

Graph-Based Insights into the Bilingual Brain

Modeling Neural Connectivity in
Bilingual Speech



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From Curiosity to a Research Question

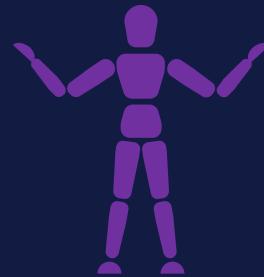
- Bilinguals often “know the word” but hesitate under pressure.
- Is hesitation linguistic – or neural?
- Can brain connectivity explain it?
- Tested via explainable graph-based modeling



Curiosity

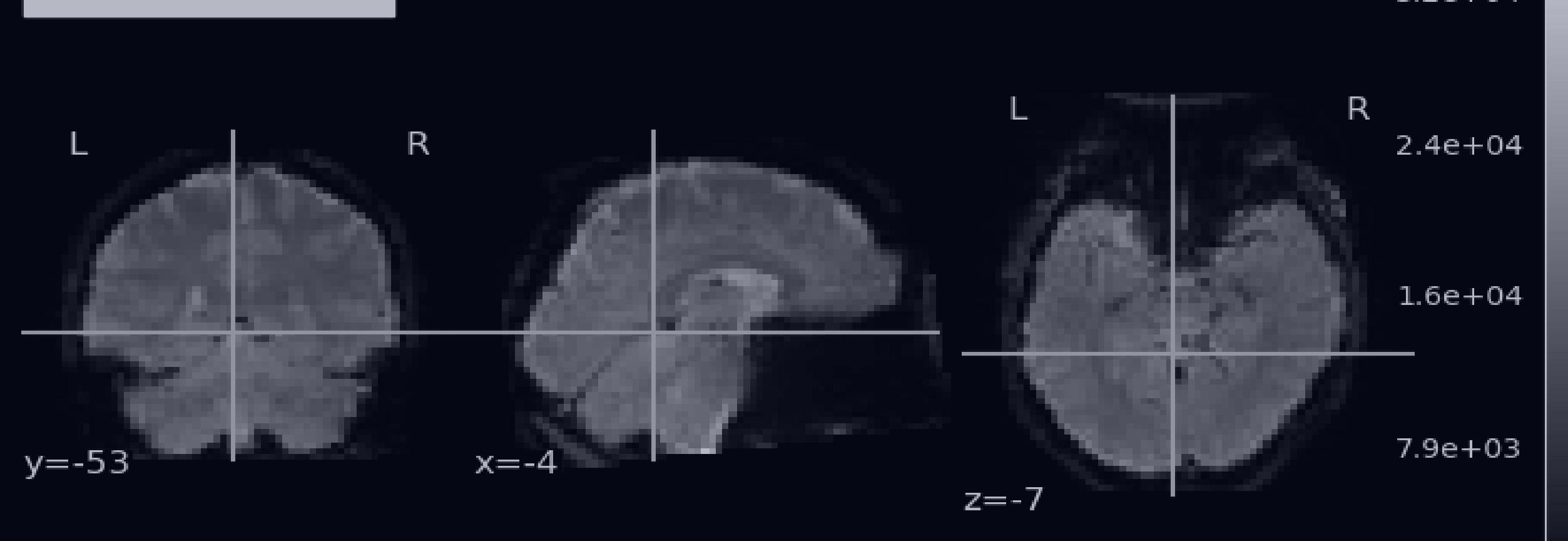


Graph analysis



Modeling





OpenNeuro Dataset ds004456 – Bilingual Speech Production

Source: OpenNeuro ds004456

Participants: 42 Polish–English bilingual adults

Tasks:

Alice: Reading aloud in English

Articulation: Silent mouthing



Subset: 19 participants analyzed

Atlas: Schaefer-2018, 100 cortical regions

From fMRI to Graph Metrics

Extract regional time-series (NiLearn)

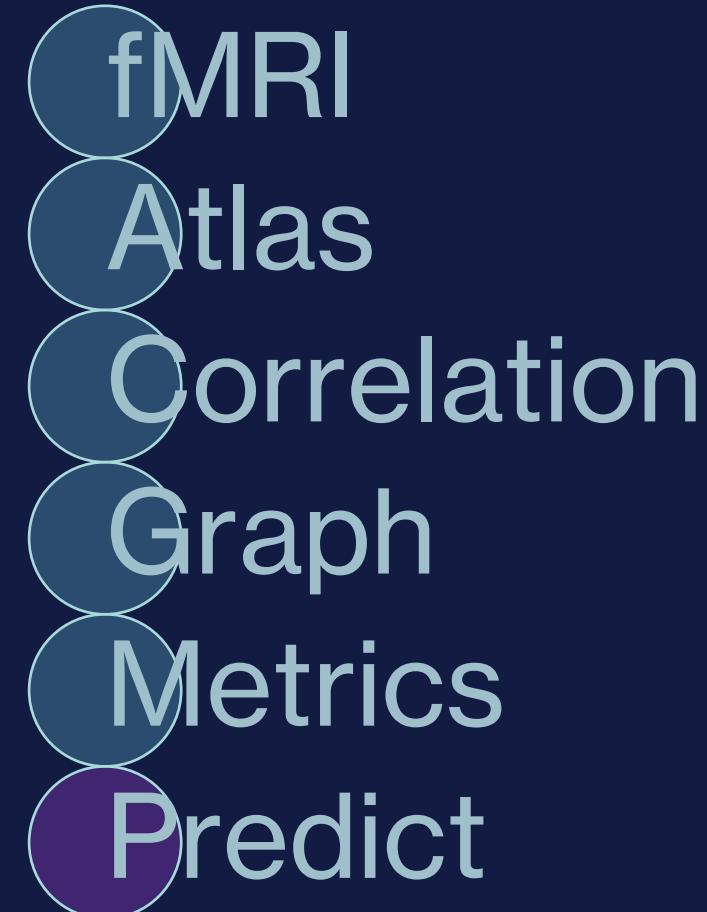
Compute correlations between region pairs

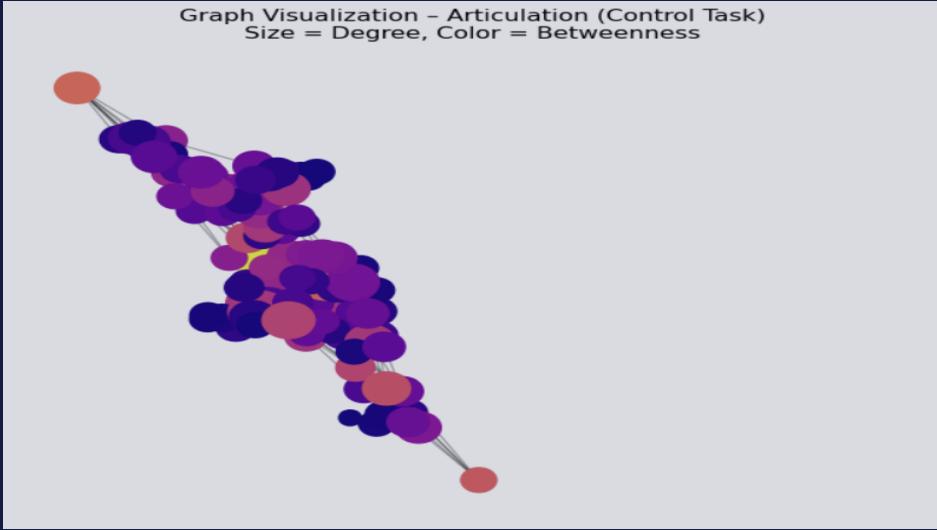
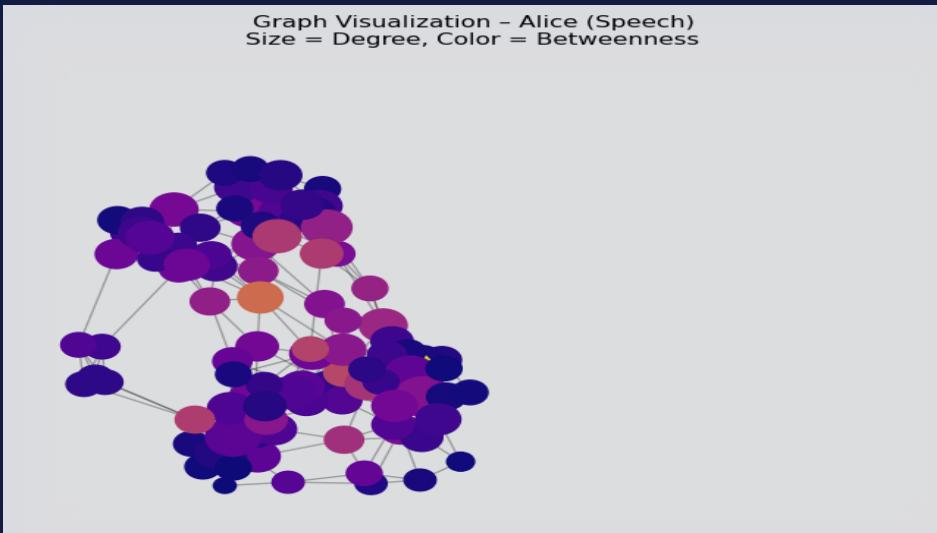
Keep top 5 connections per node

Build weighted undirected graph

Translate metrics into explainable alerts

Use metrics as inputs for predictive modeling





Individual Results (sub-01)

Example Graph – Speech (Alice)

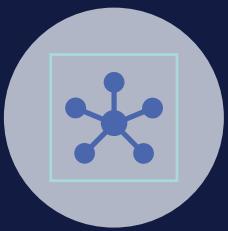
Clear small-world topology

Right Somatomotor & visual regions are main hubs

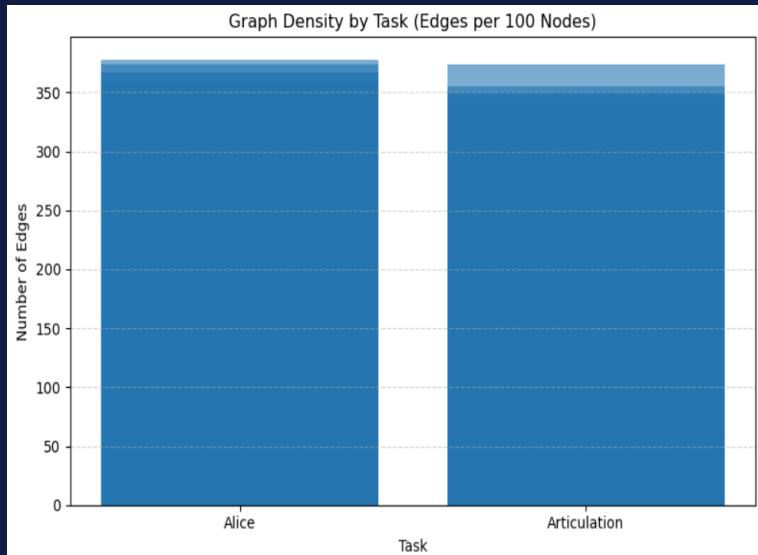
Default-mode network was less active



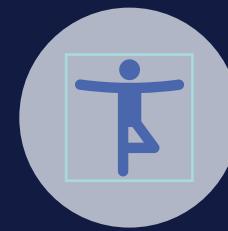
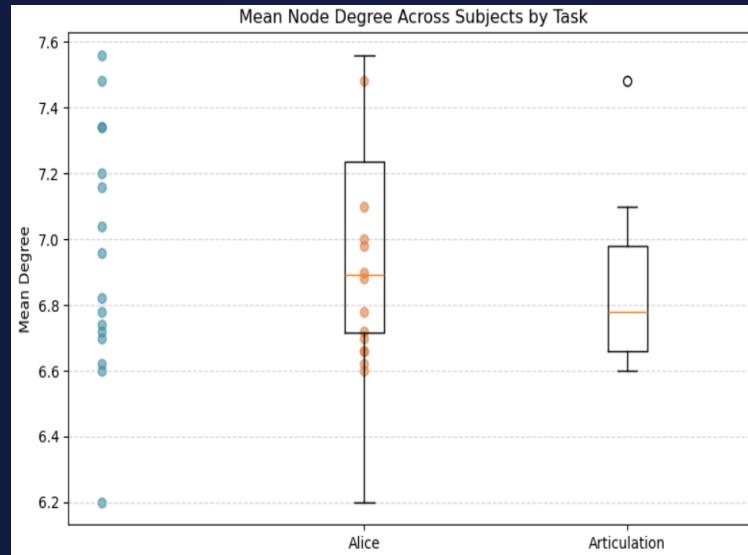
Group Findings Across 19 Participants



SPEECH GRAPHS HAD
MORE EDGES



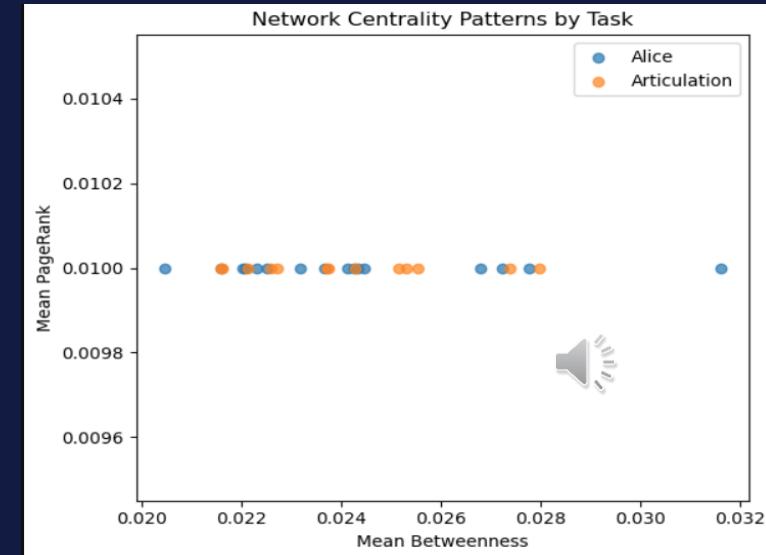
SLIGHTLY HIGHER
MEAN DEGREE



GLOBAL EFFICIENCY
REMAINED STABLE



SUGGESTS ADAPTIVE
COORDINATION, NOT
OVERLOAD



Modeling the Bilingual Brain



Models Logistic Regression, Random Forest, L1- Regularized Logistic



Best model L1- Regularized Logistic Regression



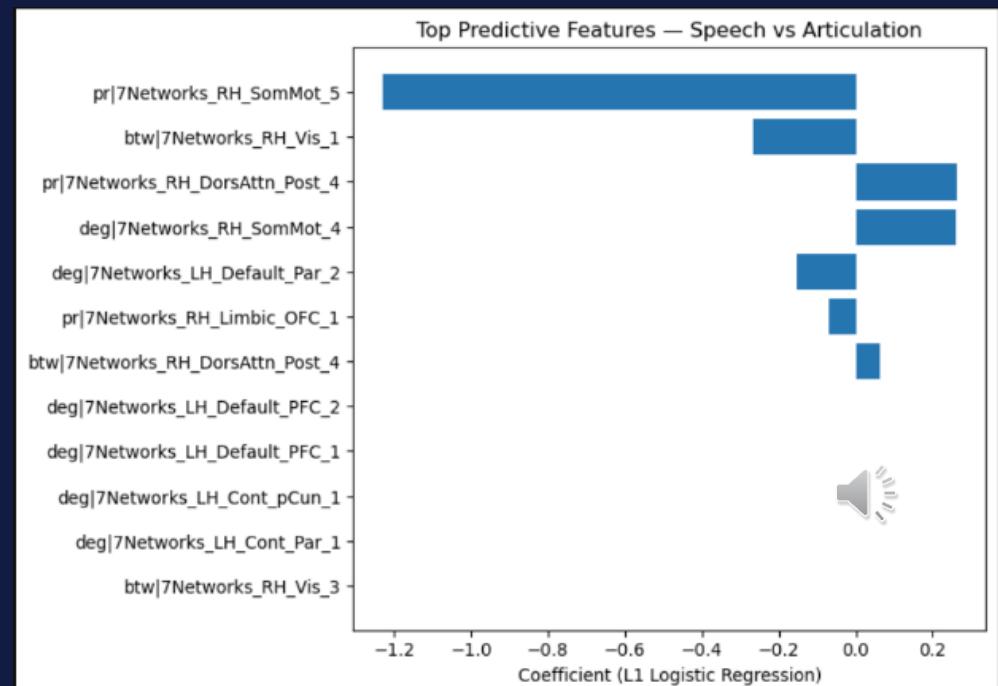
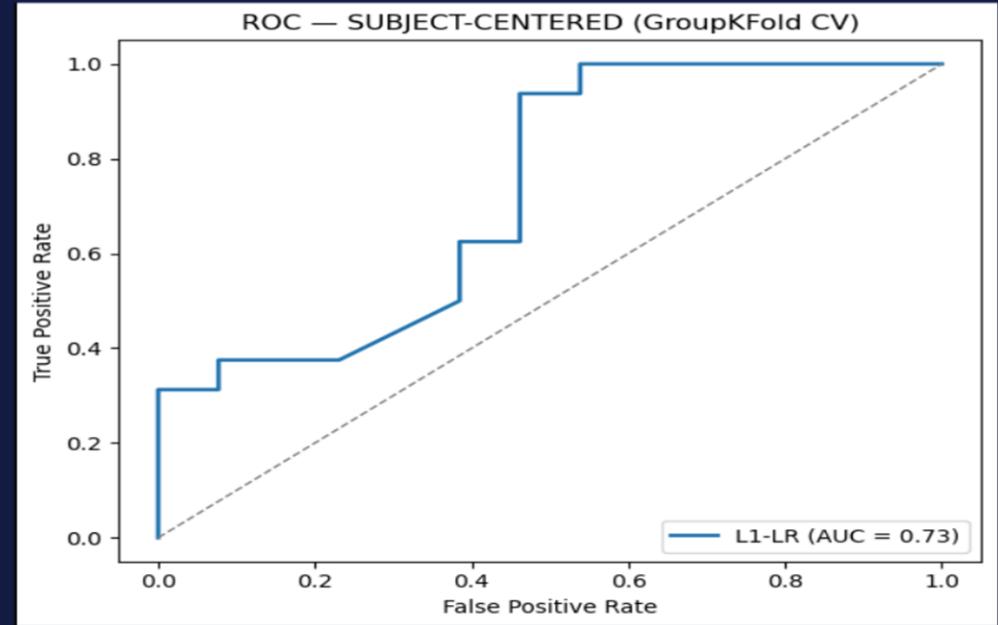
ROC-AUC ≈ 0.75



Key features right somatomotor & salience networks



Confirms consistent task-level network patterns



From Brain Graphs to Human Understanding

SPEECH INCREASE LOCAL
CONNECTIVITY (MOTOR +
ATTENTION)

GLOBAL BALANCE
REMAINS STABLE AND
EFFICIENT

HESITATION REFLECTS
CONTROL EFFORT, NOT
WEAKNESS

BRAIN REMAINS EFFICIENT
ACROSS LANGUAGES





What Comes Next

- Scale to all 42 subjects
- Compare early vs. late bilinguals
- Add motion correction & confidence intervals
- Create interactive educational dashboard



A Data Scientist's View of the Bilingual Brain

- Data science can explain human adaptability
- The bilingual brain is efficient, not divided
- *Every bilingual story is also a data story*

