

# Graph-Based Insights into the Bilingual Brain

Modeling Neural Connectivity in  
Bilingual Speech



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# From Curiosity to a Research Question

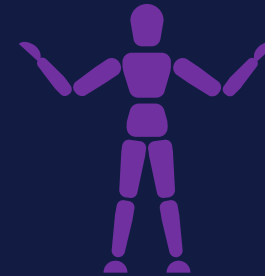
- Bilinguals often “know the word” but hesitate under pressure.
- Is hesitation linguistic – or neural?
- Can brain connectivity explain it?
- Tested via explainable graph-based modeling



Curiosity

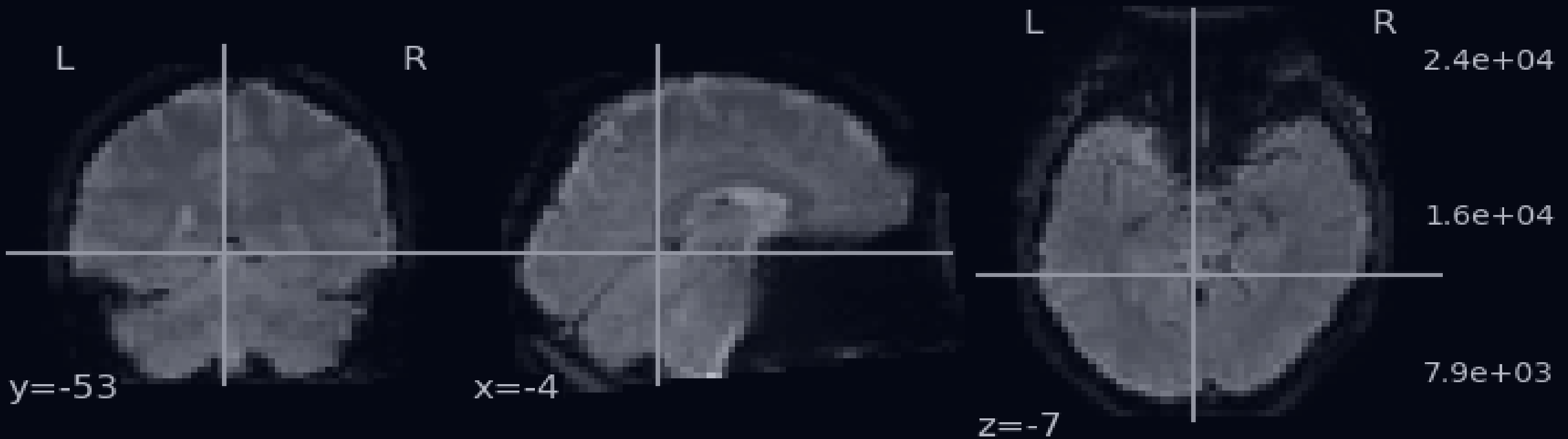


Graph analysis



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

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Extract regional time-series (NiLearn)

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Compute correlations between region pairs

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Keep top 5 connections per node

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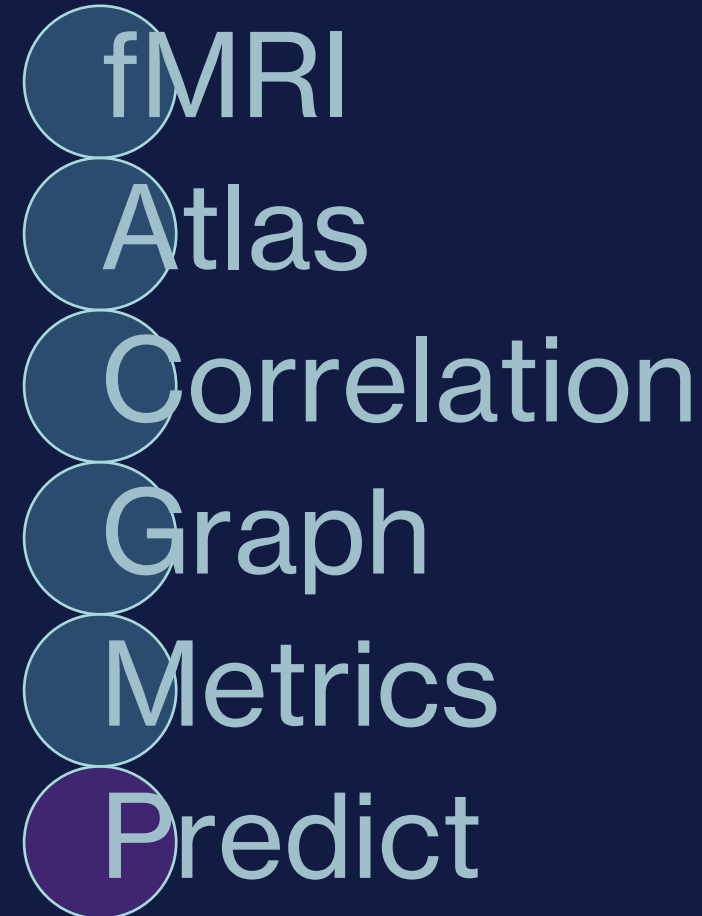
Build weighted undirected graph

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Translate metrics into explainable alerts

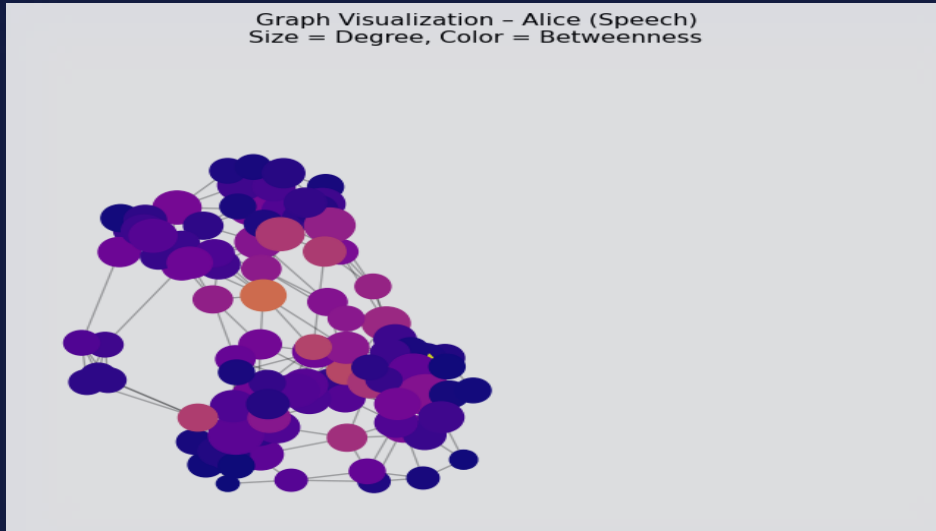
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Use metrics as inputs for predictive modeling



# Individual Results (sub-01)

## Example Graph – Speech (Alice)



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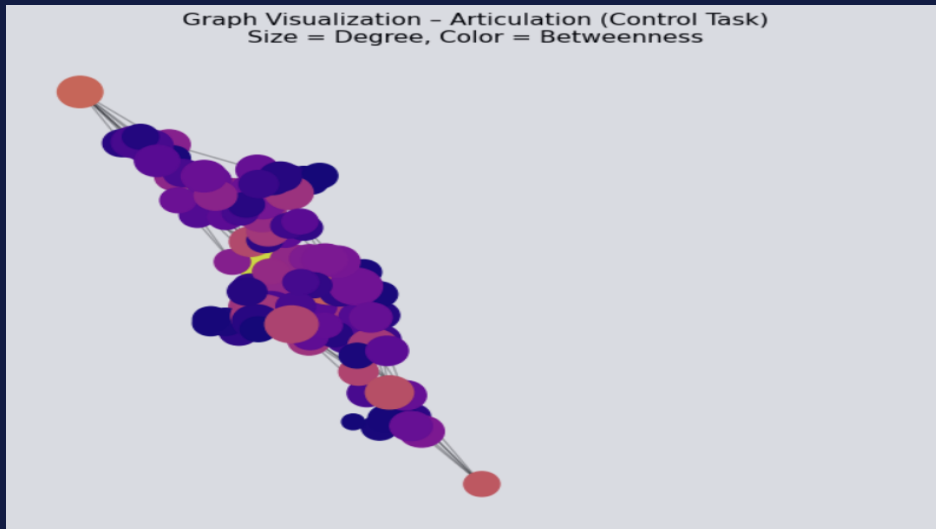
Clear small-world topology

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Right Somatomotor & visual regions are main hubs

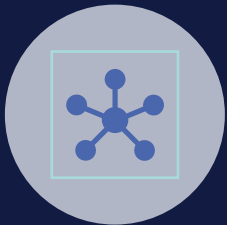
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Default-mode network was less active



# Group Findings

## Across 19 Participants



SPEECH GRAPHS HAD  
MORE EDGES



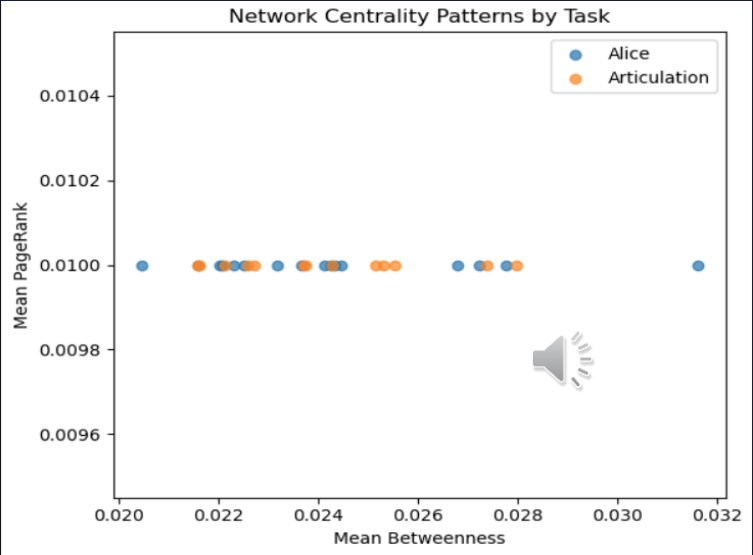
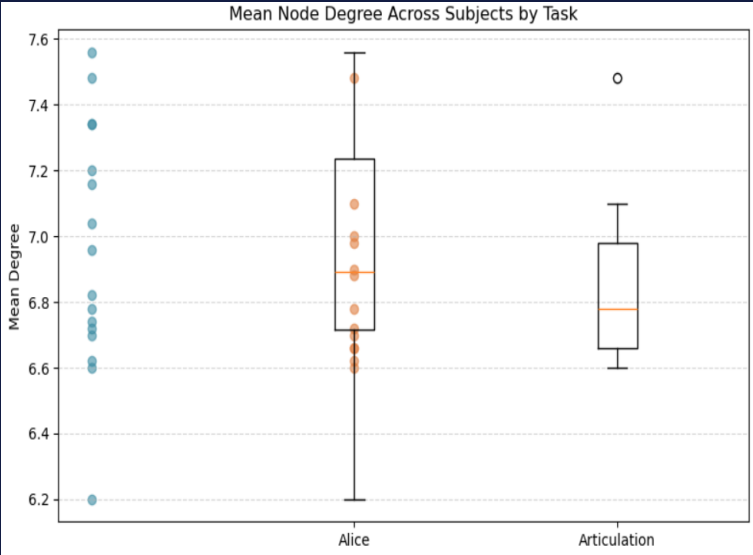
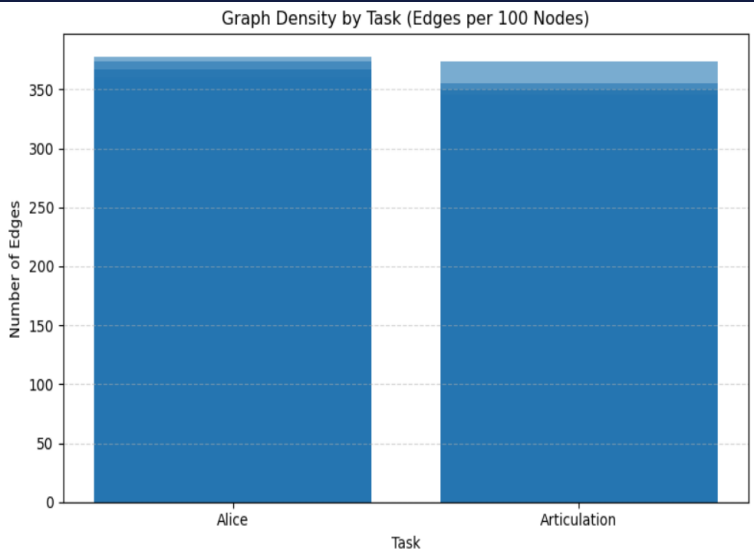
SLIGHTLY HIGHER  
MEAN DEGREE



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



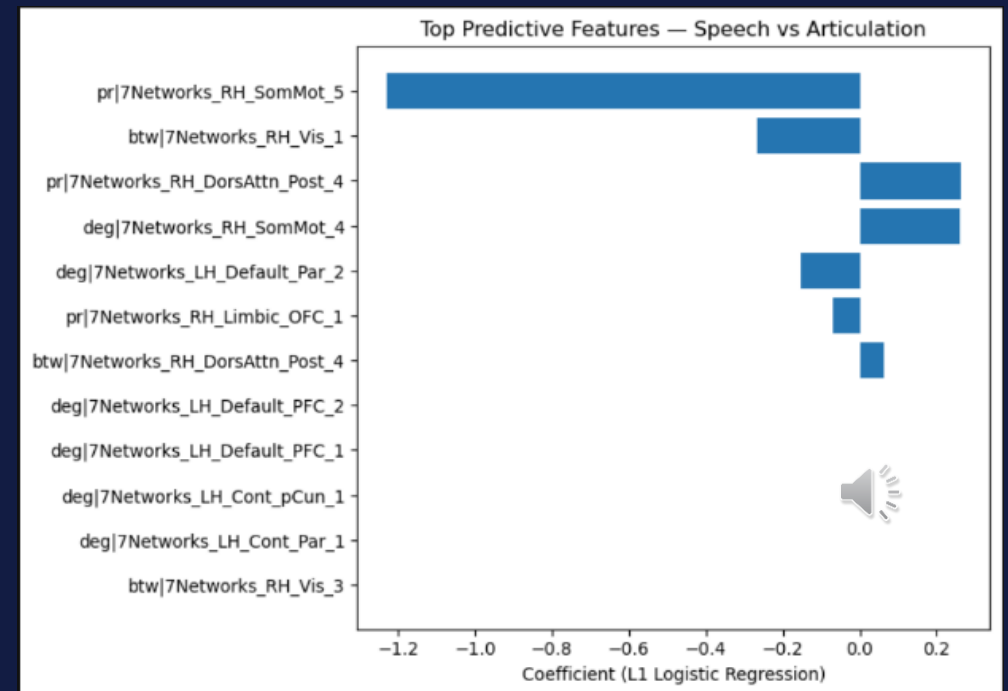
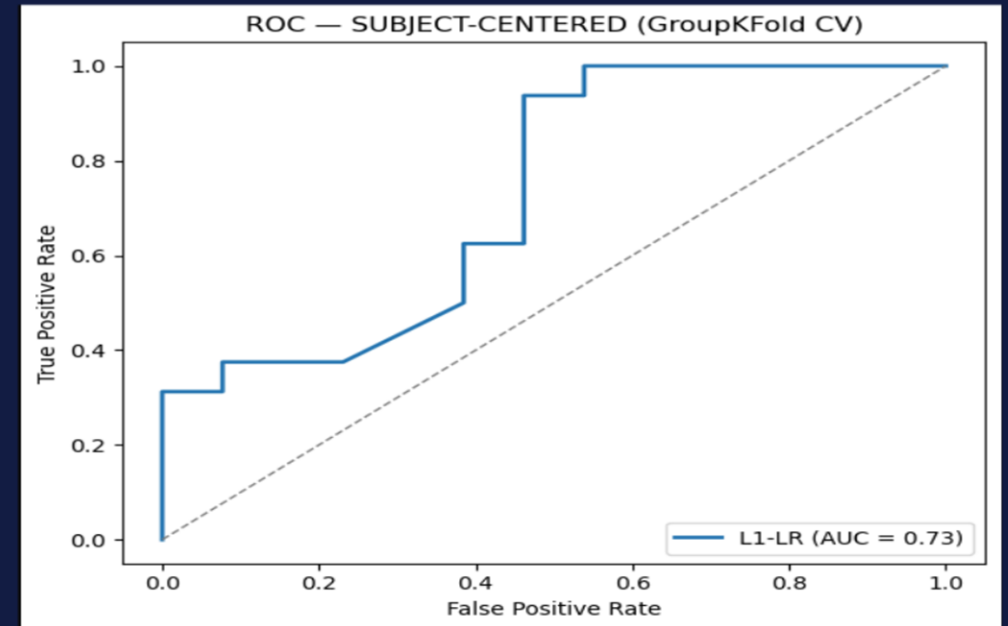
**ROC-AUC**  $\approx 0.75$



**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*

