Differentiation of French phonemes, that are not present in polish language by monolingual Polish individuals - EEG study

This study is part of the grant "NeuroPerKog: rozwój słuchu fonematycznego i pamięci roboczej u niemowląt i dzieci" led by prof. Włodzisław Duch.

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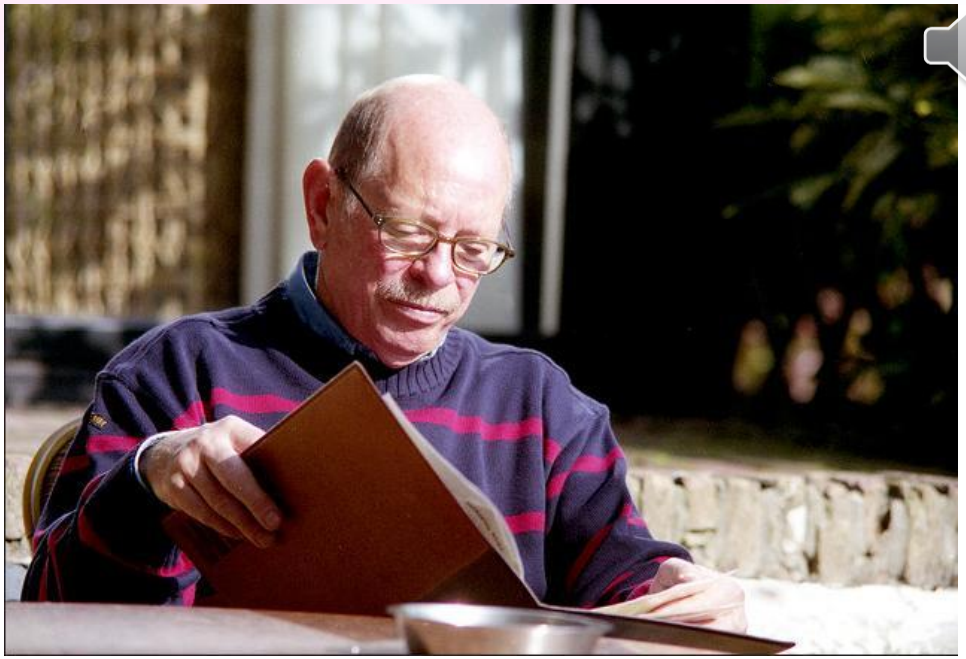
Introduction

Ability to learn language is strongly linked with age. When we get older learning foreign languages becomes more tough. That is due to phenomenon known as sensitive period of language acquisition.



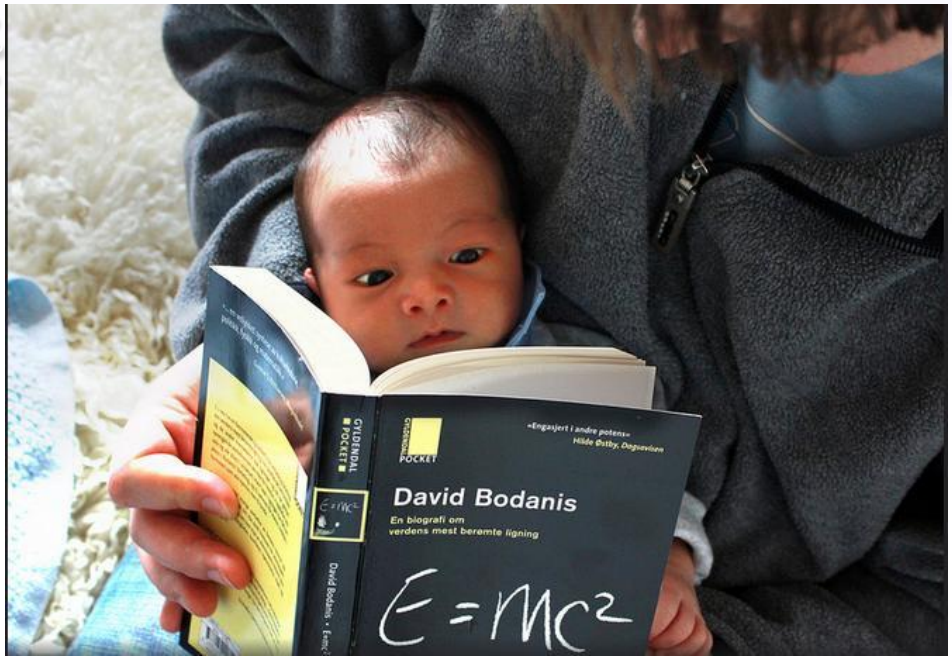


Fig 1. Huge gap exists between infants and adults, especially seniors in terms of capabilities of learning and processing new languages.

Theoretical basis of the study

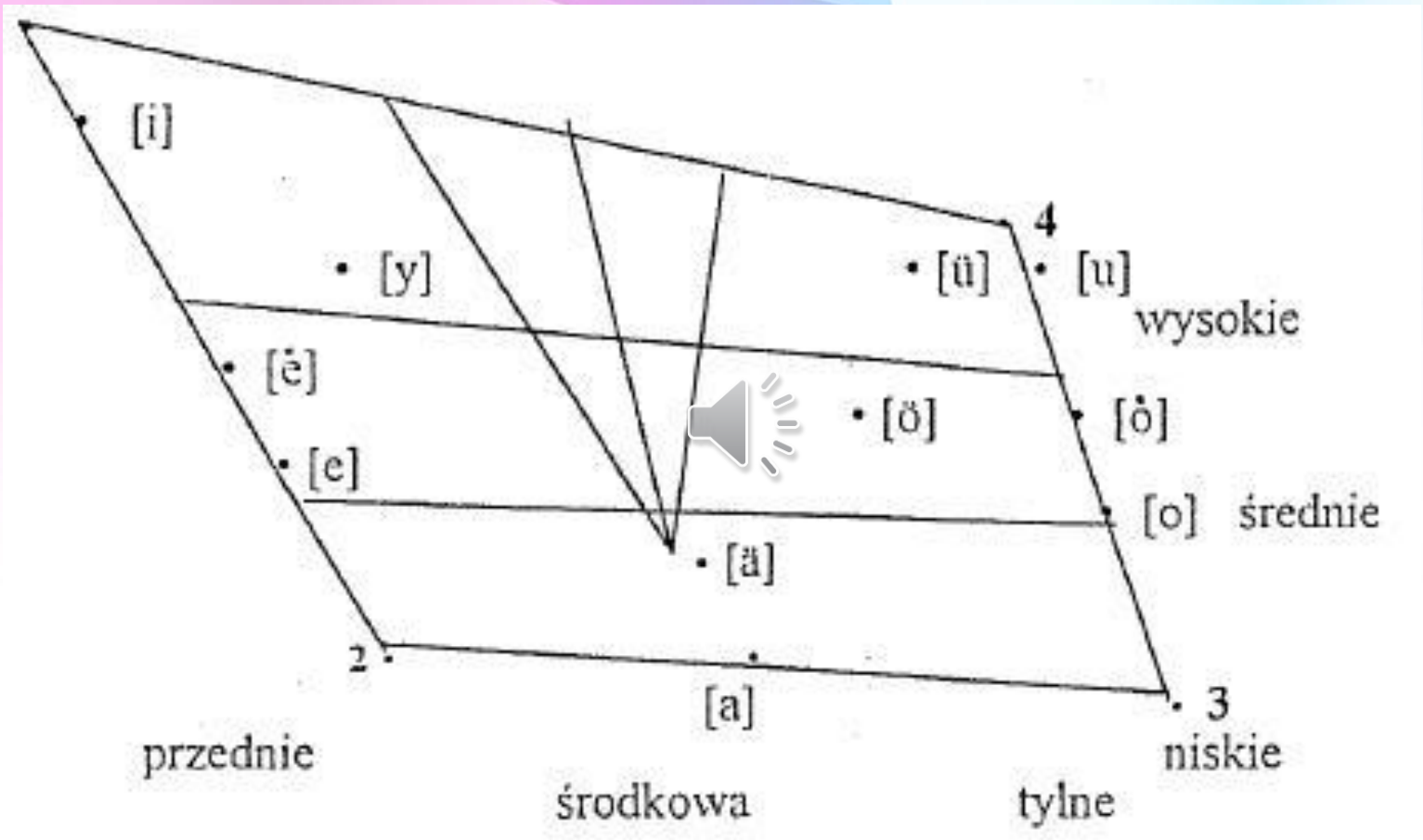


Fig 2. (from: Marek Wiśniewski, Zarys fonetyki i fonologii współczesnego języka polskiego, Uniwersytet Mikołaja Kopernika, Toruń 2001, p. 70) – Scheme of articulation areas in Polish language.

Theoretical basis of the study

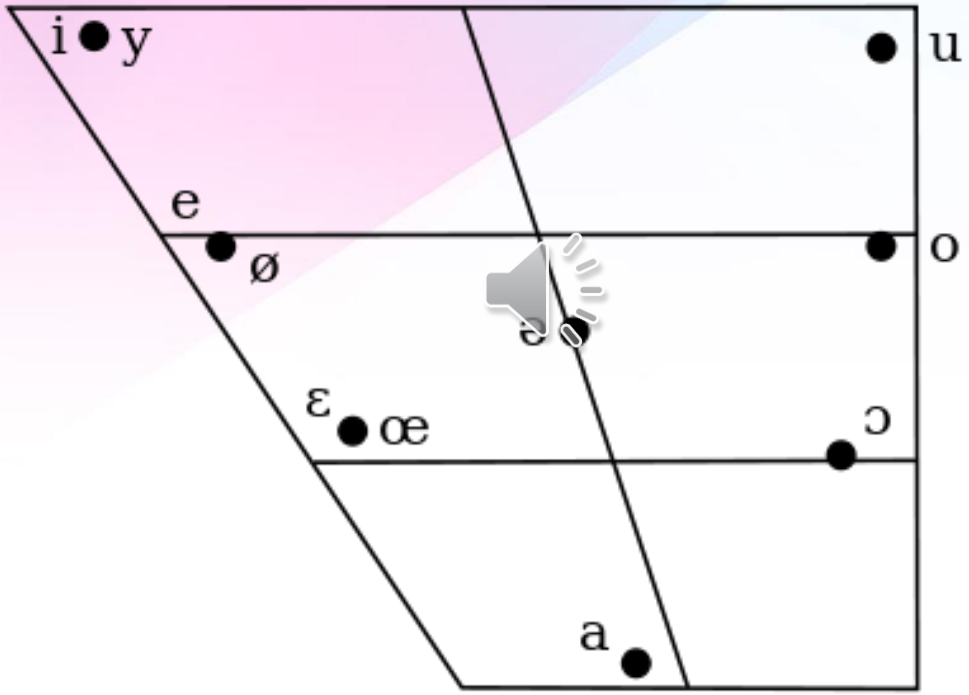


Fig 3. From Fougeron & Smith (1993:73). Collocation of vowels in french language.

Electroencephalography (EEG)

Noninvasive, painless, commonly used method of measuring bioelectrical activity of the brain with the use of electrodes placed on the scalp.

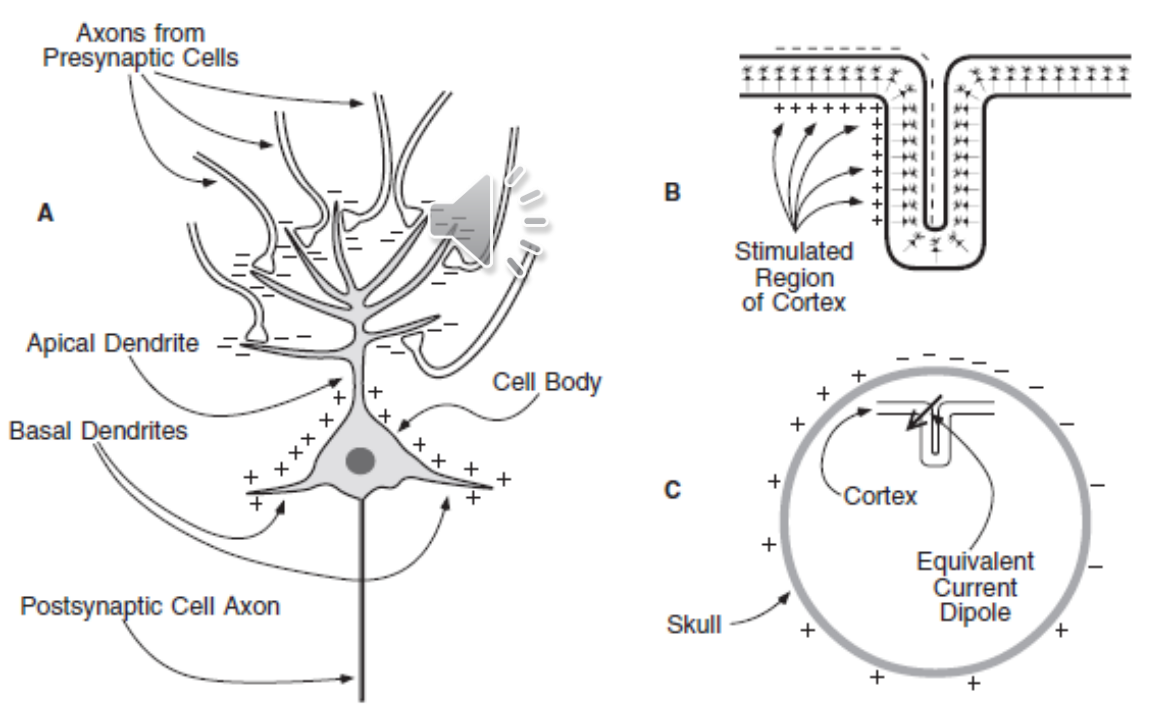


Fig 4. (from: Luck 2005 - An Introduction to the Event-Related Potential Technique ; 30p.)
The origin of electrical potentials recorded via EEG is summation of electrical potentials generated by neural cells communicating with each other, coming mostly from surface (gyruses and sulcuses) of the cortex.

Event-related Potentials (ERP)

Electrical potencial which is evoked by brains procesing of sitmulus, this response is obtained multiple times and averaged to one general response of individual.

One of the ERPs is *Mismatch Negativity* - *MMN*

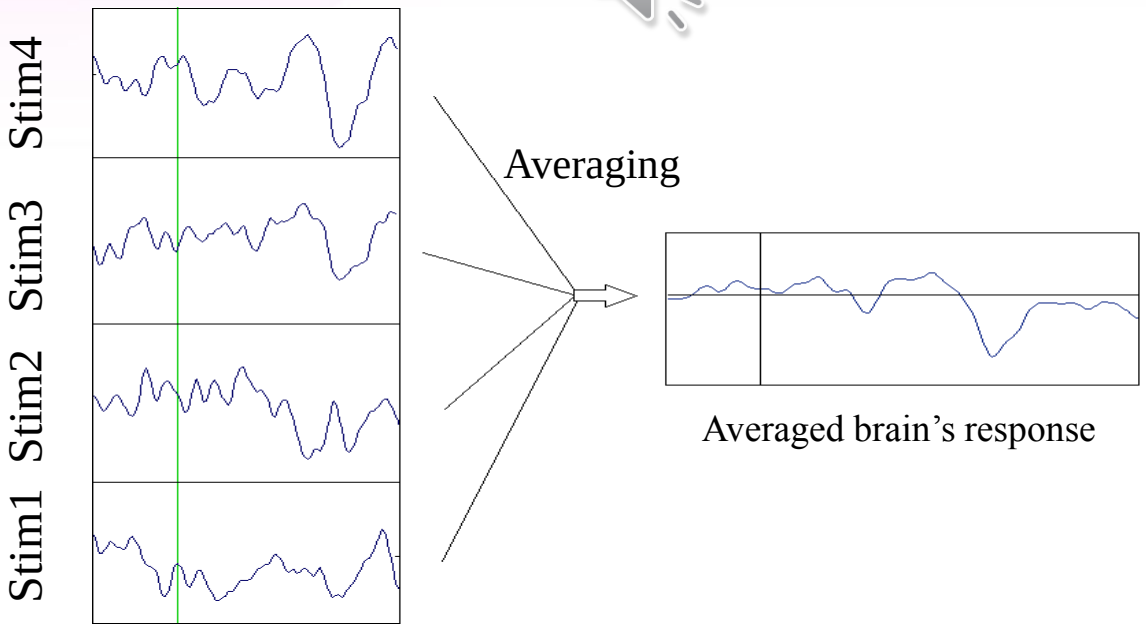


Fig 5. Example of single-trial responses and averaged EEG wave

Mismatch Negativity (MMN)

A component of EEG signal, which is being evoked by different, distinguishible stimulus in a sequence of stimuli. It appears 100 to 250 milliseconds after exposition to such stimulus.

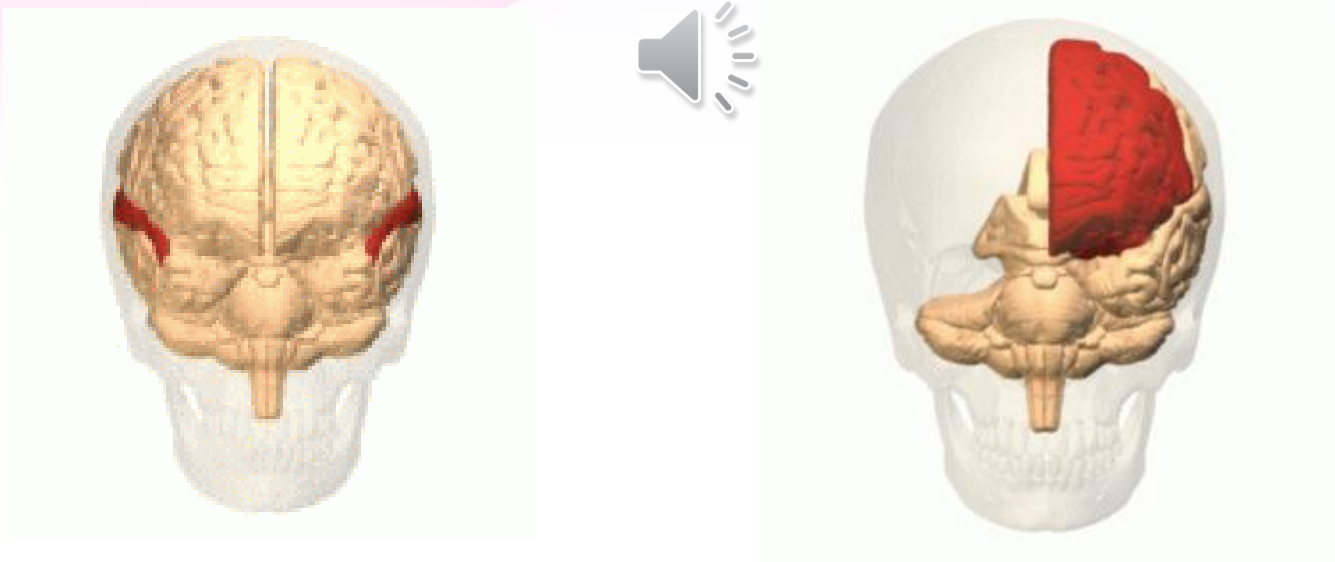


Fig 6. (From: Wikipedia) – Illustration of neural generators of **Mismatch Negativity** component, from left: 1) supratemporal gyrus (bilaterally active); 2) frontal lobes (right hemisphere is more active).

Mismatch Negativity (MMN)

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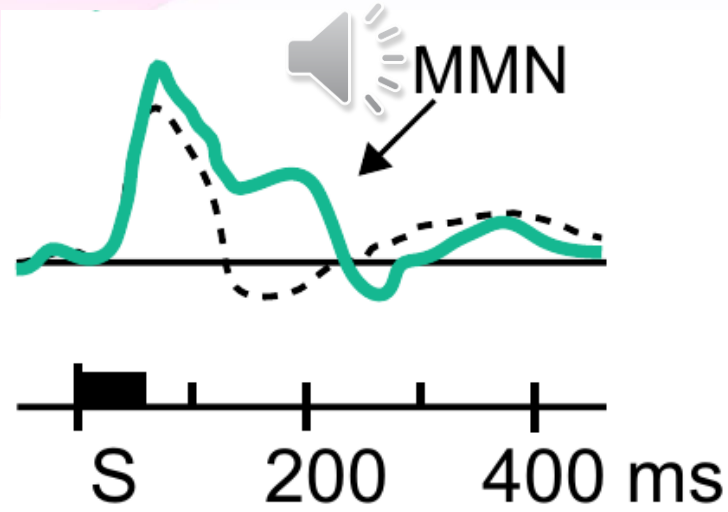

Fig 7. (From: Näätänen 2007) – Illustration of **Mismatch Negativity** component composed of ERP waveforms for two types of stimuli (black bar with "S" symbol): frequent (black line) and rare (turquoise).

MMN in auditory processing and language studies

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Invited review

The mismatch negativity (MMN) in basic research of central auditory processing: A review

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Language outside the focus of attention: The mismatch negativity as a tool for studying higher cognitive processes

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MMN in auditory processing and language studies

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Brain responses reveal the learning of foreign language phonemes

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Motivation and Hypothesis

The goal of this study was to investigate if monolingual Polish individuals distinguish French syllables, different only on the second phoneme. The indicator of differentiation is a MMN wave in EEG signal. For that we have stated following hypothesis:

Monolingual native Polish speakers cannot differentiate between French /é/ and /ê/ phonemes on neurophysiological level during passive stimulation task.

Methodology - Participants

In this study 26 individuals (19-26 years old – 21,9 on average) participated. None of them have ever learned French. We took 21 individuals that were right-handed to further analysis (9 males and 12 females).

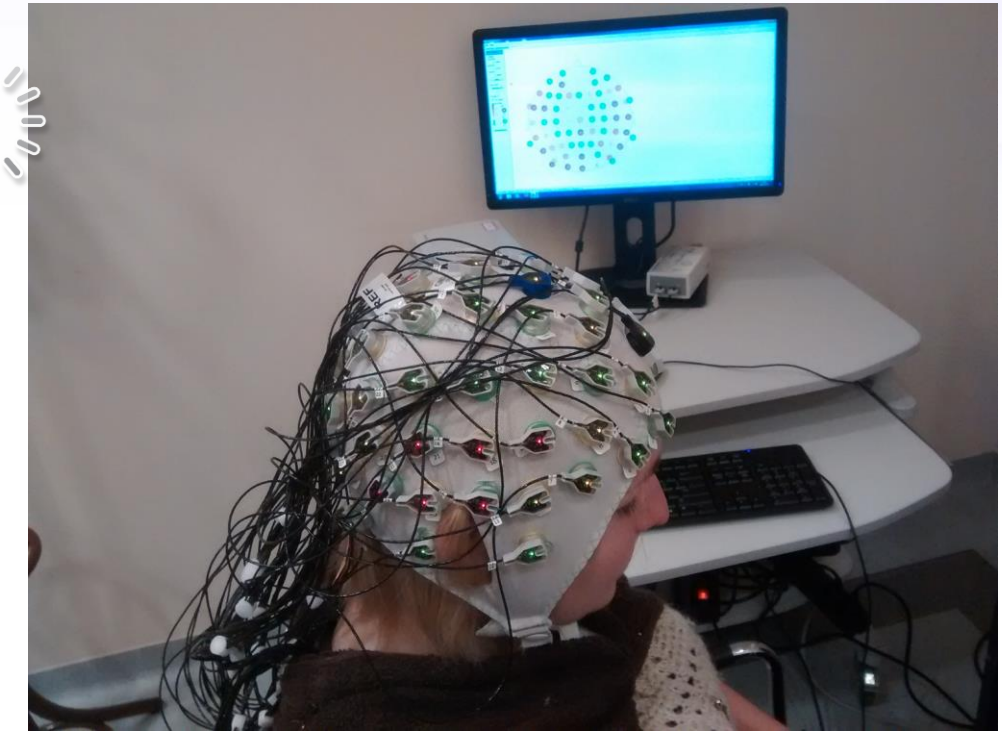


Fig 8. Photo of participant from our study during EEG cap adjustment.

Methodology - EEG

For this study a passive oddball with two deviants (different from one another) was used.

- passive paradigm: while participants have been watching the movie, stimuli were presented through the headphones
- in the stimuli sequence there was 10% of first deviant and 10% of second deviant
- duration of the stimulus was 350 ms
- the intervals between stimuli were 1,2 – 1,6 seconds
- intensity of stimuli - 75 dB
- duration of a EEG session: 45 minutes

Methodology - Stimuli

The frequent stimulus was ***fé***,

rare stimuli were syllables

feu (easy to differentiate*) and

fê (difficult to differentiate*).

*for Polish natives

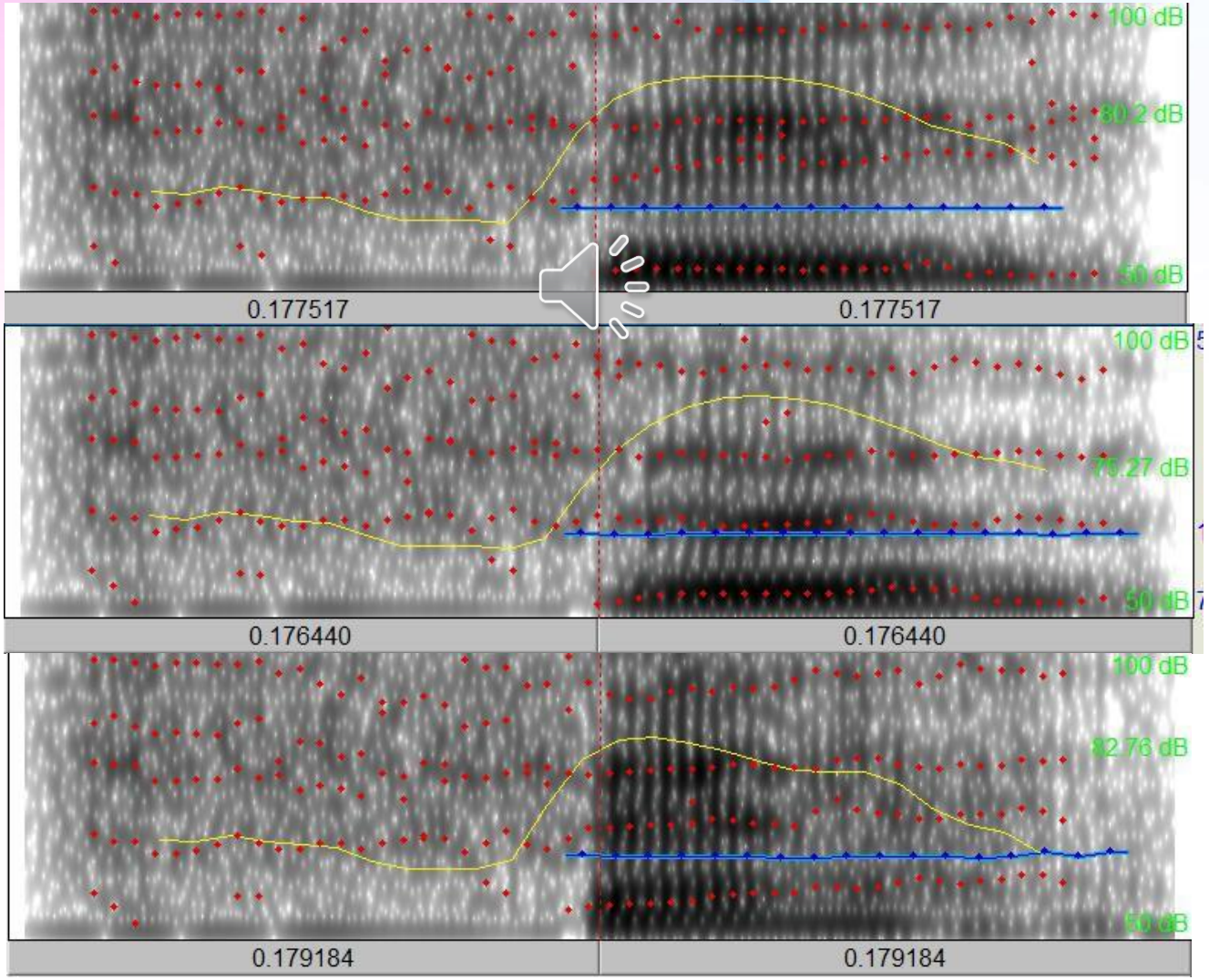
Methodology - Stimuli

Syllables were different only in first formant of a vowel.

fé

feu

fê



Methodology - Preprocesing

The signal analysis was performed in Matlab, with a toolbox: EEGLAB.

Digital filter	1 to 25 Hz
Resampling	255 Hz
Epochs analysied	- 200 to 500 miliseconds before stimulus
Baseline removal	- 200 to 0 miliseconds before stimulus
Signal re-reference	mastoids

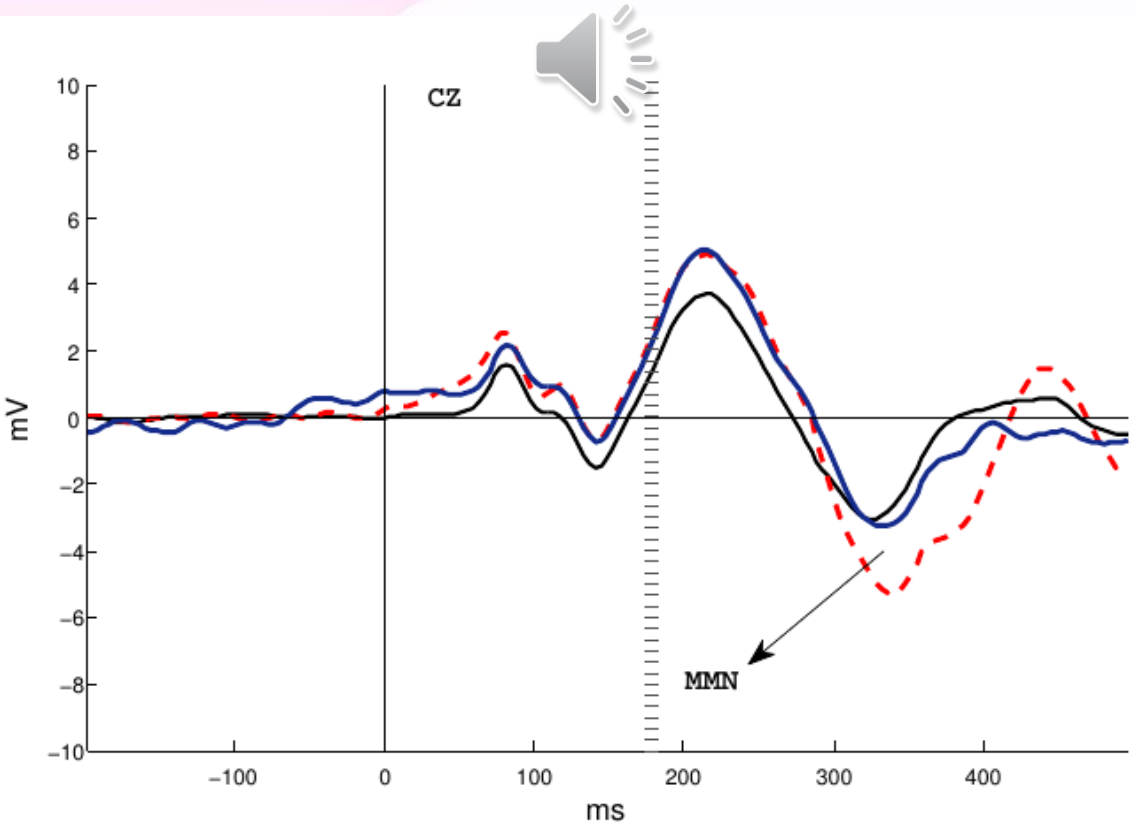
Fig 9. EEG preprocessing important paramaeters.

Results

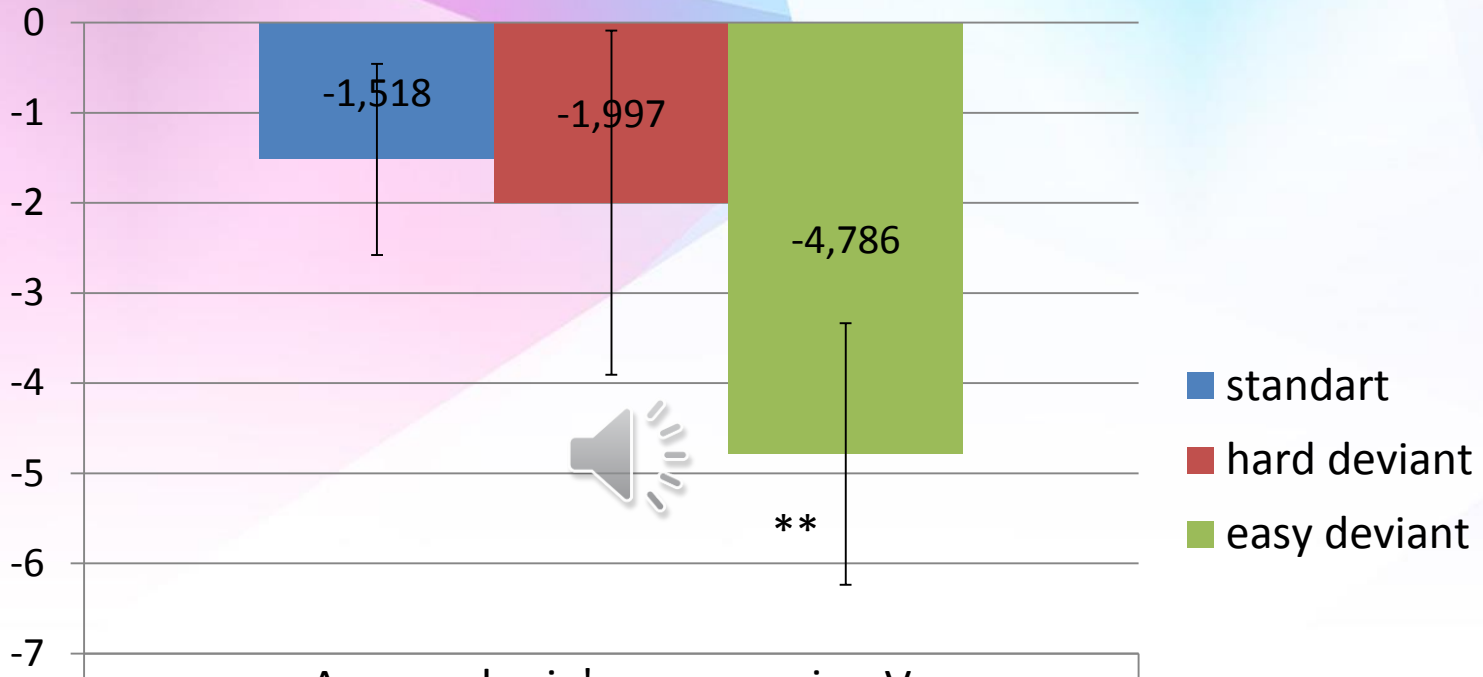
The Figure presents averaged responses from all participants to three different stimuli measured from centrally placed electrode „Cz” (also known as vertex):

1) standard: 80% of occurance – black line
2) deviant (easy to differentiate from standard): 10% of occurance - red line
3) deviant (difficult to differentiate from standard) 10% of occurance - blue line.

Vertical, dashed line represents the moment of appeariens of target phoneme.



Results



	Average brain's response in µV
standart	-1,518
hard deviant	-1,997
easy deviant	-4,786

Fig 10. Box chart of average brain's response for all paricipants from 100-200ms window after difference in stimuli, measured in µV. Significant ($p < 0.01$) difference between both standart and hard deviant vs easy deviant, and no significant difference between response for standard and hard deviant stimuli was observed.

Discussion

For the hard to differentiate pair, the MMN component was absent thus confirming the hypothesis.

The next step will be performing the experiment on a group of French native speakers to investigate their response for the same set of stimuli.

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