Do Segment Boundaries Disrupt the Processing of Non-Adjacent Dependencies? Evidence from Neural Frequency Tagging and ERP

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Introduction

- Language processing requires comprehenders to link the words and phrases of sentences.
- This can result in non-adjacent dependencies (NADs) that can span multiple words.
- NADs can be inferred from artificial grammars by children and adults (e.g. [1],[7]).
- Recent proposal: **language is sampled in chunks** [6].
- We would introduce this as a conflict: (1) NADs can be learnt; but (2) language is sampled in chunks, so (3) NADs must be restricted to chunks [2]. Thus, **non-adjacent dependencies should be restricted to chunks**.

- **Is the processing of non-adjacent dependencies across chunks harder than within chunks?**
- **What ERP components might reflect the learning of non-adjacent dependencies?**

EEG Methods

Participants

N = 10 native German speakers listened to 6-syllable strings during an artificial grammar learning task.

Procedure

- Learning phase: participants listened to four 3-min audios that contain NADs either within or across segments and answered questions.
- Test phase: participants listened to 144 trials that either contain 8 chunks of NADs or not, in both within- and across-segment conditions, and answered a question after each trial.

Recording and statistics

EEG data were recorded at 500 Hz from 61 active electrodes. EEG pre-processing was done by applying the Harvard Automated Pre-processing Pipeline [5]. Data were band-pass filtered from 0.1 Hz to 25 Hz.

- Learning phase: Data were epoched to 12.64 s. Evoked Power (EP) and Inter-trial Phase Coherence (ITPC) were computed from 0.1 to 10 Hz in increments of 0.079 Hz. The peak values of the frequency of chunk and syllable were compared with the neighboring frequency bins via one-way ANOVA.
- Test phase: The elements of dependency pairs were epoched from the onset to 300 ms and baseline-corrected. A nonparametric statistical analysis was conducted across all electrodes.

Stimuli

German syllables (12 for targeted chunks and 12 for fillers) are recorded separately as isochronous speech. Each syllable lasts 250 ms and a 80 ms silence was inserted as a segment boundary between each chunk. Four dependency pairs were created for four lists. Twelve +NAD and —NAD chunks were randomly constructed for each list. Twenty-four filler chunks were created.

Learning Phase

WITHIN (72 NAD and 72 fillers per audio)

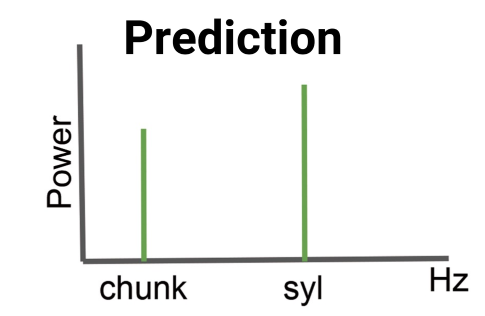
ba fu pu me la gu ma de tu he go bi **bo fu su na la mo**

bi he pe lu ki go **me fu ba na la mo** pe ki lu ma le bu…

ACROSS (72 NAD per audio)

fa na su no we me **pu ho fi bo gu mi** fa pu mo fi we su

bo ho mi no ba gu gu mo na fa we su **ba ho me no mi fi** …



Test Phase

WITHIN +NAD

bo fu su na la mo ki pe bu lu ma bi…

WITHIN —NAD

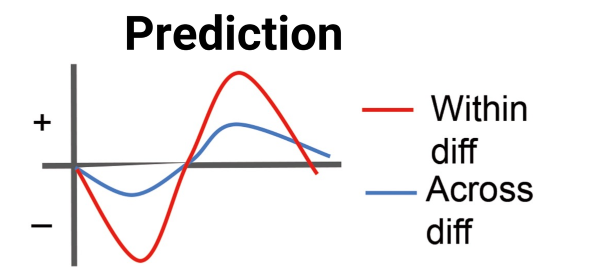
mi fu na mo bo ba ki le he pe ma li…

ACROSS +NAD

gu pu na su we ba **bo ho me mi fi mo…**

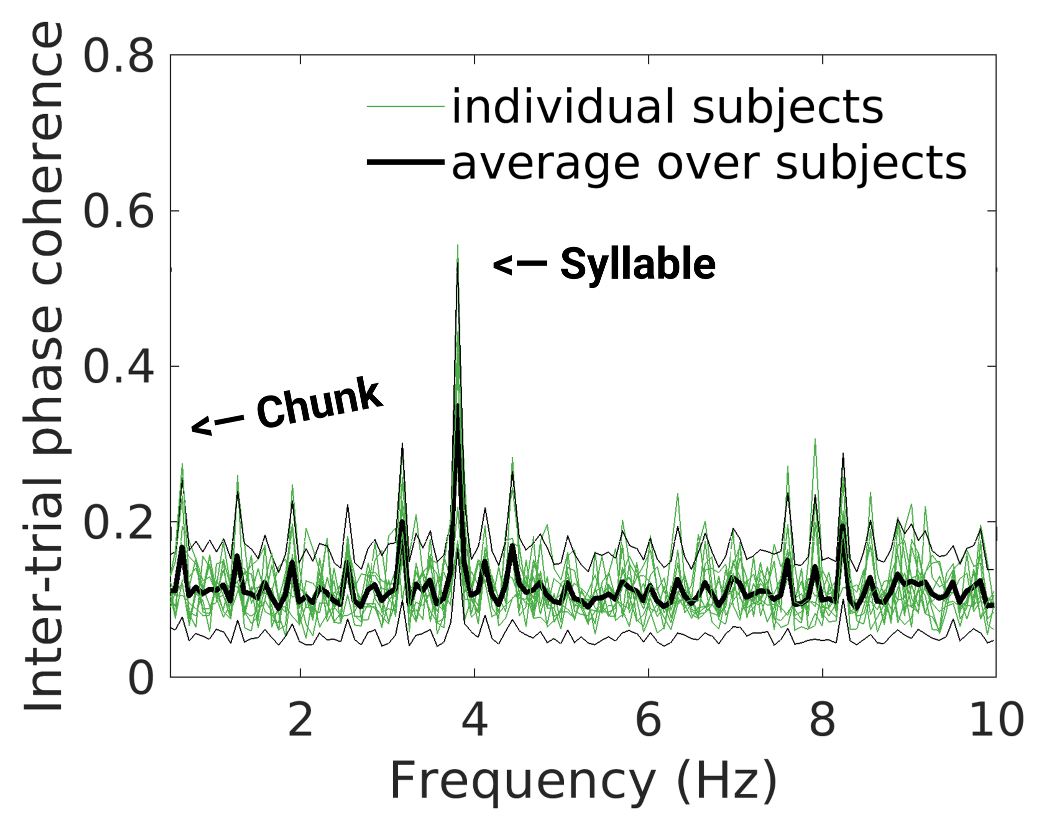
ACROSS —NAD

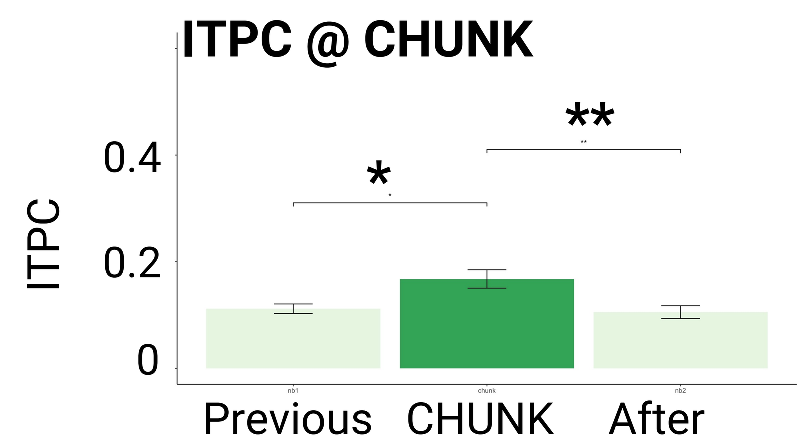
mi ba na pu we gu mo fa no me bo fi…

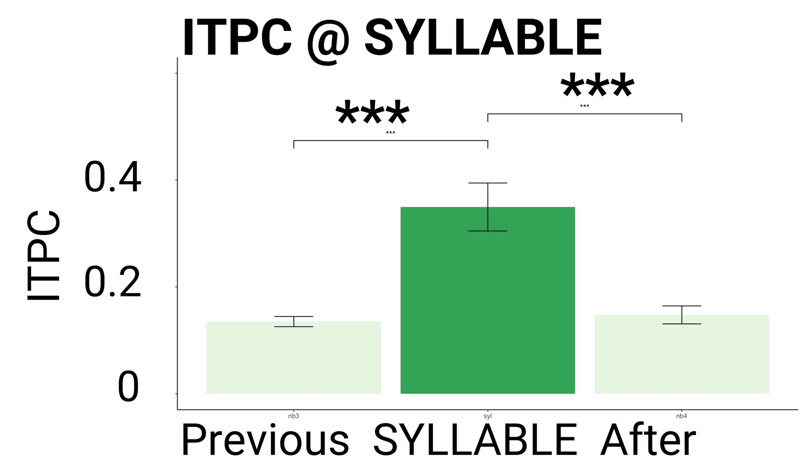


Results

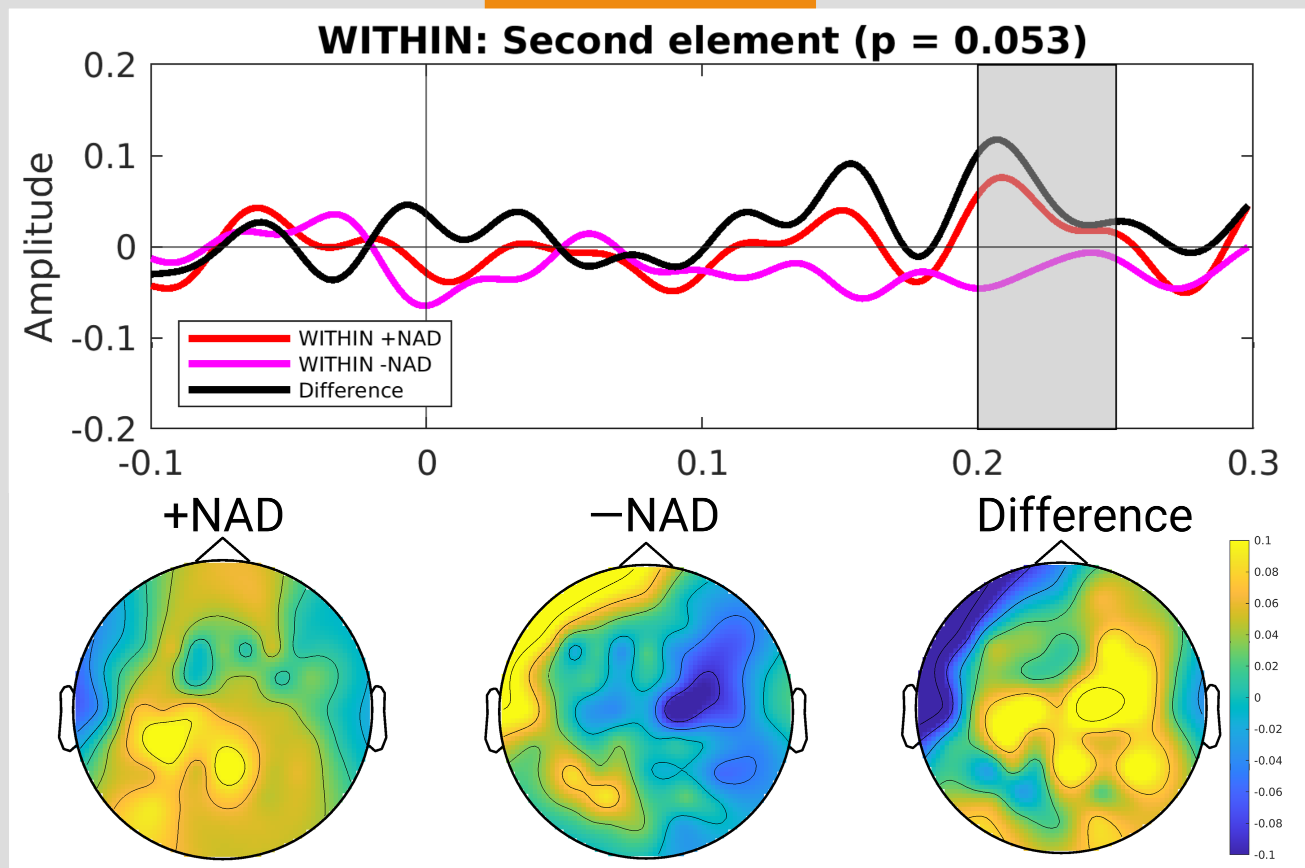
Learning Phase

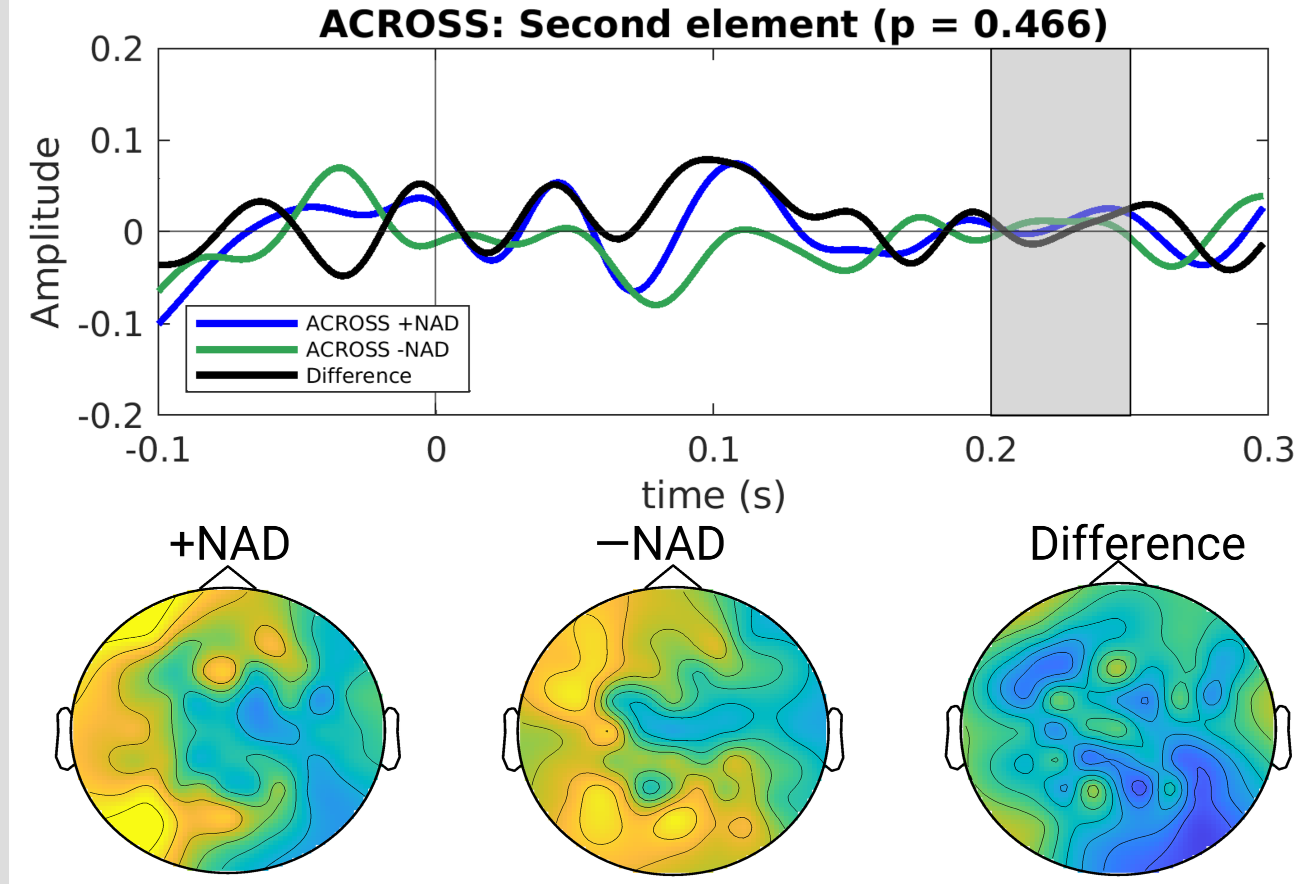






Test Phase





Discussion

Preliminary results (Data collection is still in progress!)

Learning Phase:

- Overall behavioral accuracy: 63% correct.
- Peak at chunk frequency can be observed.
- Participants learn the chunks across conditions.

Test Phase:

- Overall behavioral accuracy: 67% correct.
- A marginal significance in comparison of NADs and non-NADs in the within condition, but not across condition.
- P200?: it might reflect the segregation of a continuous unit or the expectation of a target word onset ([1],[3],[8]).
- LAN?: It might reflect the violation of non-adjacent dependencies [4].

- **Processing of non-adjacent dependencies across chunks might be harder than within chunks.**
- **P200 and LAN might reflect the learning of non-adjacent dependencies.**

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