Functional Connectivity in the Language Network in Response to Syntactic Complexity and Acoustic Degradation: A Functional Near-Infrared Spectroscopy Study

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695.14 / III40, 2018-11-07

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.[2-5] Here, using a plausibility judgment task and functional near-infrared spectroscopy (fNIRS), we aim to dissociate motivated listening and its modulation of language processing networks in response to increasing demands on executive functioning in listeners with typical hearing acuity.

QUESTIONS AND HYPOTHESES

Does listening under increasingly difficult conditions modulate the language processing networks to reflect increasing demands on cognitive executive functions (e.g., short-term verbal working memory, attention)?

H1. Compared to simple, clear speech, the processing of complex and degraded speech increases demands on cognitive executive functions.
P1. Functional connectivity between left temporal language regions, prefrontal regions, and right hemisphere temporal regions will be stronger for more difficult speech.

H2. The processing of complex and degraded speech increases demands on language networks primarily in the left temporal regions.
P2. Functional connectivity will be stronger within the left temporal regions, but not other regions, for difficult speech.

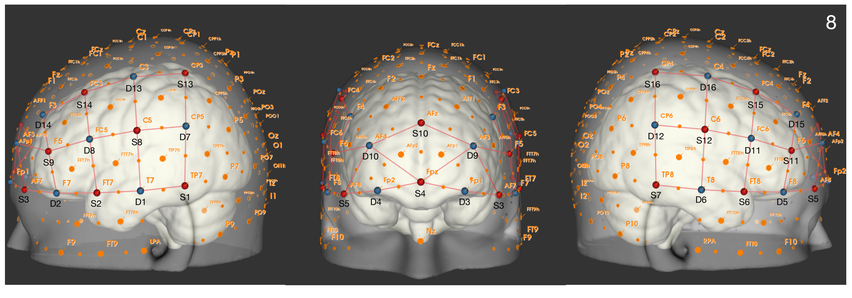
METHODOLOGY

Participants. Healthy, monolingual, English-speaking adults with clinically-defined typical hearing (N=15, F=11, Age range=19;1 to 37;9; Mean age=28;6).

Task. English sentence plausibility judgment task.[6,7]

Stimuli. 288 sentences presented at various speech rates and with or without distortions (i.e., computer-generated hearing aid and cochlear implant simulations). 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.*



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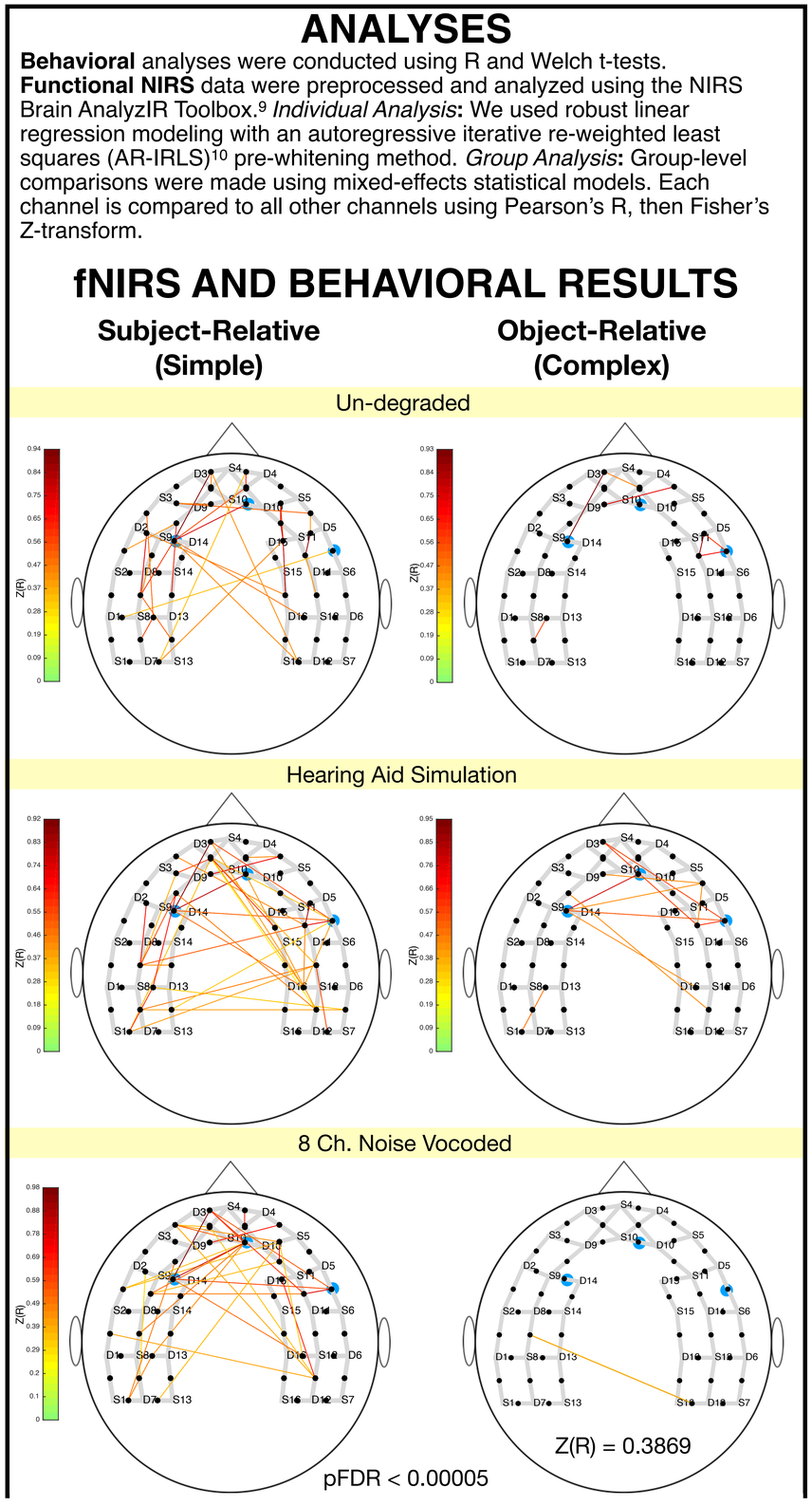
Funding: Graduate Student Research Travel Award, Office of the Dean of the Graduate School and Continuing Studies, Gallaudet University; Small Research Grant, Office of Research Support and International Affairs, Gallaudet University

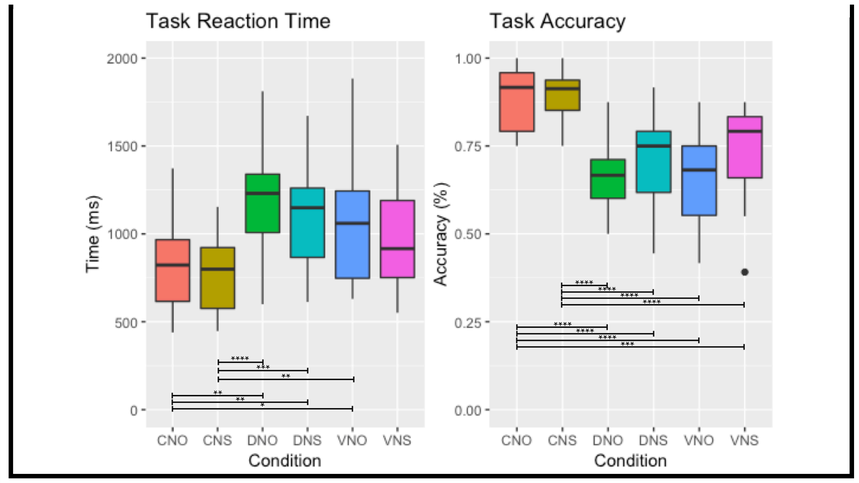
Citation: White, B. E., & Langdon, C. (2018, November). *Functional connectivity in the language network in response to syntactic complexity and acoustic degradation: A functional near-infrared spectroscopy study.* Poster presentation at the annual meeting of the Society for Neuroscience, San Diego, CA.

ANALYSES

Behavioral analyses were conducted using R and Welch t-tests.
Functional NIRS data were preprocessed and analyzed using the NIRS Brain AnalyzIR Toolbox.[9] *Individual Analysis*: We used robust linear regression modeling with an autoregressive iterative re-weighted least squares (AR-IRLS)[10] pre-whitening method. *Group Analysis*: Group-level comparisons were made using mixed-effects statistical models. Each channel is compared to all other channels using Pearson's R, then Fisher's Z-transform.

fNIRS AND BEHAVIORAL RESULTS





DISCUSSION

Acoustic manipulation effects:
- *Clear (no distortion)*: Strongest correlations are observed between three hubs located in left temporal, frontopolar, and right prefrontal regions. Multiple nodes are distributed throughout left and right temporal lobes.
- *Hearing aid simulation*: Connectivity greatly increased between left and right temporal lobes as well as frontal sites.
- *8-ch noise vocoded*: Connectivity increase primarily between frontal sites and their connection to left and right temporal lobes, while connections between left and right temporal lobes are less affected.

Syntactic manipulation effects:
- *Simple (subject-relative clause) vs. complex (object-relative clause)*: Increased syntactic complexity results in attenuated and focused connectivity, primarily in frontal sites.

Modulators. Acoustic difficulty appears to modulate the regions networked for language processing, whereas grammatical difficulty appears to modulate the robustness of the network (i.e., more robust for simple compared to complex grammar).

Network Hubs. Across acoustic manipulations, we observe that the L-DLPFC (S9-D14), frontopolar region (S10-D10), and anterior R-IFG (S6-D5) demonstrate the greatest connectivity with other nodes.

H1 Language Processing Networks. Here, we find that listening under increasingly difficult conditions does in fact modulate the neural networks for language processing. Crucially, the nature of the speech signal may predict this modulation.

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