COMPLEX NETWORKS - A3_SHORT PROJECT DESCRIPTION

Group name: Group A3 N
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Title of the project: Topological and Modular Analysis of Semantic Networks in Alzheimer's Disease: Community Structure, Modularity, and Network Reorganization (Reproduction and Extension of Zemla & Austerweil (2019)) [1]

Brief description:

1) BACKGROUND AND MOTIVATION

Alzheimer's Disease (AD) affects over 46 million people worldwide and is characterized by progressive semantic memory deterioration. While semantic fluency tests (e.g., naming animals) are used clinically, traditional measures like total items listed and perseverations provide limited diagnostic insight.

Zemla & Austerweil (2019) demonstrated that network analysis of semantic fluency data reveals structural differences between AD and healthy individuals: AD networks are more connected with randomly distributed connections, suggesting spurious associations between unrelated concepts. However, their work left critical gaps:

- Small-worldness analysis was incomplete - only mentioned theoretically but not systematically quantified.
- Semantic organization (community structure) was not analyzed.
- No predictive diagnostic model - which parameters best discriminate AD from healthy controls?

Our project addresses these gaps by reproducing their methodology and extending it with comprehensive small-world analysis, community detection, and machine learning classification.

2) OBJECTIVES

- **Reproduce** the Zemla & Austerweil (2019) network inference methodology.
- **Complete comprehensive small-worldness analysis** across all networks to quantify the degradation of efficient semantic organization in AD.
- **Detect and characterize semantic communities** to identify which semantic modules are most vulnerable to AD pathology.
- **Evaluate the Robustness of Topological Findings Against Alternative Network Inference Methods.** Determine whether the systematic differences in network structure

between AD and NC participant sare contingent upon the nonexchangeable U-INVITE methodology used by Zemla & Austerweil (2019)

3) HYPOTHESIS:

- **Community Structure Deterioration**: AD patients show lower modularity (Q) than healthy controls, indicating weakened semantic category boundaries and increased spurious inter-category connections. Rationale: Zemla & Austerweil found AD networks have more random connections. This should manifest as blurred community boundaries.

- **Small-Worldness as Early Biomarker:** Small-worldness coefficient degrades earlier in disease progression than traditional measures, making it a sensitive early diagnostic marker. Rationale: Global network organization may be disrupted before obvious local deficits appear.

- **Category-Specific Degradation:** Abstract or less-frequent semantic categories (e.g., exotic animals, insects) degrade earlier than common categories (e.g., domestic animals, pets). Rationale: Cognitive research suggests specific knowledge is lost first in dementia.
- **The detection of greater semantic network disorganization in AD patients is dependent on modeling the retrieval sequence of words.** If a network inference method that ignores the sequential order of words is applied, the diagnostic topological differences between AD and NC groups will significantly decrease.

4) METHODOLOGY (DATA)

The dataset that will be used in this study is derived from Zemla and Austerweil (2019) [1] and comprises 125 semantic networks, including 84 from Normal Control (NC) participants and 41 from individuals with Probable Alzheimer's Disease (PAD/AD). These networks were constructed from longitudinal semantic fluency data, with each participant contributing an average of approximately nine years of follow-up and at least three congruent diagnostic visits. Verbal fluency responses were collected using the animal category, and individual-level networks were generated using the University of South Florida (USF) semantic network—consisting of 160 animal concepts and 393 associative edges built from more than 6,000 participants—as the baseline structural reference.

REFERENCES

[1] Zemla, J. C., & Austerweil, J. L. (2019). Analyzing Knowledge Retrieval Impairments Associated with Alzheimer's Disease Using Network Analyses. Complexity, 2019, 4203158. https://doi.org/10.1155/2019/4203158