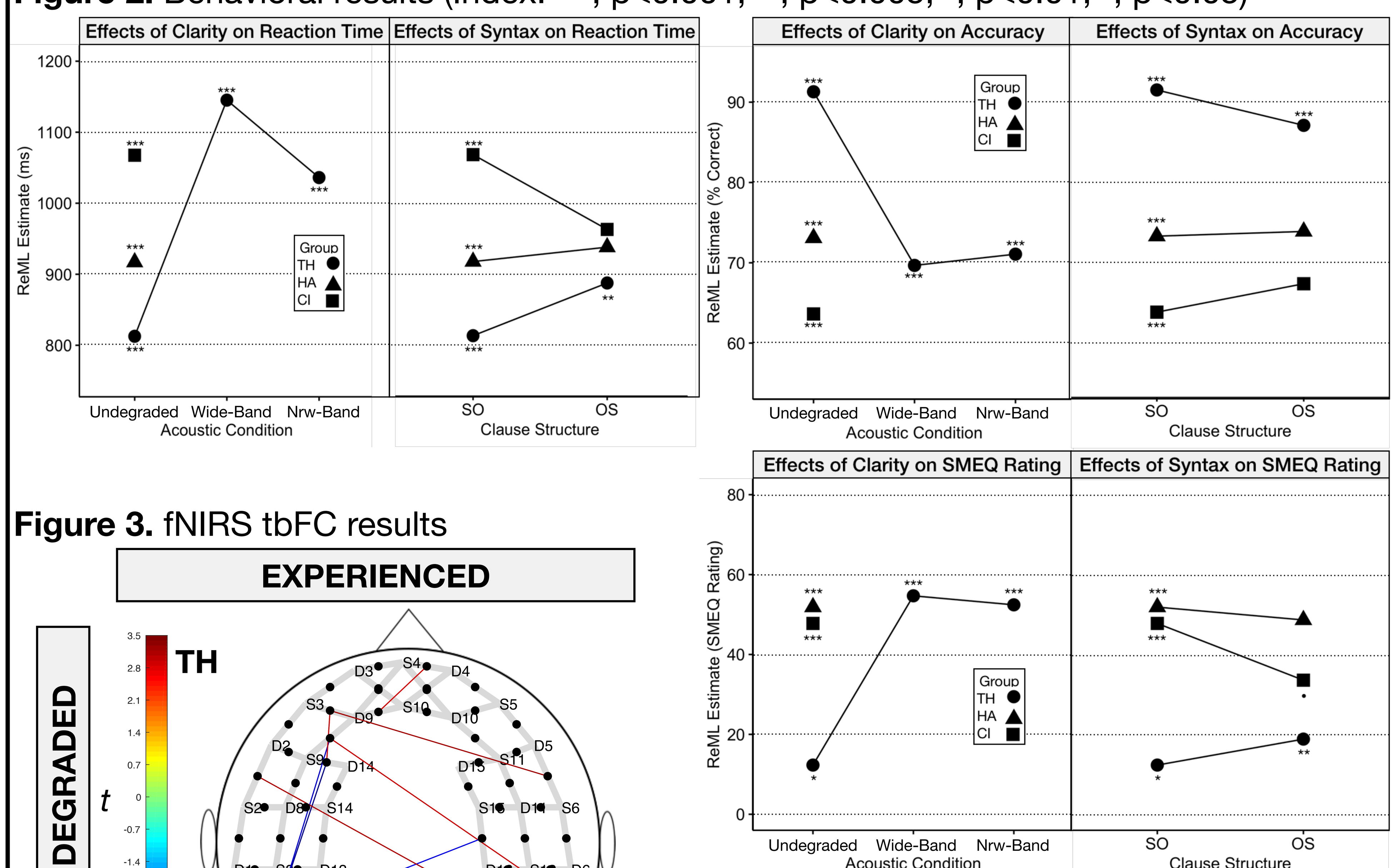
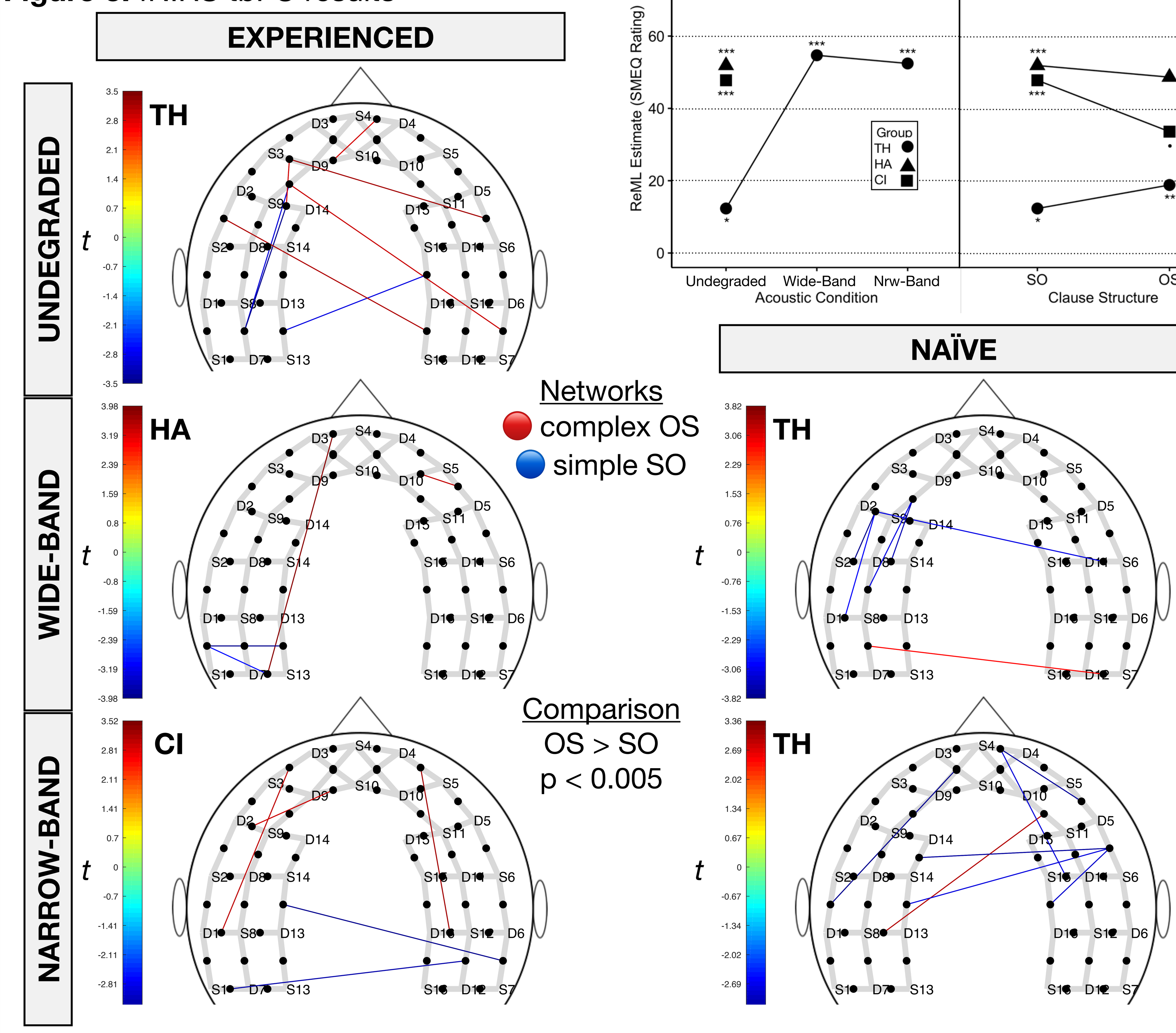


Figure 3. fNIRS tbFC results



DISCUSSION

Undegraded speech. Salient distinction between simple SO and complex OS tbFC networks, which indicate greater processing demands (viz. longer memory trace) in the more complex condition.[1]

Wide-band speech. Experienced listeners had less connectivity in the left inferior frontal gyrus and surrounding regions than naïve listeners and experienced listeners of undegraded speech.

Narrow-band speech. Experienced listeners show salient distinction between SO and OS tbFC networks, though this is less robust and slightly dissimilar in pattern to experienced listeners of undegraded speech. Naive listeners show overlapping networks with node clusters in the left inferior frontal and frontal cortices.

Other findings. Experienced HA and CI users both performed less accurately and slower on the task, reported greater levels of expended mental effort, and had less inter-hemispheric connectivity than naïve listeners and experienced listeners of undegraded speech.[2,9]

Future directions. Graph theory and models (node analysis).

Conclusion. Evidence was found to support hypothesis 2. Listening experience and syntactic complexity both appear to modulate behavioral performance and task-based functional connectivity networks in the prefrontal and bilateral temporal-parietal cortices during online speech and language processing. These findings suggest that speech alone may not be sufficient to facilitate compensatory neuroplasticity for speech and language in early, life-long HA and CI use.

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