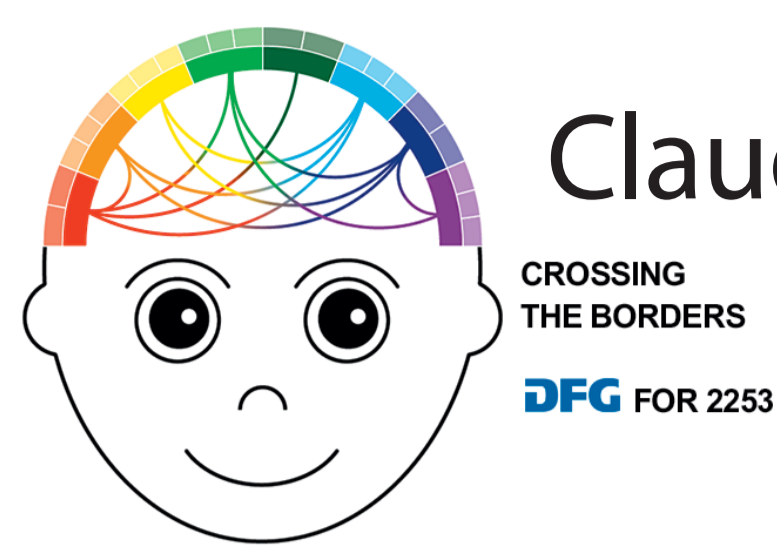


# P1: The sensitive period for associative learning of non-adjacent dependencies in the linguistic and non-linguistic domain



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## Introduction

Infants effortlessly learn their native language within a few years.

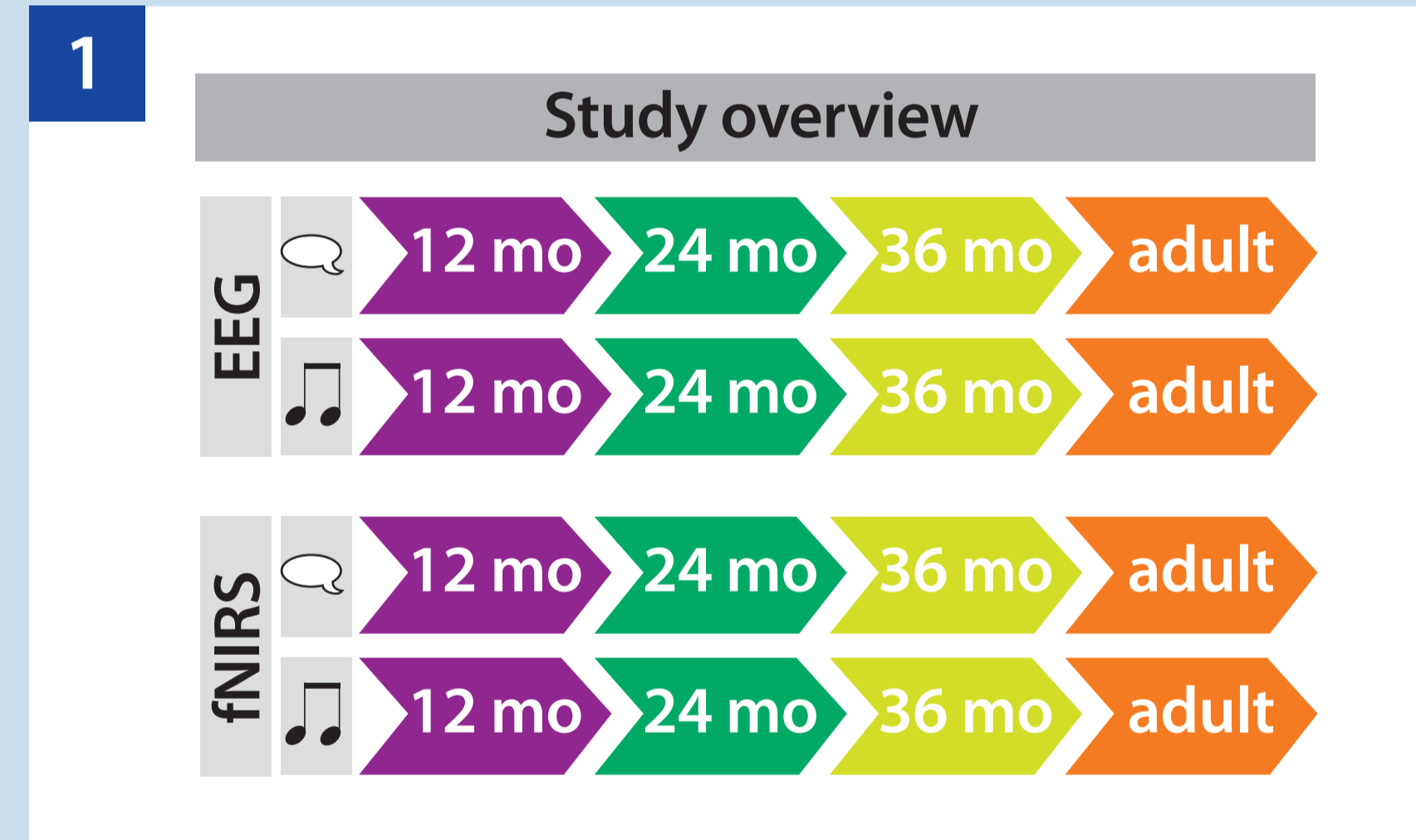
Infants are equipped with remarkable language learning abilities. The ability to extract and generalize dependencies between non-adjacent elements in predictive sequences is present very early in life: Infants at 3 to 4 months discriminate grammatical from ungrammatical dependencies following only brief exposure, while adults fail to do so during passive listening<sup>[1,2]</sup>.

### How do infant and adult learning differ?

Delayed prefrontal cortex maturation has been proposed as major determinant of infant vs. adult learning<sup>[3]</sup>. Increase in cognitive control upon maturation of the prefrontal cortex may lead to a change from *associative* to more *controlled learning*.

### In our study, we aim to specify (Fig 1):

- When the developmental change from *associative* to more *controlled learning* of non-adjacent dependencies (NAD) occurs,
- Whether the learning of NADs follows the same trajectory in the linguistic and non-linguistic domains, and
- Which brain regions underly the learning of NADs in the different domains.



## Methods

### Participants

- Children: 12-, 24-, and 36-month-olds;  $n = 40$  (each)
- Adult control group:  $n = 20$
- Infant control group: 4-month-olds,  $n = 35$ .

### Methods

- Event-related brain potentials (ERPs) from electroencephalography (EEG)
- Functional near-infrared spectroscopy (fNIRS)
- Behavioral tests of cognitive function and language skills (eyetracking and standardized tests)

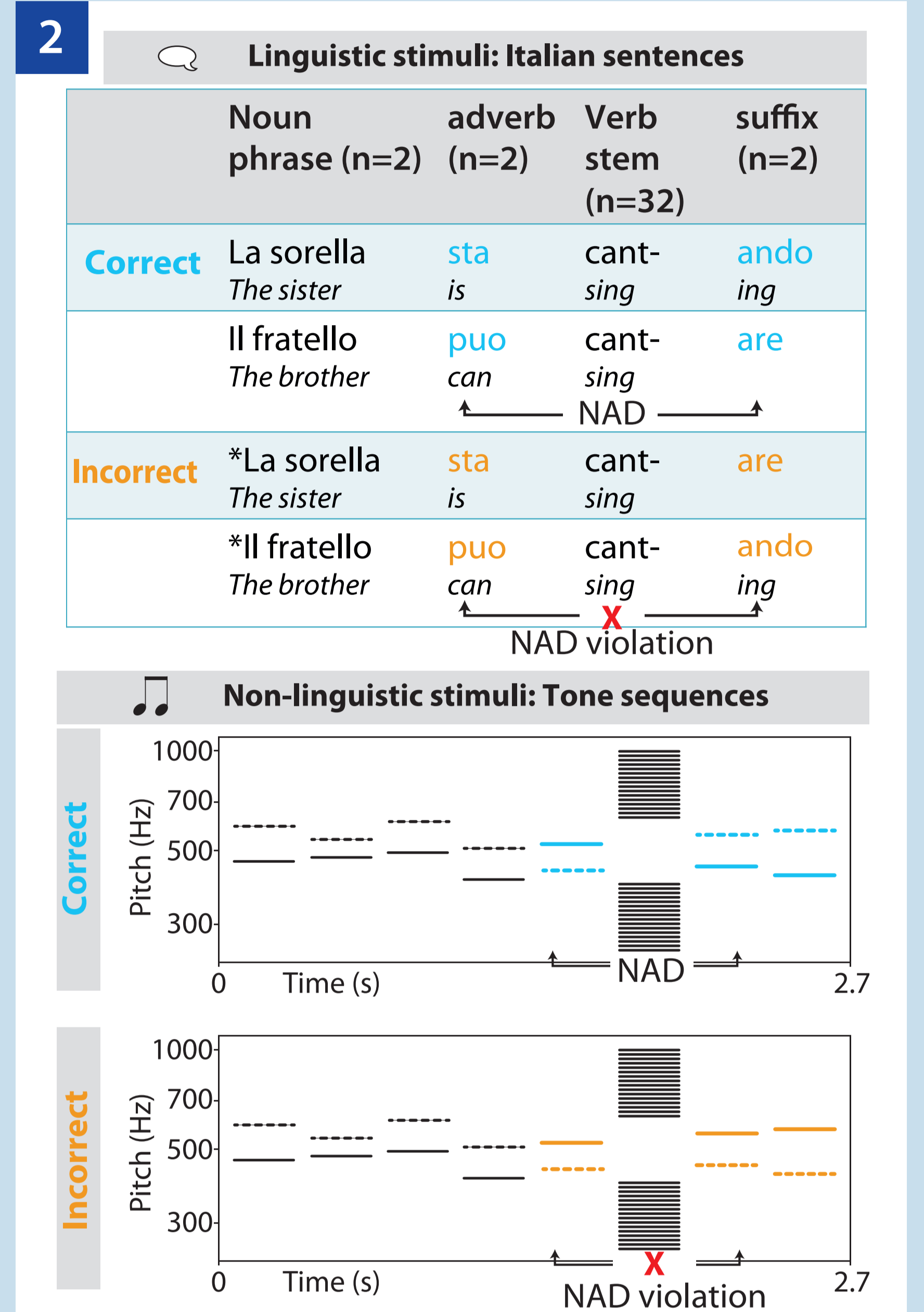
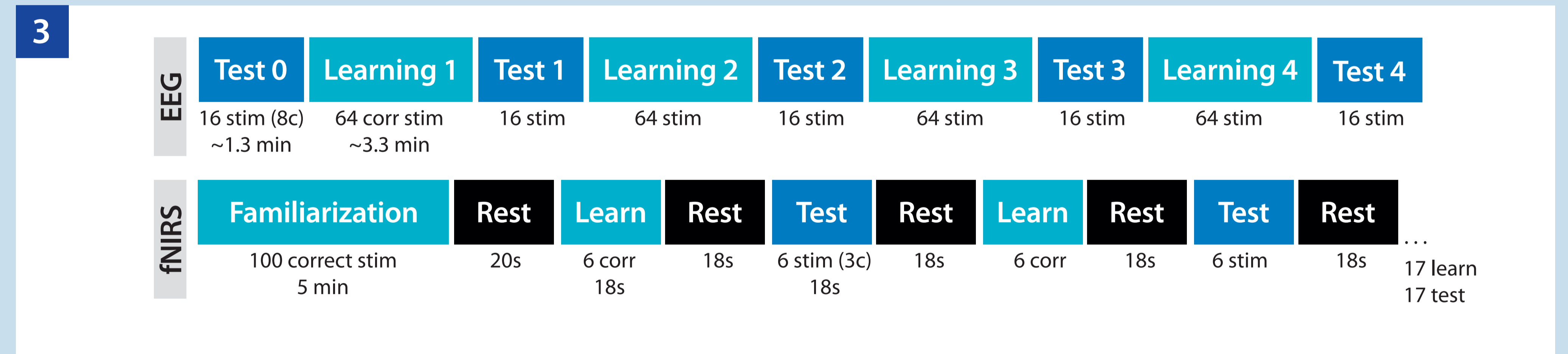
### Stimuli

The linguistic (Italian sentences) and non-linguistic (tone sequences) experiments contain correct stimuli with NADs and incorrect stimuli with NAD violations (Fig 2).

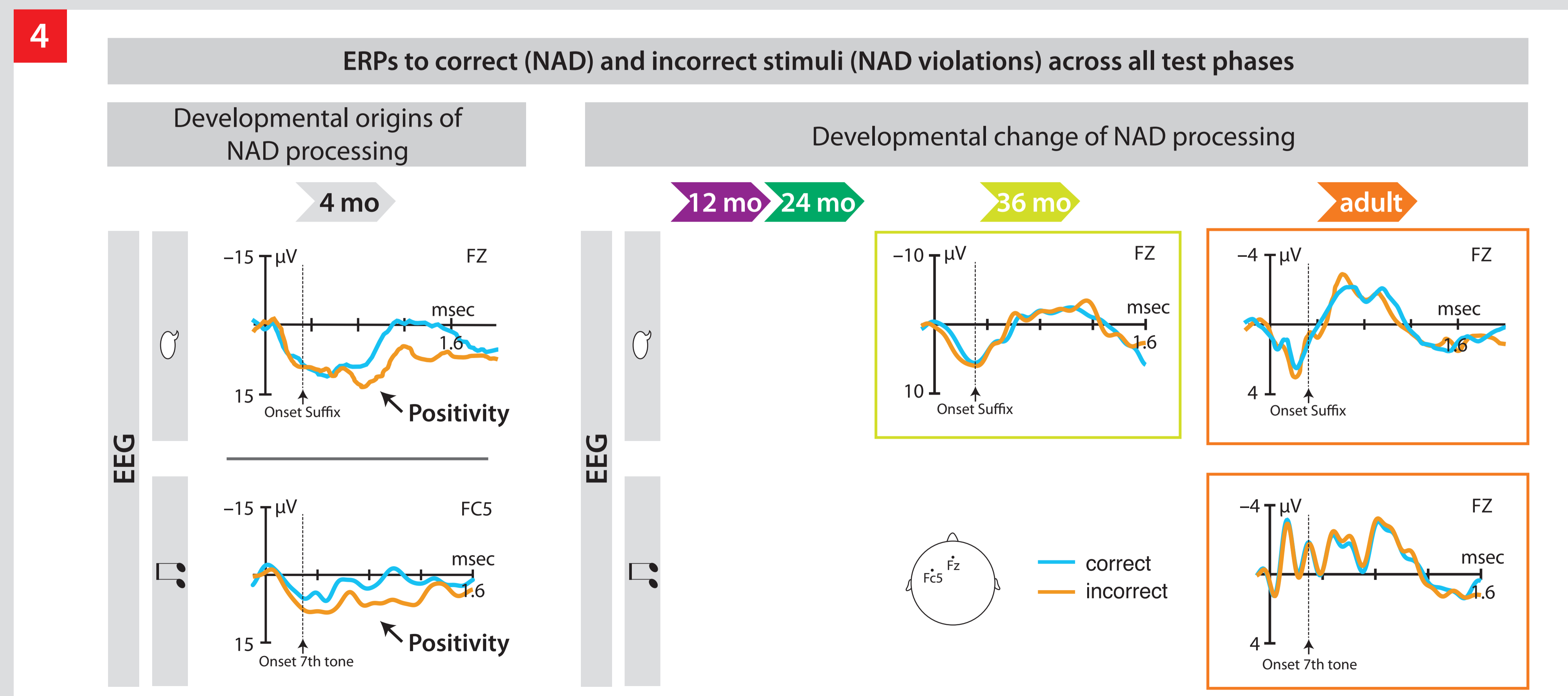
- Italian sentences: NAD between Adverb and Suffix (verb stem as variable middle element)
- Tone sequences: Italian syllables are replaced by pure tones, preserving NADs
- Linguistic and non-linguistic stimuli are matched on mean overall duration and mean duration of the individual tones / syllables.

### Paradigm

Stimuli are presented in a **passive-listening learning-test paradigm**. In both EEG and fNIRS studies, *learning phases* containing correct items (with NADs) are followed by *test phases* containing correct and incorrect items (with NAD violations). Comparison of brain responses to correct and incorrect items reveals whether the dependency was extracted from the input (Fig 3).



## Results



## Summary and next steps

**Developmental changes in associative NAD learning:** ERPs show detection of NAD violations in both linguistic and non-linguistic stimuli upon passive listening in 4-month-olds, but not in adults. ERPs to NAD violations reveal no signs of NAD learning from passive listening at 3 years of age.

**Validation of non-linguistic material:** Comparable ERPs are observed in response to NAD violations in non-linguistic material (current data) and Italian sentences<sup>[1]</sup> in 4-month-olds and adults.

**Determine shift between associative and controlled learning of NADs:** Expected before the age of 36 months in the linguistic domain.

**Exploring the relation between brain correlates of NAD processing and behavioral cognitive/language skills.**

## References

- [1] Friederici, A.D., Mueller, J.L., Oberecker, R. (2011). Precursors to natural grammar learning: preliminary evidence from 4-month-old infants. *PLoS One*, 6(3), e17920.  
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