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Development of cortical and subcortical responses to speech sounds during infancy

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Introduction

Event-related brain potentials to speech sounds are efficient tools for studying speech perception development in young infants. (Thierry, 2005; Hervé et al, 2021)

M Mismatch Response, a cortical component evoked by **M** change detection in a series of similar auditory stimuli
R → speech sound discrimination
(Cheour et al, 1998; Dehaene-Lambertz & Pena, 2001; Näätänen et al, 2007)

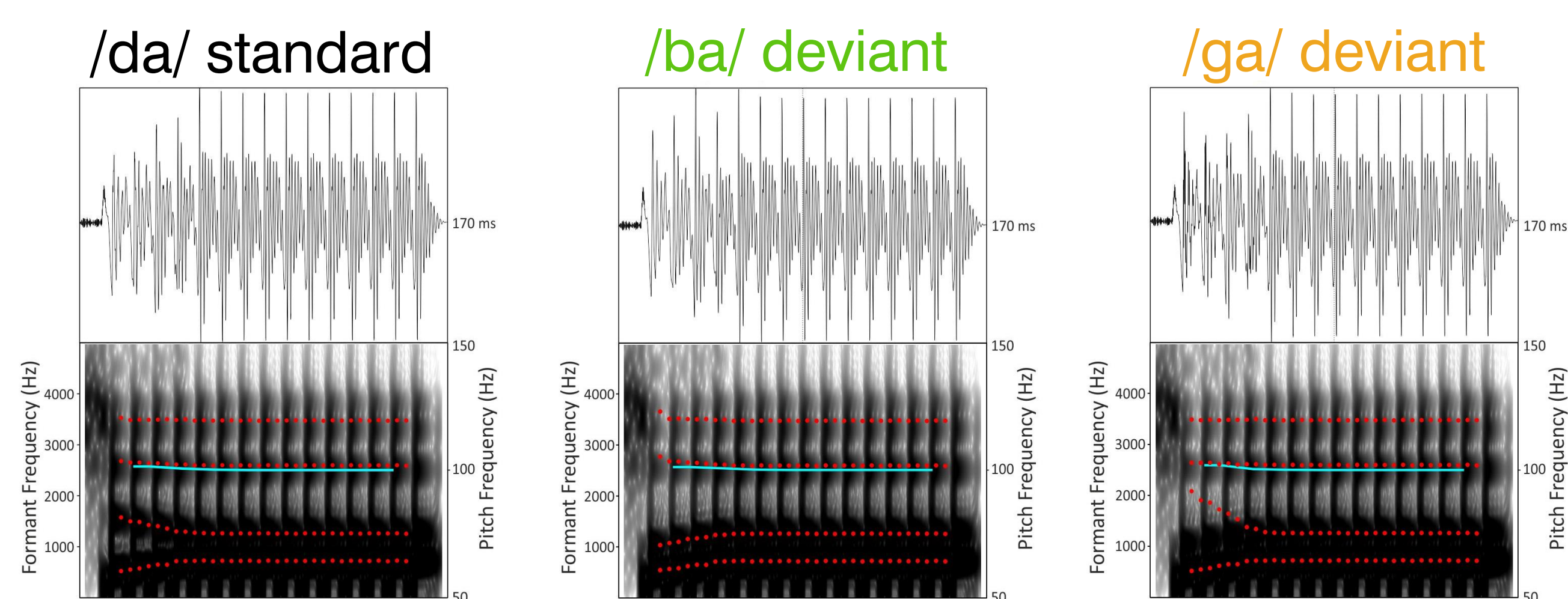
F Frequency-Following Response, a subcortical brain response that **F** follows the spectro-temporal features of the auditory stimulus
R → fine-grained encoding of speech sounds' characteristics
(Anderson, 2015; Ribas-Prat et al, 2019, Arenillas-Alcón et al, 2021)



- Evaluate the feasibility of simultaneous cortical and subcortical EEG recordings in infants.
- Understand the mutual contribution of subcortical and cortical structures during speech processing.
- Decipher the neuroplasticity mechanisms supporting the maturation of the auditory system during early development.

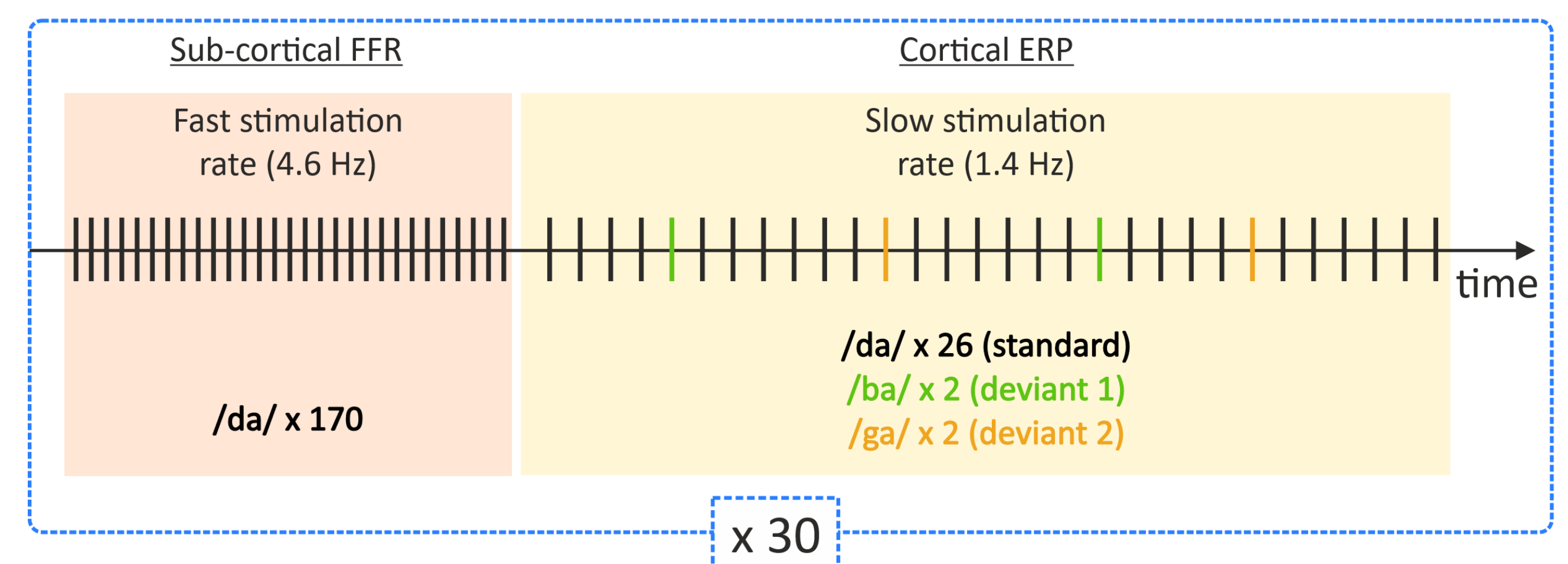
Materials and Methods

FIG.1a: Stimuli : synthetic CV syllables



From Skoe & Kraus, 2010. F0 = 100.4 Hz, duration: 170 ms

FIG.1b: Procedure: passive listening oddball paradigm



30 alternating blocks of fast and slow stimulation frequency (Fs). (Bidelman et al., 2015)

90 infants, aged 6 to 24 months; healthy, no developmental or hearing disorder. Recorded semi-longitudinally and separated into two age groups: the younger (6- to 10-month-olds) and the older (18- to 24-month-olds).

Results

Cortical Event-Related Potentials (n = 80)

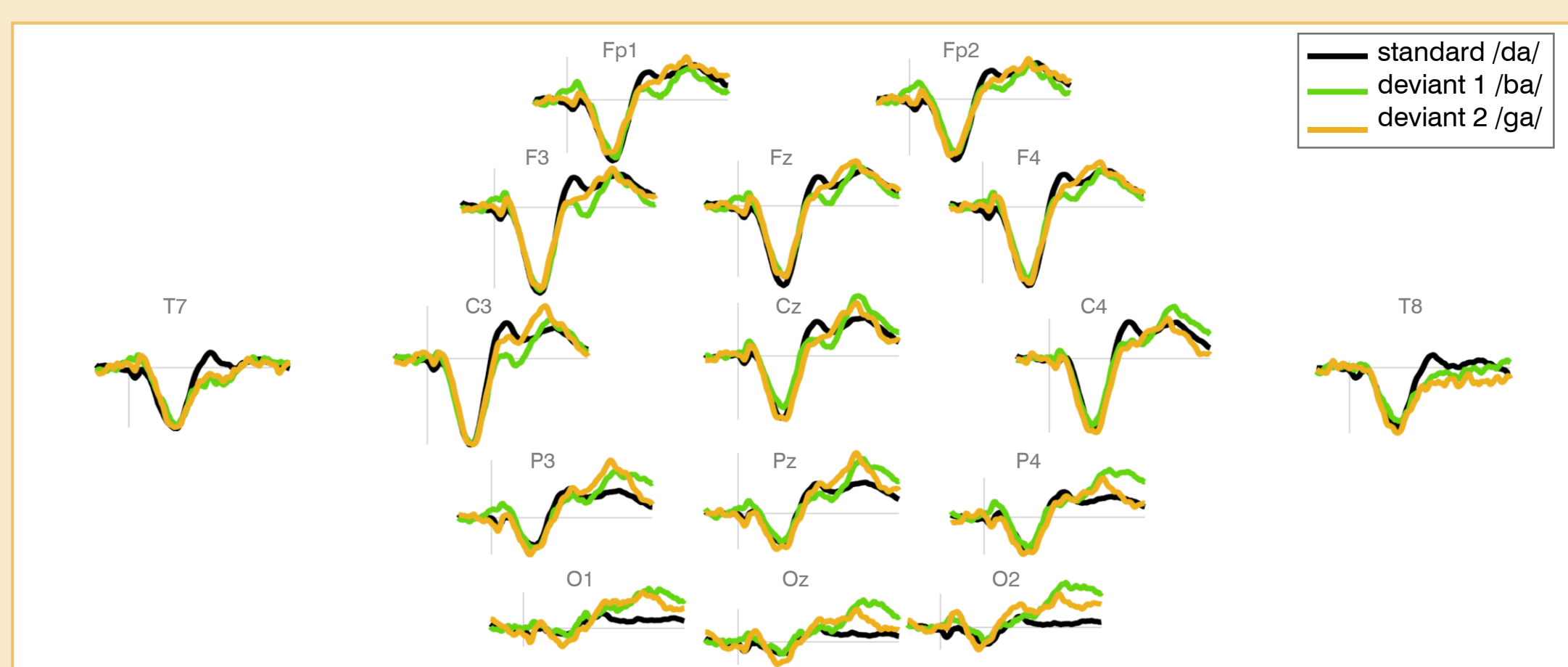


FIG.2a: Mean evoked activity by electrode for each condition, all subjects (n = 80).

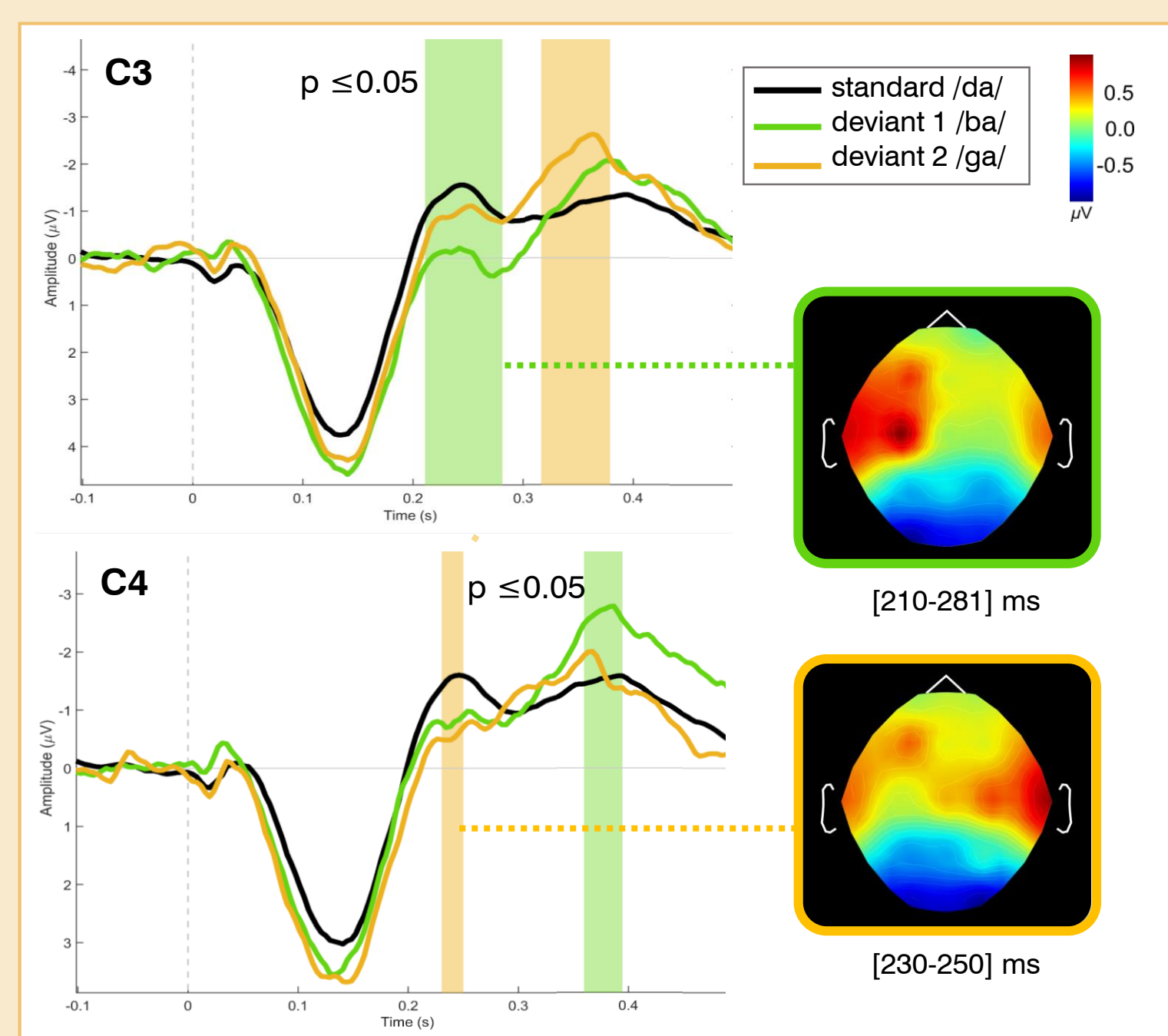


FIG.2b: (Left) Event-related potential (ERP) to standard /da/ stimulus, deviant 1 /ba/ stimulus and deviant 2 /ga/ stimulus at central C3 (top) and C4 (bottom) electrodes. Colored areas: significant results to Student's t-test between standard and deviant for each condition ($p \leq 0.05$). (Right) Spatial representation of brain activation at significant time windows (deviant minus standard).

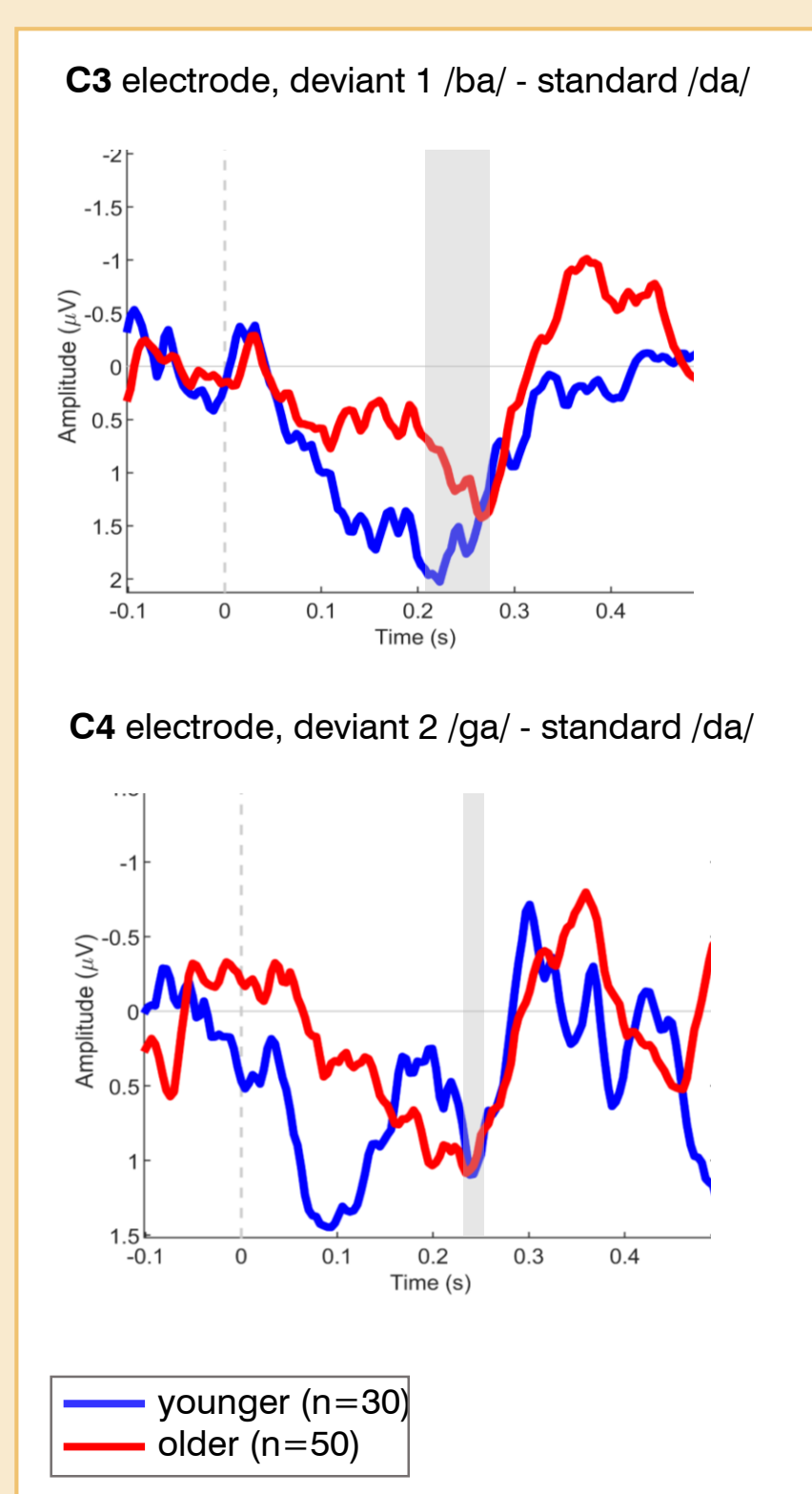


FIG.2c: Subtracted activity (deviant - standard) for each deviant, group comparison. Grey areas: group-level time window for MMR (see Fig.2b).

Subcortical response: FFR (n = 62)

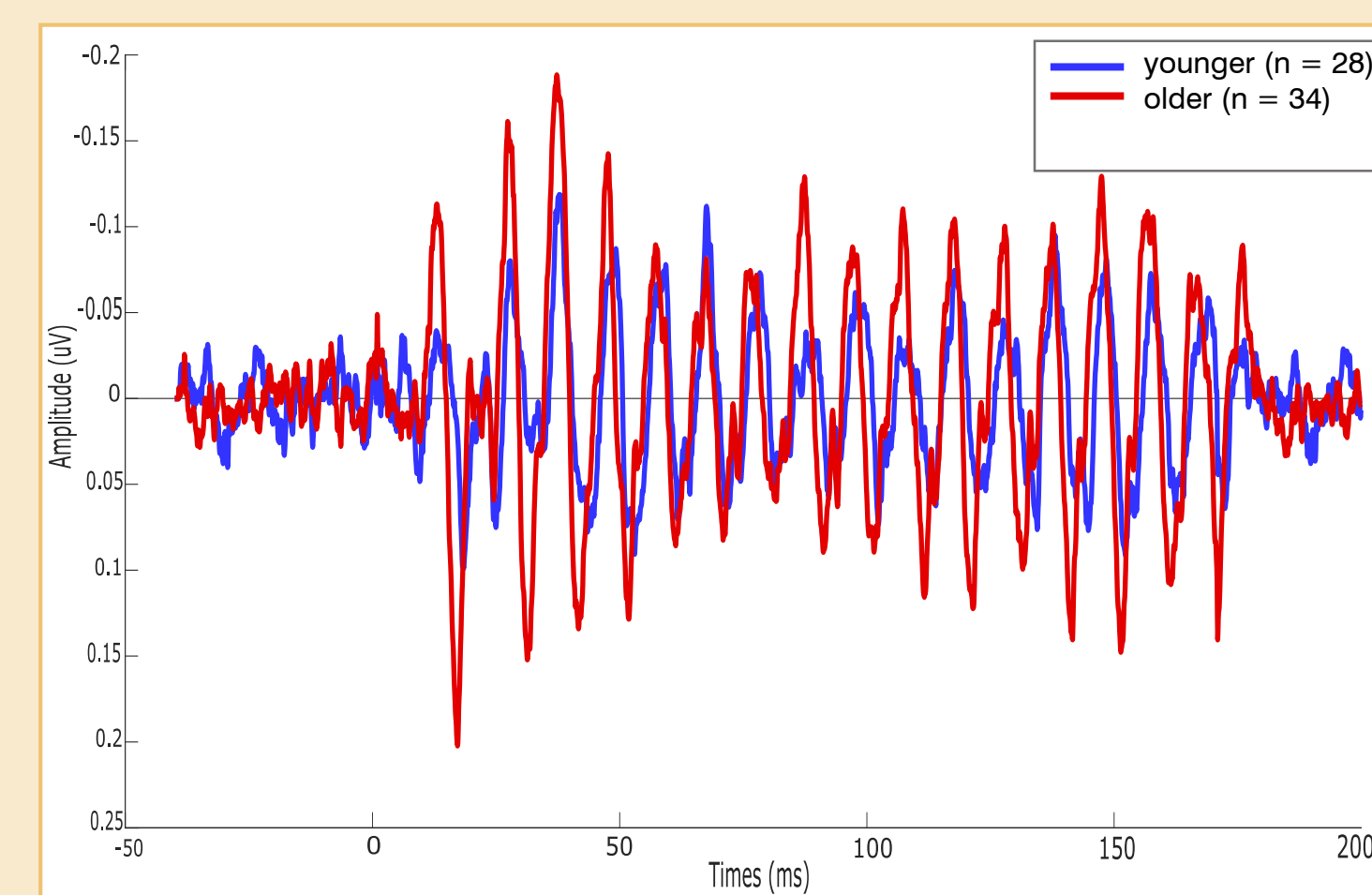


FIG.3a: Temporal domain, group comparison.

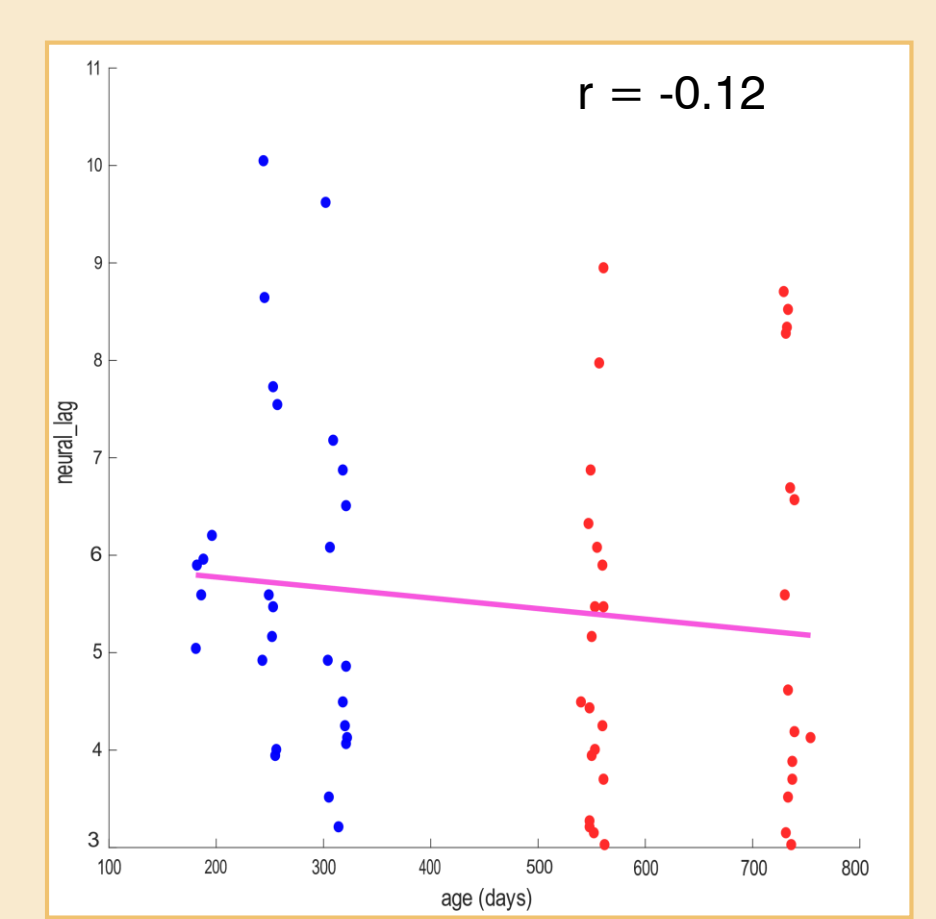


FIG.3b: Neural lag as a function of age.

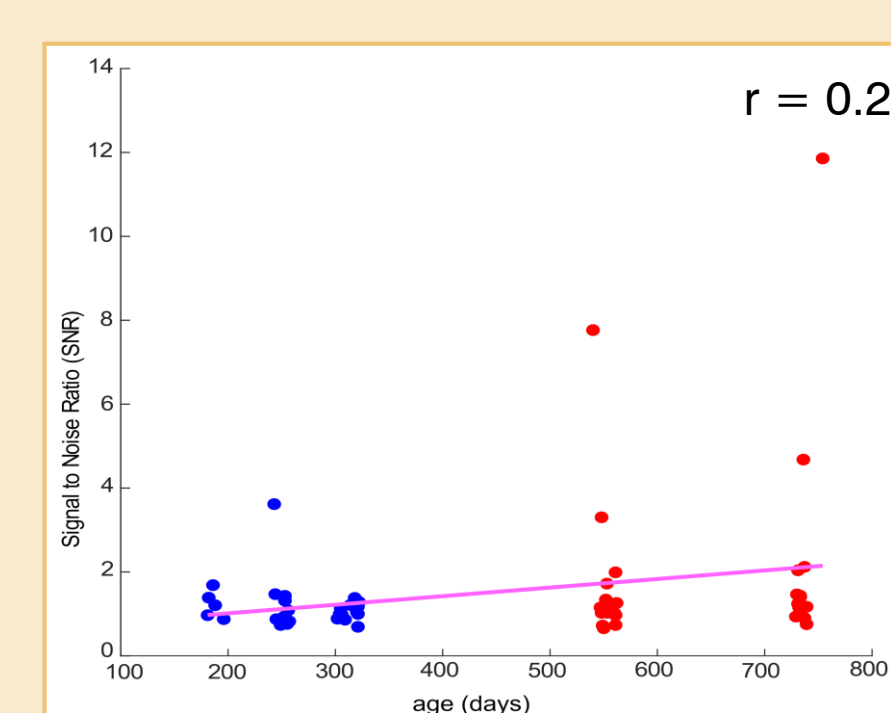


FIG.3c: SNR at vowel time-window as a function of age.

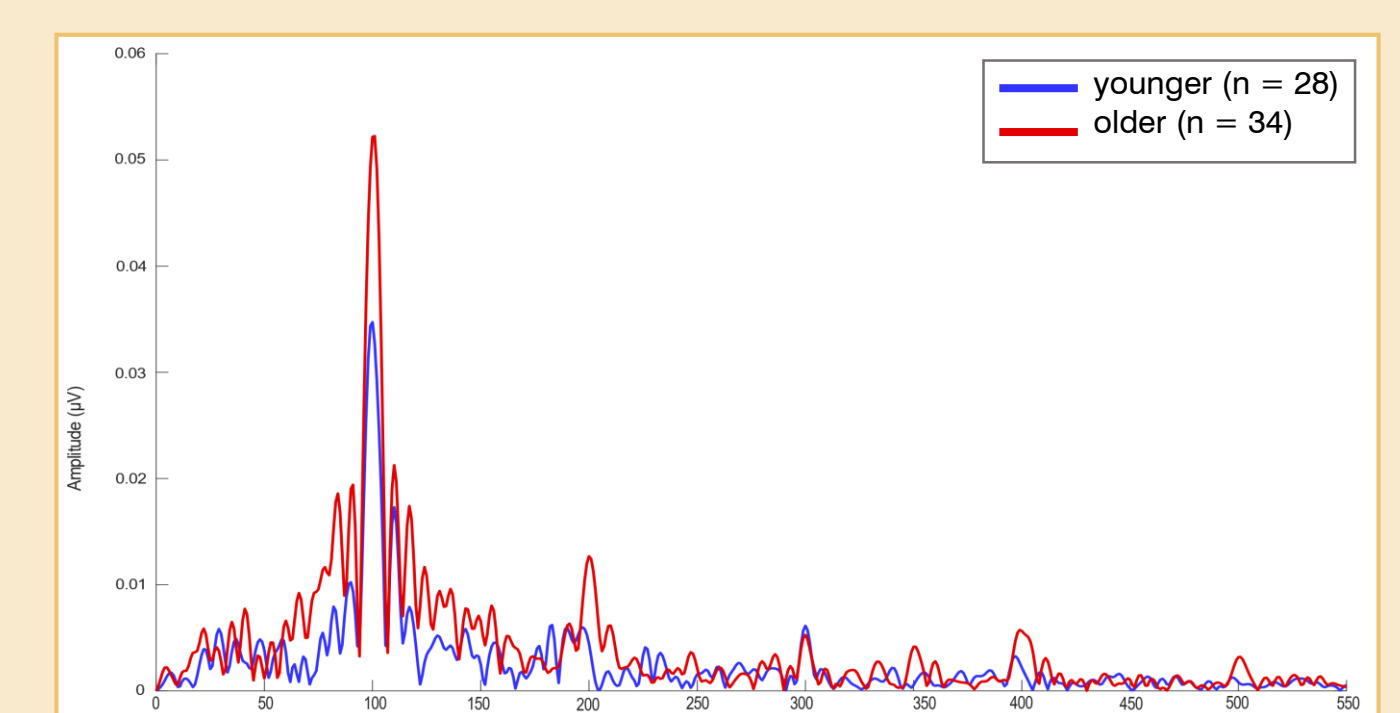


FIG.3d: Fast-Fourier transform of the FFR, group comparison

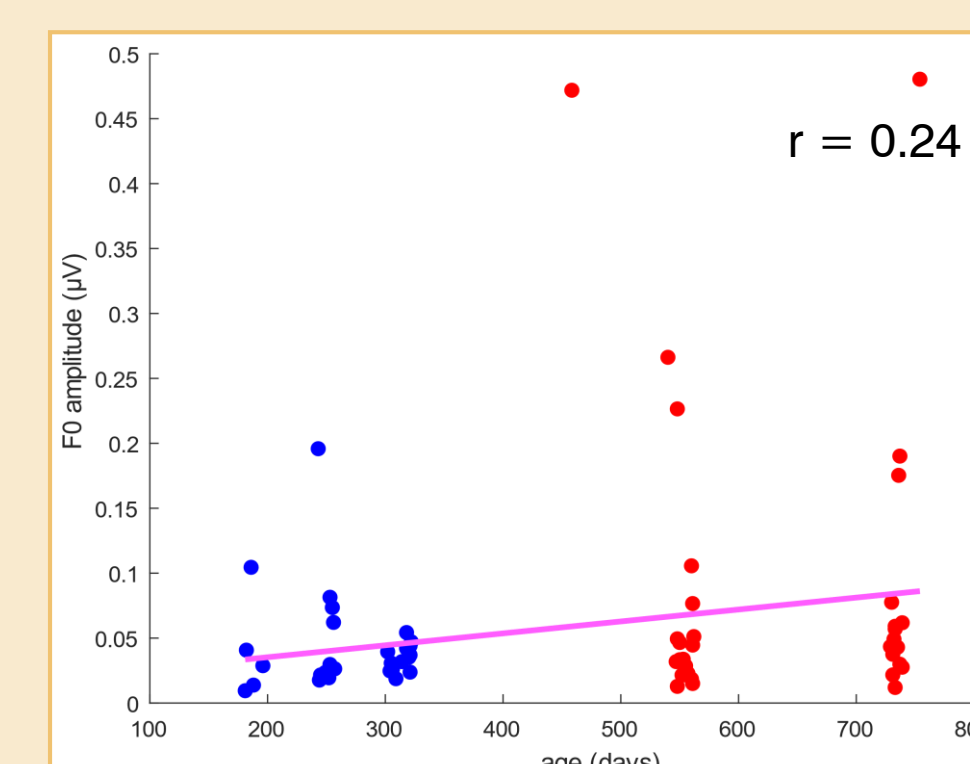


FIG.3e: Amplitude of the FFR F0 as a function of age.

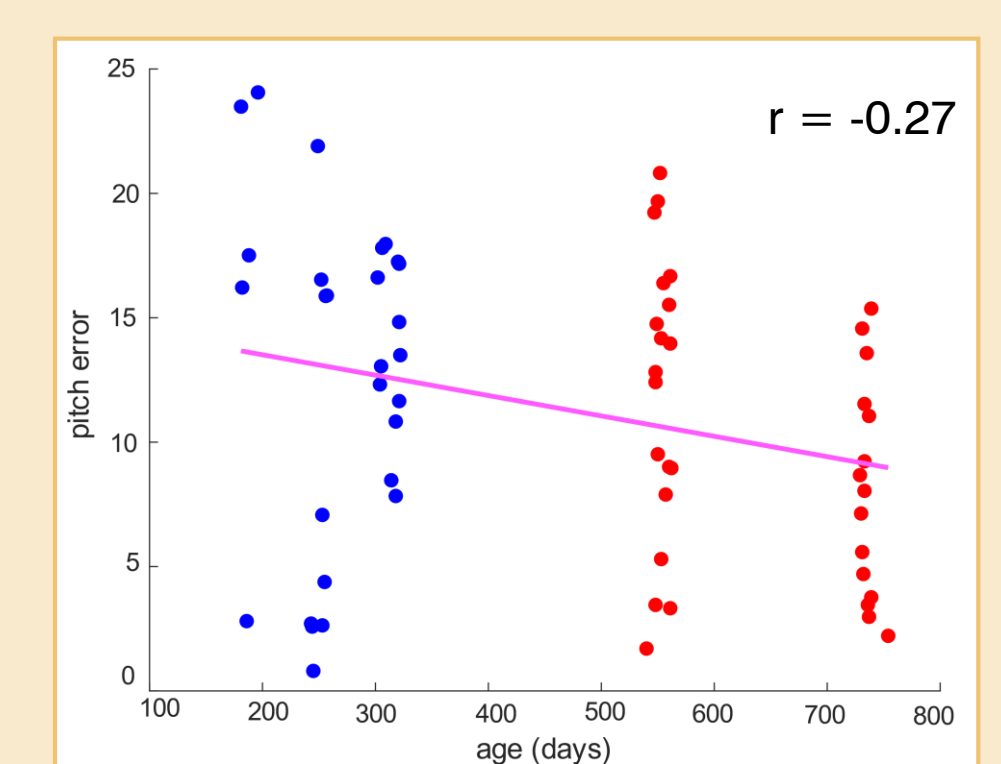


FIG.3f: Pitch error as a function of age.

Discussion

- Consistent results with literature for both cortical ERPs and FFR:
 - Better non-native speech sounds discrimination in younger infants (Kuhl et al, 2007)
 - Better encoding of speech sounds features (temporal and frequential domains) in older infants (Anderson et al, 2015)
- A new tool for neurodevelopment of speech perception abilities from lower to higher levels of processing?

Limits: • attrition rates varies between cortical ERPs analyses and FFR analyses; • large number of participants needed.

Perspectives: • longitudinal design; • correlations between cortical ERPs and FFR indices? • applicable at the individual level?

References



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