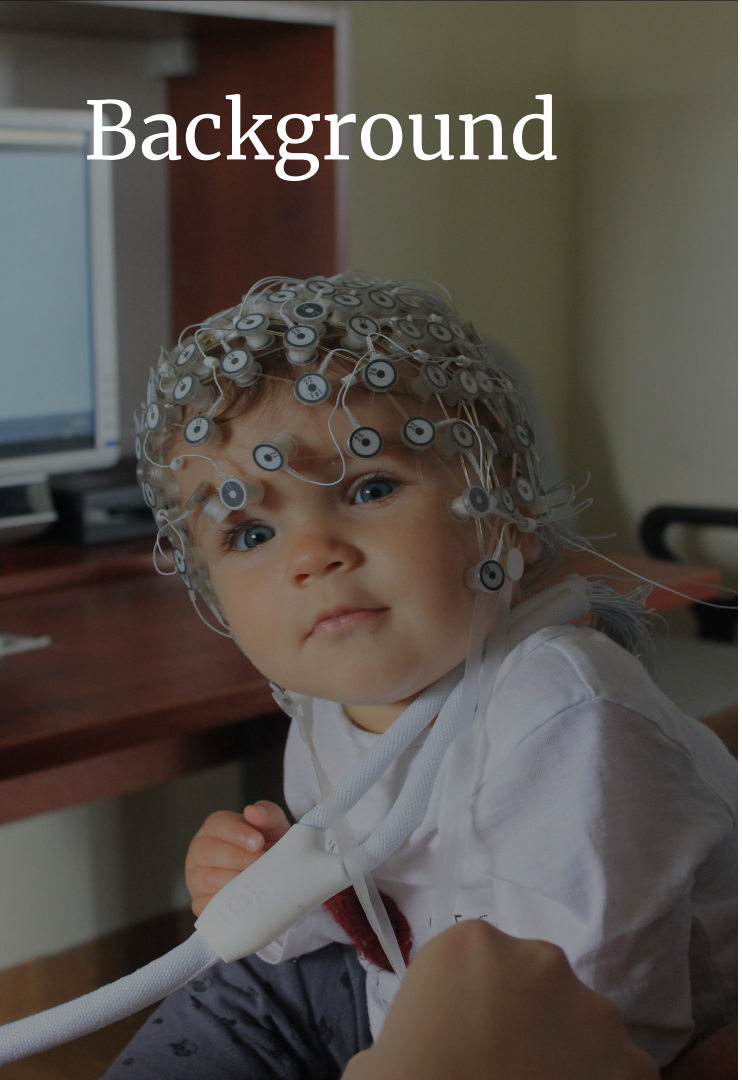
Perception of non-native phoneme contrasts in 8-12 months infants: tensor-based analysis of EEG signals

Mansoureh Aghabeig
Nicolaus Copernicus University

Overview

- Background
- Main goal
- Description of infant datasets
- Preprocessing
- Time frequency analysis
- CP Tensor decomposition
- Results
- Conclusion

Background



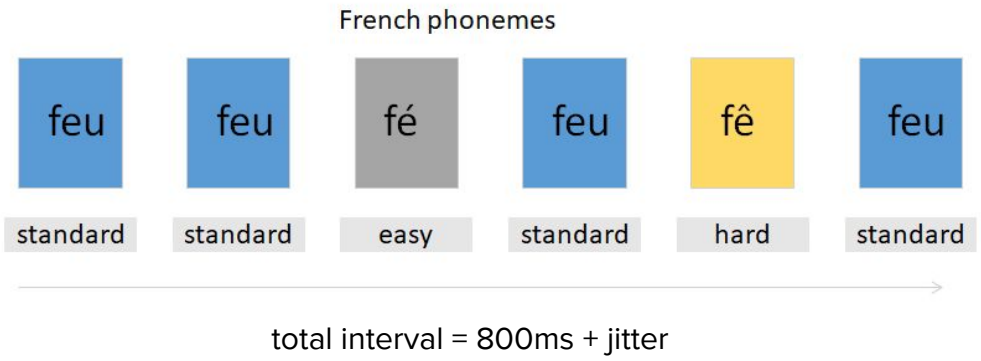
- Mismatch Response (MMR) is considered as a evoked potential elicited by a change in a repetitive acoustic pattern in an oddball paradigm (Naatanen et al, 1978)
- MMR provides the information only in time domain
- Time-frequency representation (TFR) analysis allows to investigate EEG signal in both time and frequency domain
- MMR is present in our work by considering different response of standard & deviant in time-freq-spatial domains simultaneously

Subjects

Native Polish infants (n=22, 10 boys, mean age = 10 ± 1 month, age range: 8 – 13 months)

Procedure

- *Oddball paradigm:* 2 types of deviant stimuli (15% „hard" and 15% „easy") and standard (70%)



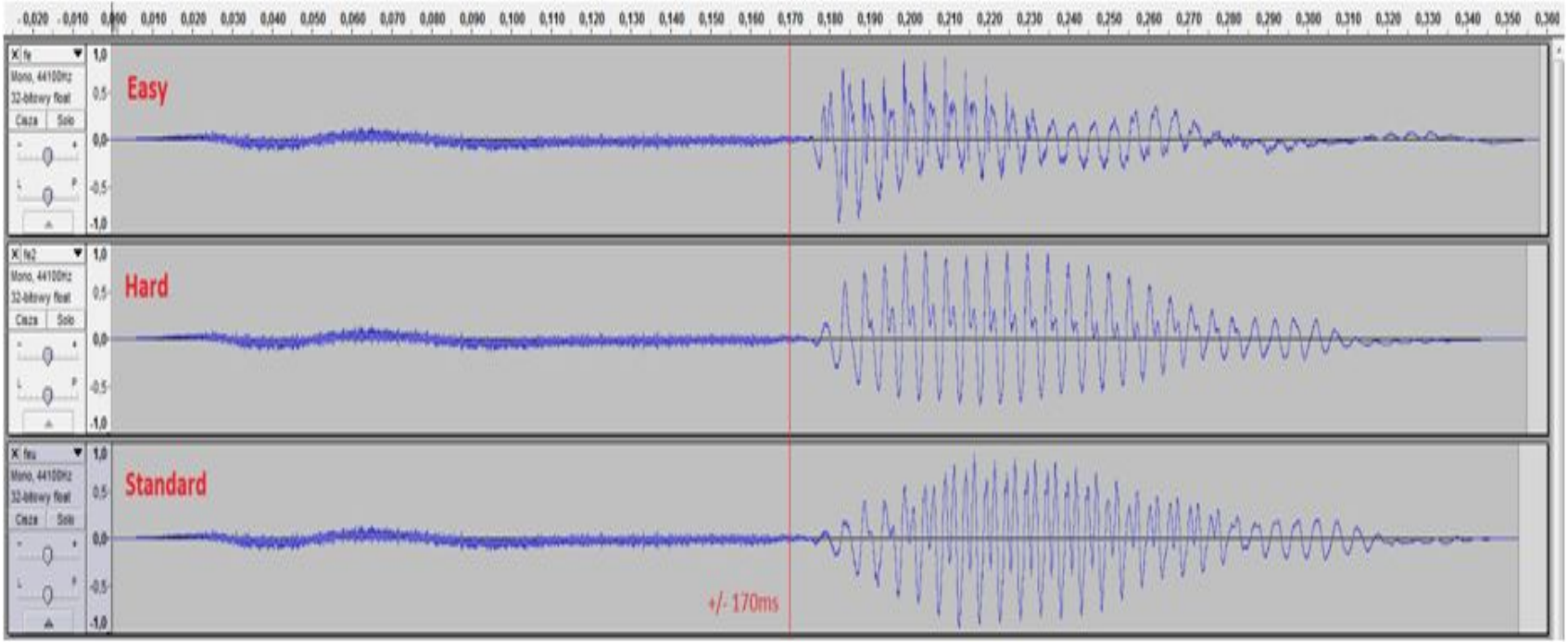
total interval = 800ms + jitter

A.
The jitter used for varying the length of the interval between subsequent stimuli onset was drawn from exponential distribution with mean 100 ms. The jitter was added to base interval of 800 ms between stimuli.

B.
Furthermore, the random variable "number of standards before deviant" follows geometric distribution with success probability p=1/3, which implies that on average there were 75% of standard stimulus and 25% deviant stimuli.

C.
Finally, for a given occurence of deviant stimuli, the random variable "easy deviant or hard deviant" was drawn from Bernoulli distribution with p=0.5 (toss of fair coin).

French phonemes



EEG data acquisition and preprocessing

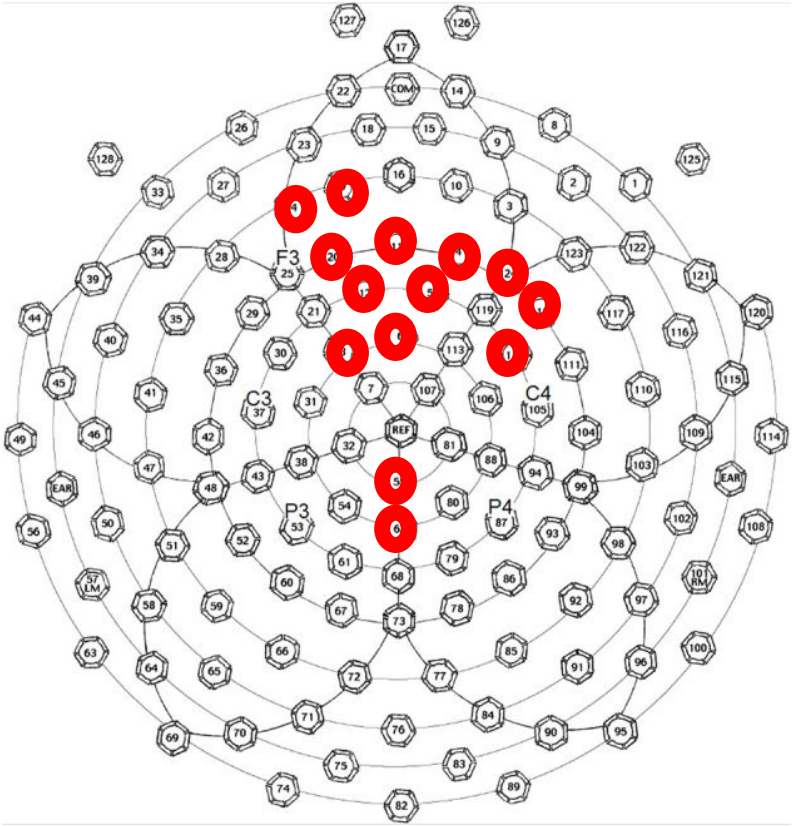
- 10-10 system, fourteen elecs: E4, E5, E6, E11, E12, E13, E19, E20, E24, E55, E62,E112, E 118, E124 referenced to the common electrode

  Sampling rate = 1000Hz

  On-line filter: 0.1 - 100Hz

Preprocessing:

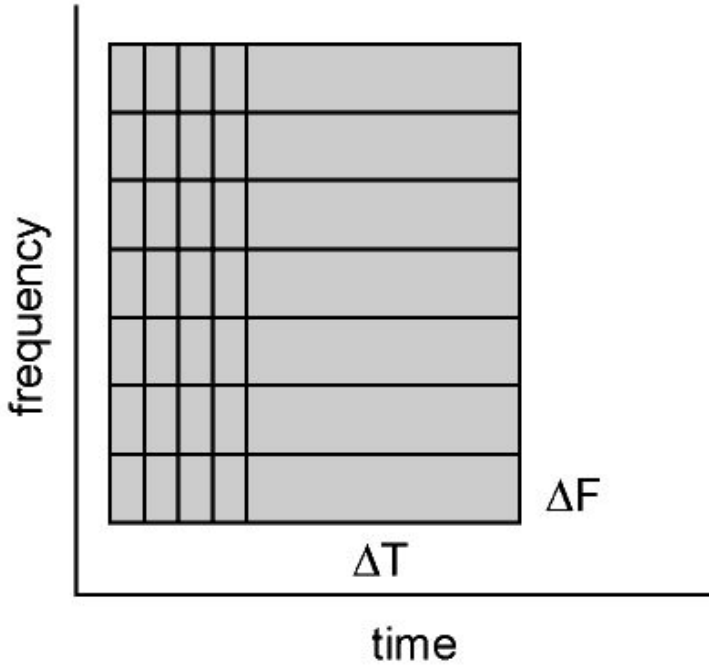
- Off-line filter: 0.5-20Hz
- The signal downsampled to 128Hz and re-referenced to the mastoids
- Artifact removal: amplitude rejection (120mV) and visual inspection
- Baseline removal



Electrode positions of the EGI 128-channel Geodesic Sensor Net

Time frequency analysis

- Using fixed window length
  - the frequency resolution is defined according to the length of the time window
- Our whole trial interval is [-0.1 0.79]
- The time of interest is [0.5 0.7]
  - We need to have 0.2s window length
  - This time window results to 5hz freq resolution



Tensor

- A four-order tensor:
  - **4** frequency bins
    26 timeframes
    14 channels
    44 subjects (22 in each stimulus)

- Apply non-negative tensor decom
  - In terms of canonical polyadic (CP) model

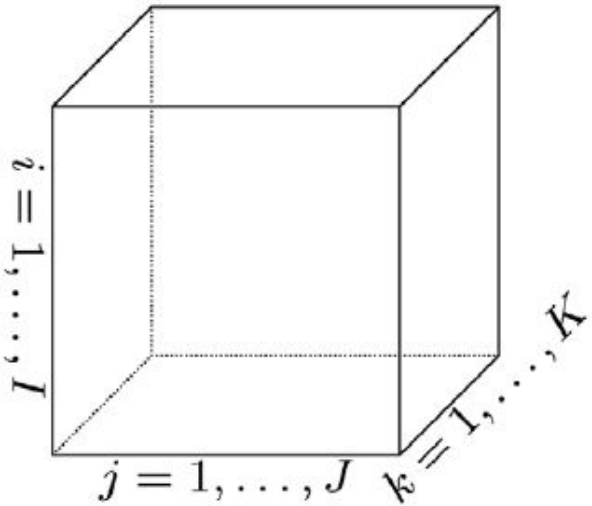
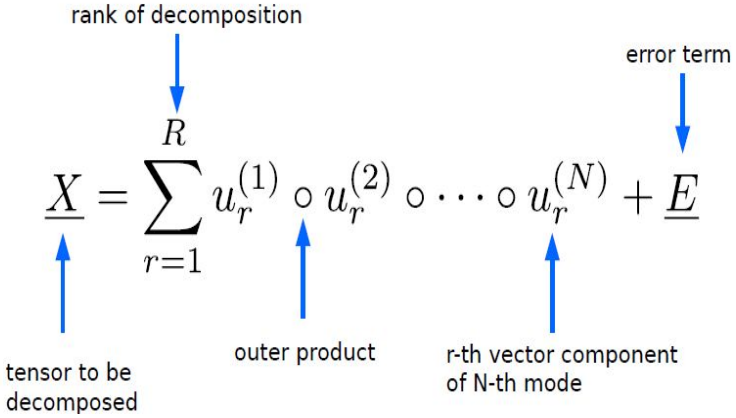


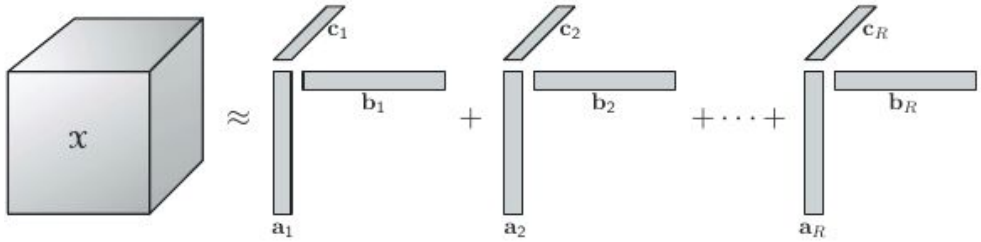
Fig. 1.1 *A third-order tensor:* $\mathcal{X} \in \mathbb{R}^{I \times J \times K}$.

CP Decomposition

Factorizes a tensor into a sum of component rank-one tensors tensors:

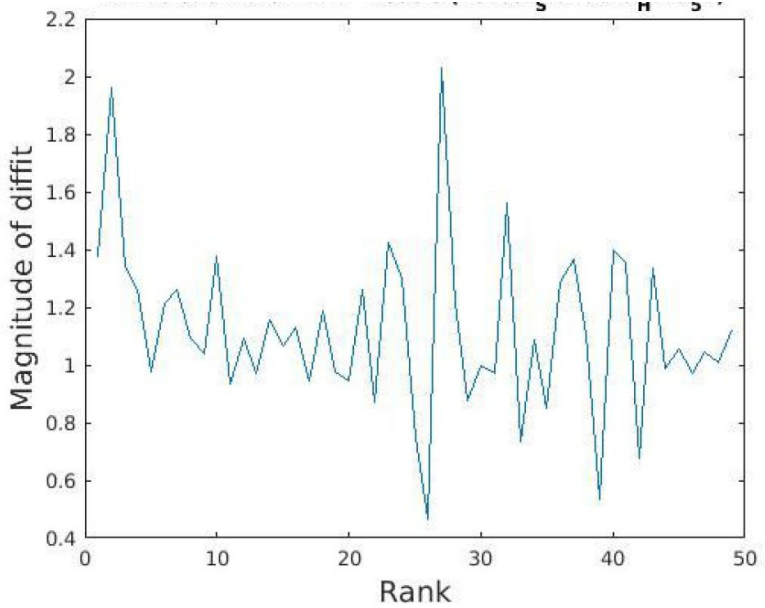
- Unique
  - It means that this is the only possible combination of rank-one tensors that sums to X
- The core tensor is an identity tensor
  - It means there is no interaction between different components





Number of features to be extracted

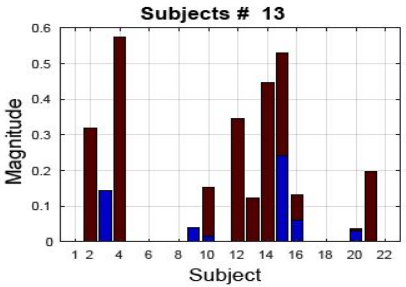
- The number of features is the number of extracted components in each factor of tensor factorization
- Determining this number is very important
  - Different numbers may probably correspond to very different decomposition results.
- Using DIFFIT method
  - The number of components ranged from 1 to 50
  - Maximum fit among 100 runs were chosen

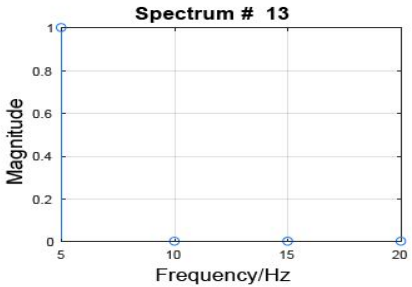


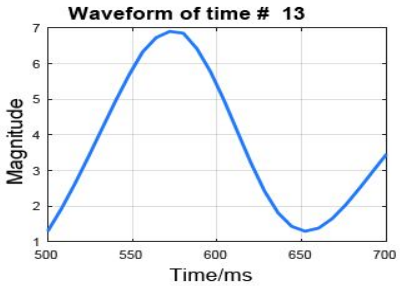
The best number of components based on DIFFT method is: **27**

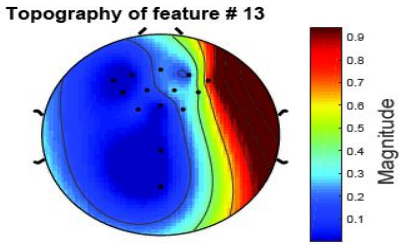
Results (Standard vs Easy deviant)

- According to the threshold (p = 0.05) the difference between two groups of stimulus in the multi-domain feature of components [7,11,13,18] were different significantly.
- Among these components we chose component number 13.









Blue bar indicates the Standard stimuli & Brown bar indicates the Easy deviant stimuli

We found right-side asymmetry for 5-frequency (Hz) theta

Results interpretation

- Right-hemispheric advantage in theta rhythm may represent anticipation of incoming stimuli (Orekhova et al., 1999),

- The results might indicate a dynamical process of expectancy and surprise which correspond to deviance detection reflected in the MMR (Gilley et al., 2017)

Conclusion

- Tensor decomposition approach enables us to find three dimensions characteristic of multi-domain feature
- EEG data acquisition was obtained on a very difficult infants data

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