Event Related Potentials as a Measure of Implicit Grammatical Knowledge in Artificial Grammar Learning

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INTRODUCTION

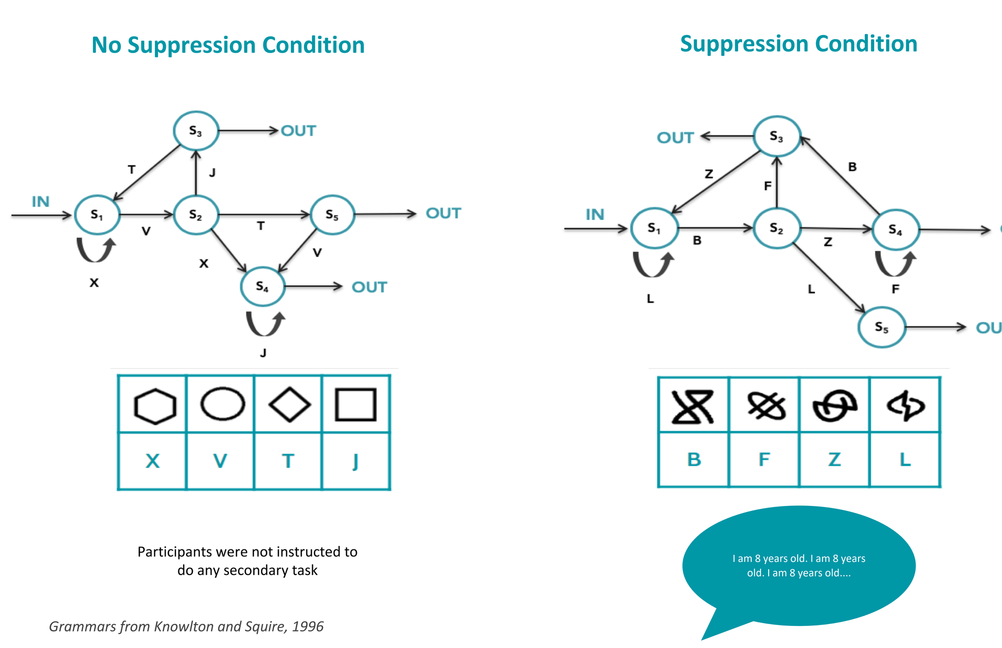
Language development during infancy is dominated by the extraction of regularities from environmental input, a process known as implicit learning. However, after this initial period, learning becomes a constant interaction between two learning systems, the implicit (unconscious, gradual, statistical) and the explicit (conscious, intentional, rule based) learning systems. It is challenging to measure the effect of one system on learning without the involvement of the other. The study tests a method for isolating implicit learning by suppressing the use of explicit learning strategies. It evaluates the effect of suppressing explicit learning strategies on learning outcomes and processing at the neurophysiological level when children learn an artificial language. Event Related Potentials sensitive to grammatical violations (P300, P600) were examined under the two conditions (with suppression, without suppression).

METHODS

Participants - children between ages 9-12. The study contains behavioral data from 22 participants (Mean age $\pm$ SD=11.6 $\pm$ 0.9, 14 male) and EEG data from 19 participants (Mean age $\pm$ SD =11.4 $\pm$ 1, 13 male).

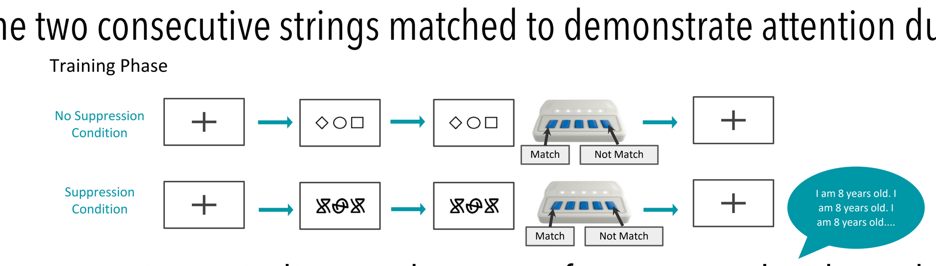
Task - visual AGL task in which sequences are generated from a finite grammatical structure defining the rules of the "language". Grammatical sequences follow permissible transitions in the language. Nongrammatical sequences violate the structure of the language at one position. In the training phase, participants are exposed to grammatical strings only. In the testing phase, participants judge the grammaticality of new strings that either abide by the grammar structure of the language or violate it.

- *Chunk strength* in test items refers to subsequence familiarity, characterized by bigrams and trigrams ("chunks") in test items appearing at higher relative frequencies in training items. High chunk strength test items contain chunks that appeared more frequently and are more familiar to participants

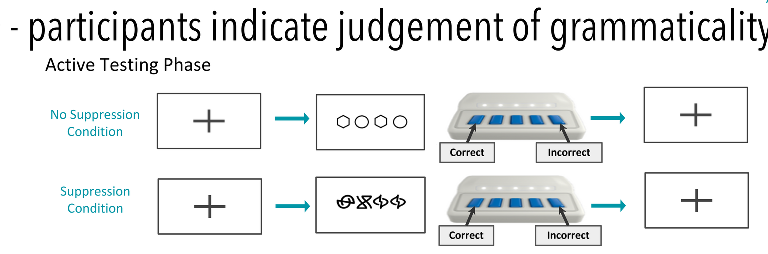


- ***No Suppression*** condition - children were passively exposed to grammatical sequences in the training phase. Stimuli consisted of known, easily identifiable shapes to facilitate explicit learning strategies.
- ***Suppression*** condition - participants repeated a sentence out loud during the training phase. This secondary task targeted occupying participants' phonological loop by decreasing their ability to rehearse and memorize the incoming strings. Stimuli consisted of abstract symbols taken from the Brocanto language that are unfamiliar and difficult to verbalize (Friederici et al., 2002). The Suppression condition aimed to decrease participants' ability to engage in conscious, explicit strategies.

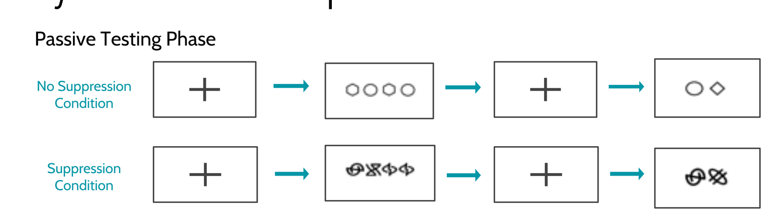
- **Training Phase** - participants are presented two grammatical strings in succession and must indicate whether the two consecutive strings matched to demonstrate attention during the training phase.



- **Active** Testing Phase - participants indicate judgement of grammaticality through a button press.

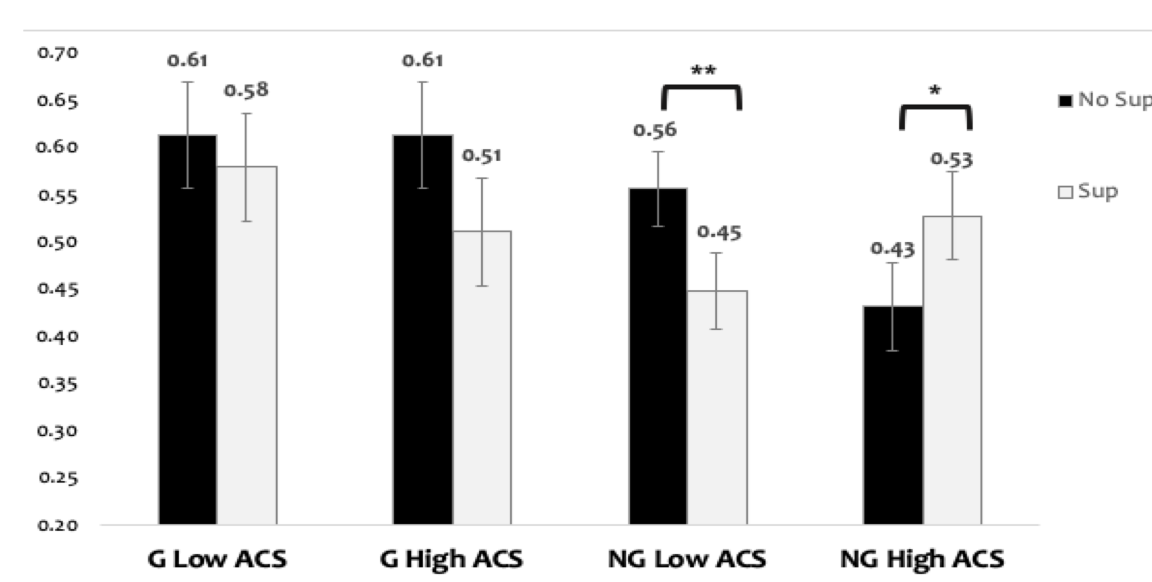


- **Passive** Testing Phase - participants count the number of non-grammatical strings in their head. This distinction in phases is to try to isolate whether preparing and making the motor response of judgment via the button press has any effect on ERP amplitudes.

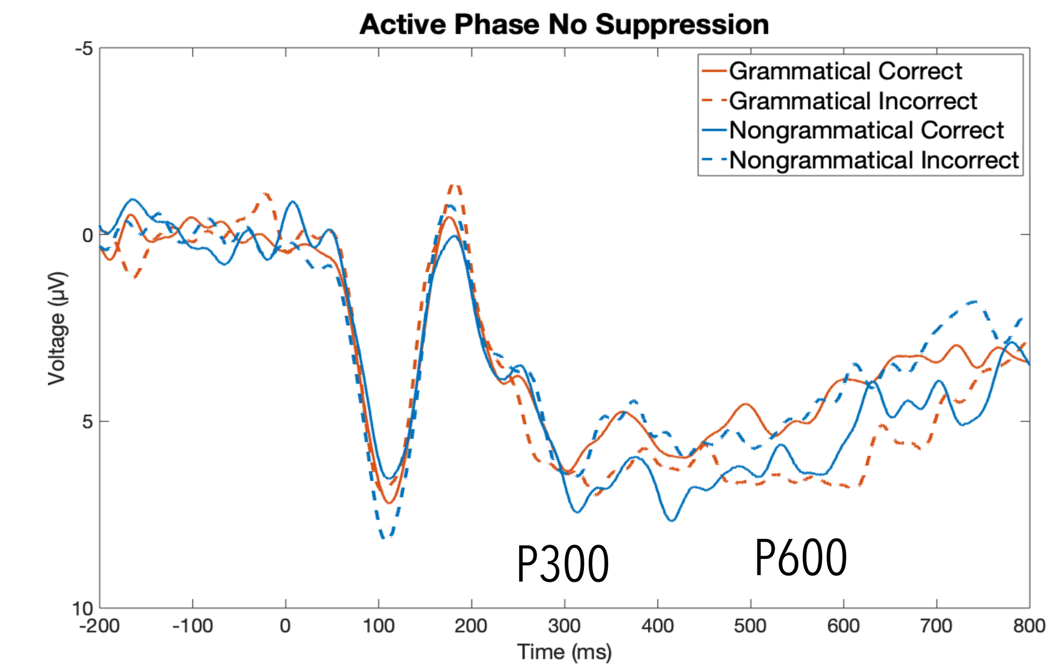


EEG Data Collection - EEG data was acquired using a 32-electrode Hydrocel Geodesic sensor net from the GES 400 System by Electrical Geodesics Inc. EEG data from the testing phases is offline filtered using a bandpass filter of 0.1-30 Hz. Epochs are time-locked to presentation of stimulus (the sequence), with 200 ms before stimulus presentation to 800 ms after. Filtered data is re-referenced to the average and baseline corrected. Independent component analysis is conducted to remove artifacts. Temporal principal component analysis is applied to electrode Pz.

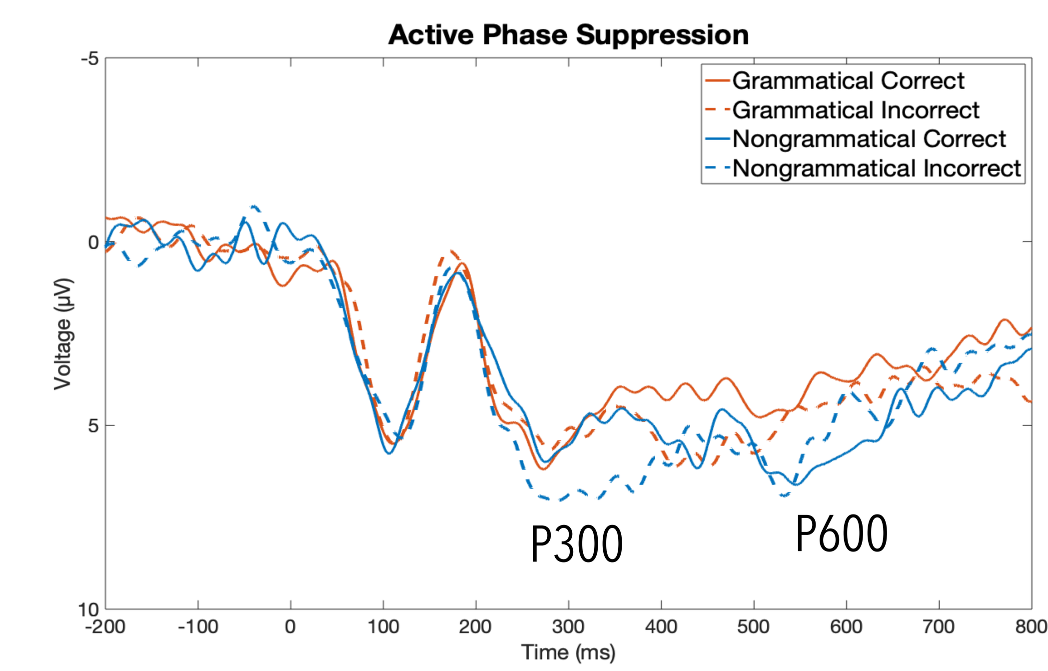
RESULTS



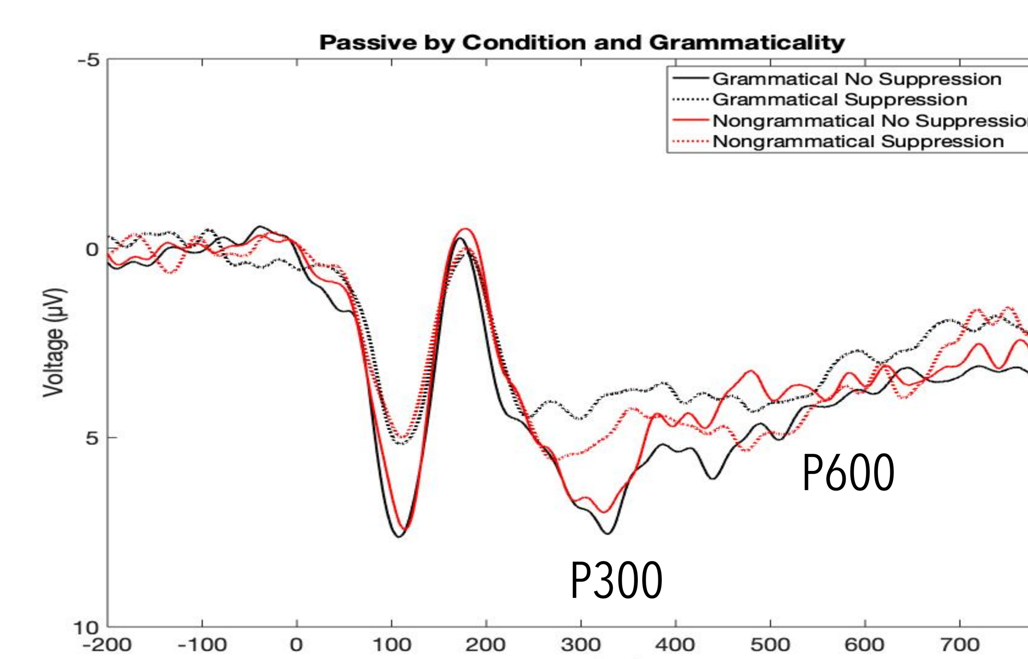
- Mean **accuracy** for each condition (No Suppression and Suppression) for each level of grammaticality and chunk strength (ACS).
- Overall, participants identified grammatical sequences with greater accuracy than rejecting non-grammatical sequences.
- In the **No Suppression Condition**, participants were better at identifying ***non-grammatical low chunk strength*** items, i.e., non-grammatical strings different from training items.
- In the **Suppression Condition**, Participants were better at identifying ***non-grammatical high-chunk strength*** items. This could reflect better implicit learning as rejecting strings that are similar to training items requires some implicit knowledge of the underlying structure of the grammar.



Larger P300 in the active phase of the No Suppression Condition was elicited by items that were **judged by the learner as nongrammatical**, either correctly or incorrectly.



Larger P300 in the active phase of the Suppression Condition to **non-grammatical items judged incorrectly**, which could reflect unconscious detection of non-grammaticality.



In the passive phase of the **No Suppression Condition**, the **P300** elicited to grammatical and nongrammatical items was similar.
In the passive phase of the **Suppression Condition**, a larger **P600** to **non-grammatical** items was detected, indicating a detection of non-grammaticality even without an active motor response.

References:

- Knowlton, B. J., & Squire, L. R. (1996). Artificial grammar learning depends on implicit acquisition of both abstract and exemplar-specific information. *Journal of Experimental Psychology: Learning Memory and Cognition, 22*(1),
- Friederici, A. D., Steinhauer, K., & Pfeifer, E. (2002). Brain signatures of artificial language processing: Evidence challenging the critical period hypothesis. *Proceedings of the National Academy of Sciences, 99*(1), 529-534.

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