Computational Complexity in Phonotactics Modulates Brain Response: Evidence from EEG

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The **AIM** - to observe the neural correlates of computationally different (SL3 vs SL5) phonotactic patterns.

The **QUESTION** - Is computational complexity reflected in the brain? ERP amplitude or latency?

RESULTS - After an implicit learning task, the brain showed prediction error (P3) and anomaly detection (LPC) for the more local pattern.

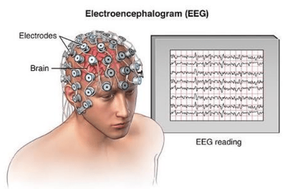
Phonotactic patterns in natural languages inhabit proper subsets within the regular region. Strictly Local and Strictly Piecewise classes include almost all natural language phonotactic pattern[1]

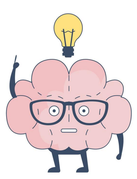
Sibilant Harmony[2] pattern in the form of CV.CV words (i.e., sasa or ʃaʃa) can be described as both (strictly) local and (strictly) piecewise:

	[s]	[ʃ]
[s]	✓	✗
[ʃ]	✗	✓

[· · ·— · · ·— · · ·]

- the SL 3-factors of ***sasa***:
  - {#sa, sas, asa, sa#}
  - *sVʃ or *ʃVs
- the SP 2-factors of ***sasa***:
  - {s…a, a…s, s…s, a…a}
  - *s…ʃ or *ʃ…s





❖ P3 and LPC

Using EEG, we can measure the neural commitment of computationally different patterns.

P3 – **index of categorization**[3]

Peaks 300ms after stimulus onset before the button press, P3 difference wave reflect processing difference grammatical and ungrammatical

LPC – **anomaly detection**[4] in rule-governed forms

Peaks 600ms after stimulus onset, Ungrammatical words elicit higher positivity

Locality matters!

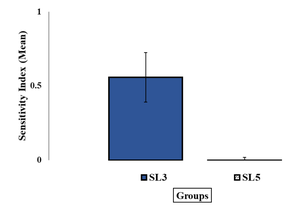
Computationally **less complex** pattern leads to better **neural response!**

Subjects: N=24
Pattern: SL3 and SP2
Stimuli: CV.CV
C: [s, ʃ], V: [a, ɛ, ɔ, i, u]
Ex: saso, ʃuʃi, seʃa, ʃisu
Each word 400 ms long
Violation at 200ms

Subjects: N=20
Pattern: SL5 and SP2
Stimuli: CV.CV.CV
C: [s, ʃ,k], V: [a, ɛ, ɔ, i, u]
Ex: sakiso, ʃukeʃi, sekoʃa, ʃikasu
Each word 650 ms long
Violation at 450ms

Behavioral Results

The difference between groups was significant: t(42)=3.13, p=.003, 1-β=.863.

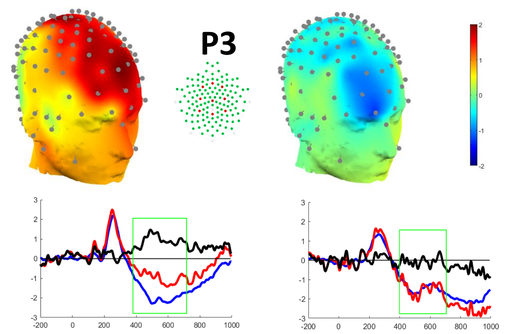


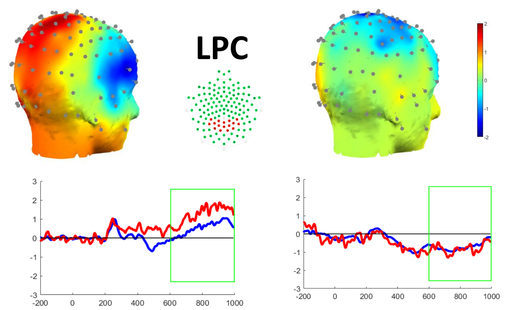
SL3

saso
saʃo

SL5

sakaso
sakaʃo





The local group showed a predicted P3 and LPC modulation to rule violation, while the nonlocal group showed no modulation, despite the presence of a robust auditory evoked potential (AEP) and readiness potential (RP), which reflects the response selection process.

The degree of locality in the phonotactic pattern leads to different types of neural encoding of the acquired phonotactic rule.

The computational complexity of the pattern plays a role in the pattern extraction process; participants easily extracted the rule that is less complex.

References

[1] Heinz, J. (2010). Learning long-distance phonotactics. *Linguistic Inquiry*, *41*(4), 623-661.
[2] Applegate, R. B. (1972). Ineseno Chumash grammar. Ph.D. dissertation, University of California, Berkeley.
[3] Luck, S. J., Kappenman, E. S., Fuller, R. L., Robinson, B., Summerfelt, A., & Gold, J. M. (2009). Impaired response selection in schizophrenia: Evidence from the P3 wave and the lateralized readiness potential. Psychophysiology, 46(4), 776-786.
[4] Núñez-Peña, M. I., & Honrubia-Serrano, M. L. (2004). P600 related to rule violation in an arithmetic task. Cognitive Brain Research, 18(2), 130-141.

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