

Combining Temporal Dynamics And Semantic Embeddings To Assess Memory Search In Early Alzheimer’s Disease

Felipe Diego Toro Hernández¹, Diego Morales², Daniela Olivares^{3,4}, Joaquin Migeot⁵, Enrique Canessa⁶, Sergio Chaigneau⁷

¹Center of Mathematics, Computing and Cognition (CMCC), Federal University of ABC, São Bernardo do Campo, Brazil,

²Faculty of Engineering and Science, Adolfo Ibañez University, Santiago, Chile,

³Doctoral Program in Neuroscience, School of Medicine, Pontificia Universidad Católica de Chile, Sant, Doctoral Program in Neuroscience, School of Medicine, Pontificia Universidad Católica de Chile, Santiago, Chile, Santiago, Chile,

⁴Neuropsychology and Clinical Neuroscience Laboratory (LANNEC), Physiopatology Program – Institute of Biomedical Sciences (ICBM), Neuroscience and East Neuroscience Departments, Faculty of Medicine, University of Chile, Santiago, Chile, Santiago, Chile,

⁵Latin American Brain Health Institute, Adolfo Ibañez University, Santiago, Chile,

⁶Faculty of Engineering and Science, Adolfo Ibañez University, Viña del mar, Chile,

⁷Center for Social and Cognitive Neuroscience, Universidad Adolfo Ibáñez, Adolfo Ibañez University, Santiago, Chile.



Background & Rationale

Semantic Memory in Alzheimer’s (AD):

- Impairments in semantic memory are prominent early in AD.
- In the **Semantic Fluency Task (SFT)**, retrieval involves **Clustering** (fast retrieval of semantically similar words) and **Switching** (global search to a new category).
- Some SFT studies show that AD patients exhibit an **exploitation bias** (reduced switching, but relatively intact cluster sizes).

Research Question: Does the exploitation bias in AD generalize from semantic fluency (SFT) to a more open-ended property (or feature) listing task (PLT)?

Property Listing Task (PLT) vs. SFT:

- The SFT asks for category members within a time limit. The PLT asks for open-ended properties of a single concept (e.g., dog → bark, loyal), usually **without a time limit**.

Methods: Design & Procedure

Participants

Group	N	Age (M ± SD)	MoCA (M ± SD)
Control (CN)	35	71.8 ± 6.1	24.9 ± 3.2
Alzheimer’s (AD)	24	76.9 ± 8.8	13.5 ± 6.0

Groups did not differ in education or sex. Age was a model covariate.

Procedure:

Task: Participants orally listed properties for **10 concrete concepts** (e.g., *tree, airplane, house, sun*) with no time limit.

Coding: Responses sorted into 6 categories ($\kappa = 0.747$; two coders); repetitions and off-topic responses excluded from analyses.

Timing: Property onset/offset times extracted from audio waveforms.

Semantic Similarity: Pairwise cosine similarity computed using **BAAI/bge-m3** sentence embeddings.

Statistical Analysis:

Modeling: Fitted Generalized Linear Mixed-Effects Models (GLMMs) to account for nesting (multiple trials/concepts per participant).

Fixed Effects: Diagnosis group (CN vs. AD), trial-level Task Duration (time covariate), and Age.

Random Effects: Random intercepts for both Participant and Concept.

Methods: Slope-Difference Clustering

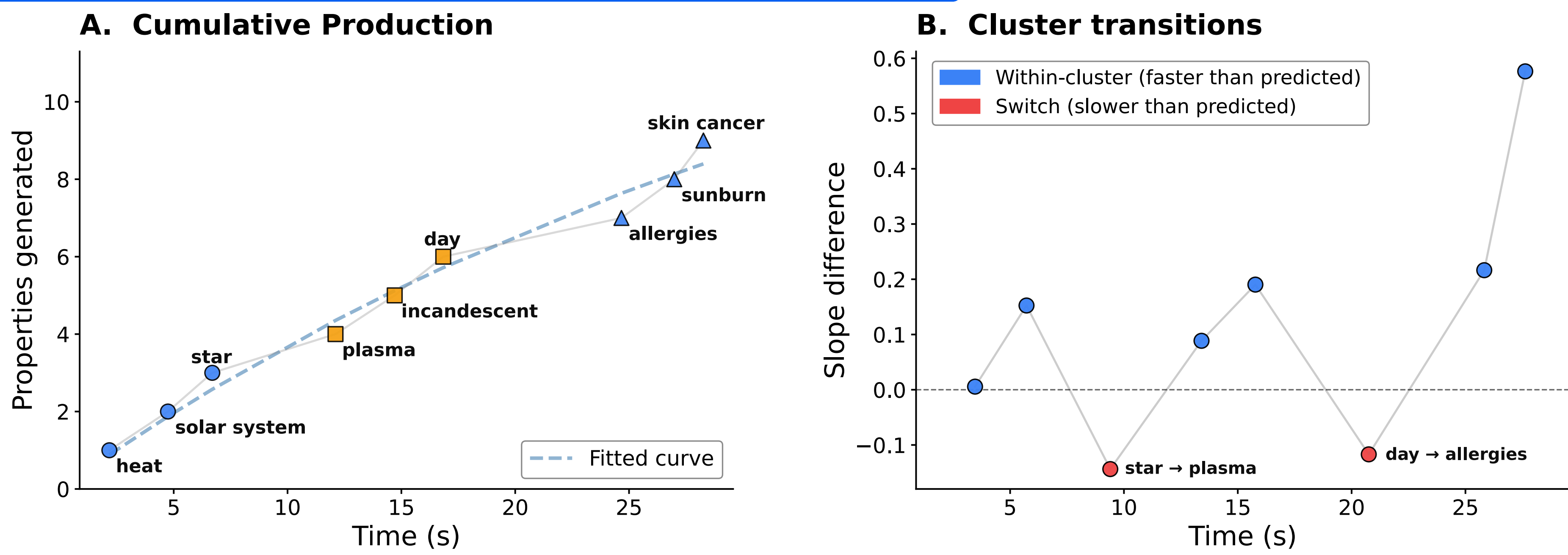
Slope-Difference Clustering (Bushnell et al., 2022):

Fits an exponential curve to cumulative production. Compares actual vs. predicted slope at each property transition.

Faster than predicted → **Within-Cluster Property** (local exploitation).

Slower than predicted → **Cluster Switch** (global exploration).

Methods: Slope-Difference Clustering — Worked Example



Results: Clustering & Switching Dynamics

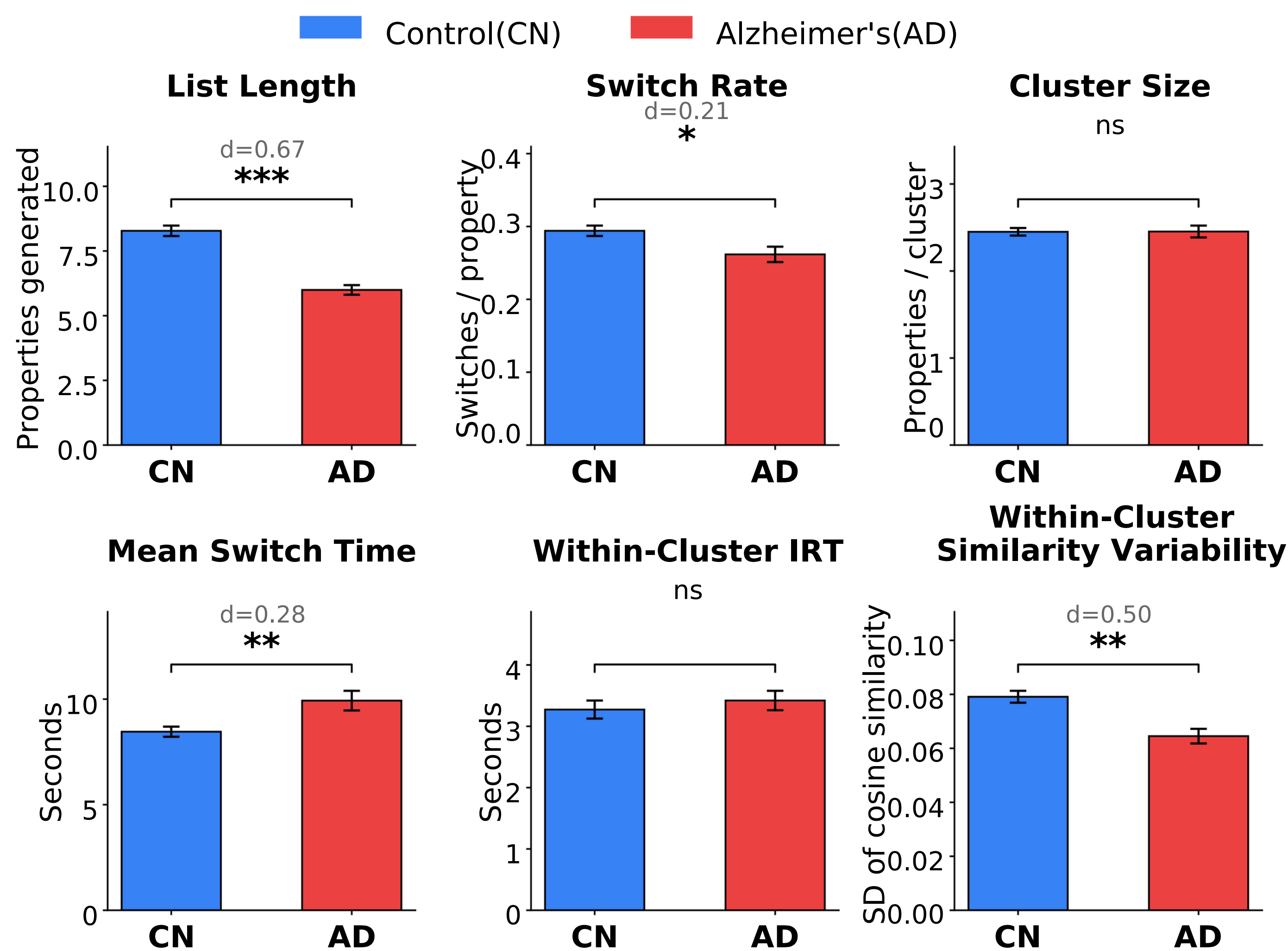
Response Profile & Task Duration:

- AD patients produced a lower proportion of **Valid Properties** (54.8% vs. 69.7% in CN) and more **Metacognitive/Off-topic responses** (18.1% vs. 7.1%) ($p < .001$).
- Despite the non-timed design, AD patients spent less total time on the task (32.9s vs. 38.4s in CN; $p < .001$). All metrics below control for this time difference.

Temporal Dynamics & Semantic Metrics:

Group differences were analyzed via **GLMMs**, controlling for age and total task duration (random intercepts for participant and concept).

Error bars show ± 1 SEM.



Discussion & Limitations

- **Exploitation Bias:** Evidence for SFT exploitation bias (intact local retrieval, impaired global exploration) in the property or feature listing task (PLT).
- **More Homogeneous Clusters:** AD showed less variable within-cluster semantic similarity, indicating more uniform property neighborhoods.
- **Clinical profile:** AD patients produce less properties, with a more homogeneous profile, highlighting possible impairment in efficient retrieval of items for semantic memory.
- **Limitations:**
 - Small, clinically heterogeneous AD sample (MoCA $SD = 6.0$).
 - Switch-rate effect did not survive stricter (maximal) random-effects models.
- Metrics need ≥ 3 properties. AD participants fell short more often, so these reflect a less-impaired AD subsample.
- Results may be sensitive to the switch-detection (slope-difference) method.