Neurophysiological correlates of speech perception in adult and 8-10 year old Spanish-English bilinguals

PANEL: Event-related brain potentials correlates of speech perception in language impaired vs. bilingual children

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Purpose of study

- (A) **To examine discrimination of English vowel contrasts in Spanish/English bilingual speakers who acquired L2 before age 5**
  - Do their brains process phoneme contrasts in the same way as monolinguals?

Purpose of study

- (B) Do populations differ in their MMN response when attention is directed to the stimulus stream?
  - i.e., is speech perception equally automatized in both groups?

Participants

- 25 monolinguals (American English)
  - Mean age: 29.9 (range = 19 to 40; SD=7)
  - 14 women, 11 men
  - 1 left hander
- 15 Spanish/English bilinguals
  - *All learned English and Spanish before 5 years of age*
  - 11 women, 4 men
  - 2 left handers
  - 11 women and 3 men (two women were left-handed), with a mean age of 28.6 (range = 19 to 40; SD=6.3).

Stimuli

- Two 50ms phonetically similar vowels, /ɪ/ as in ‘bit’ and /ɛ/ as in ‘bet’
- Mismatch paradigm
  - Deviant: /ɪ/
  - Standard: /ɛ/

Design

- /ɛ/ (79%) served as the standard stimulus, and /ɪ/ (17%) served as the oddball.
  - 50ms stimuli with SOA = 650ms
- Stimuli presented in an ATTEND condition as well as in an PASSIVE condition
  - PASSIVE: ignore stimuli, watch a silent video
  - For directing attention to stimulus stream, two different targets were used
    - A speech category target (“ba” or “da”)
    - A non-speech category target (500/2000Hz tone)

Design

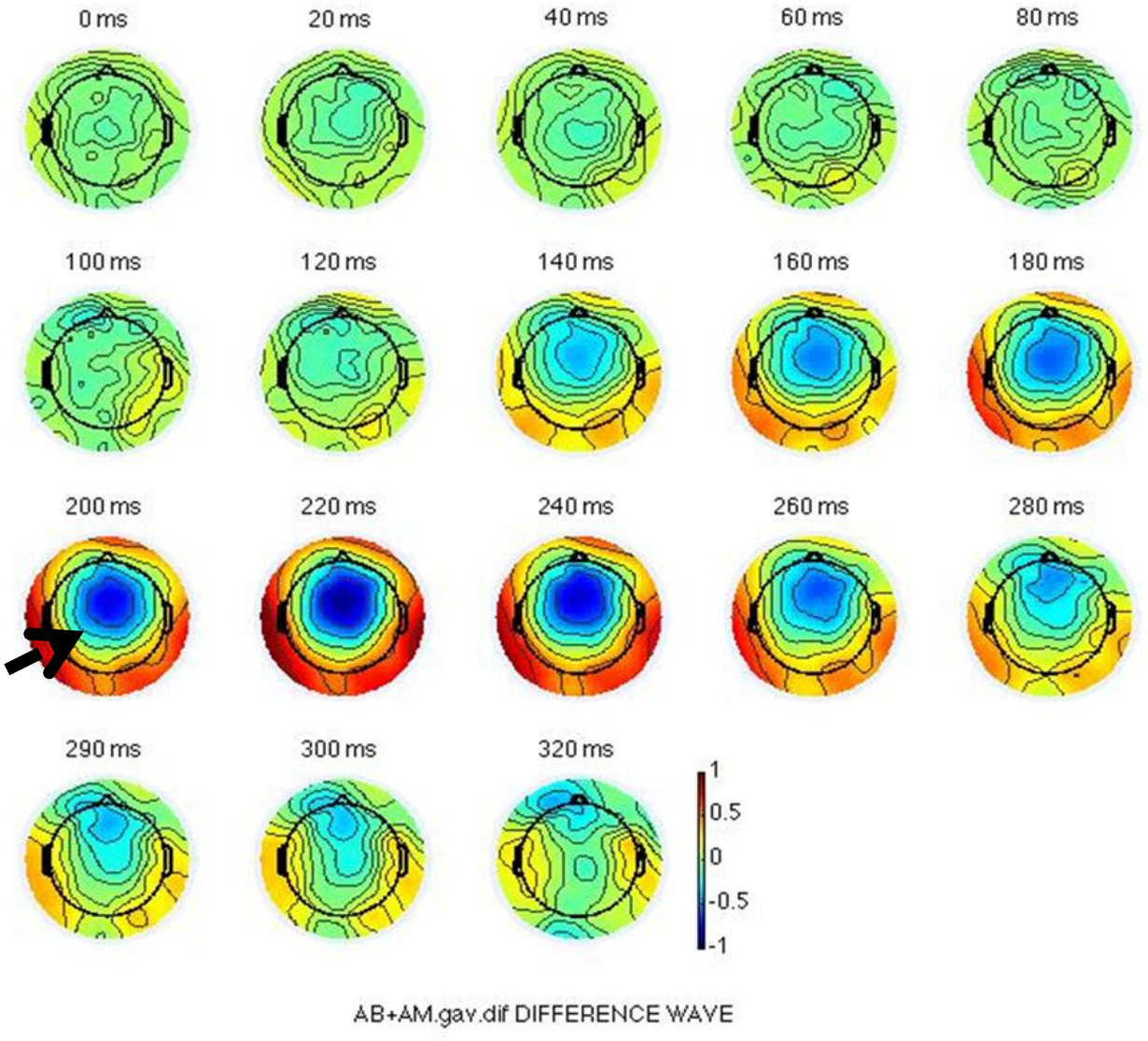
- Repeated for times:
- 4 blocks of trials: the PASSIVE condition
  - “watch the movie!”
- 4 blocks of trials : ATTEND to tone
  - Press button 1 when you hear tone 1, press button 2 when you hear the tone 2
- 4 blocks of trials: ATTEND to speech
  - Press button 1 when you hear “ba”, button 2 when you hear “da”

Three different brain responses

- (a) MMN (100-300ms)
  - related to automatic vowel difference detection:
- (b) Late negativity (300-600ms)
  - Related to vowel difference and related to attentional processes
- (c) Processing negativity
  - An early response (~100ms) related to degree of attentional resources allocated to general stimulus processing

ADULTS: (a) MMN; 100-300ms

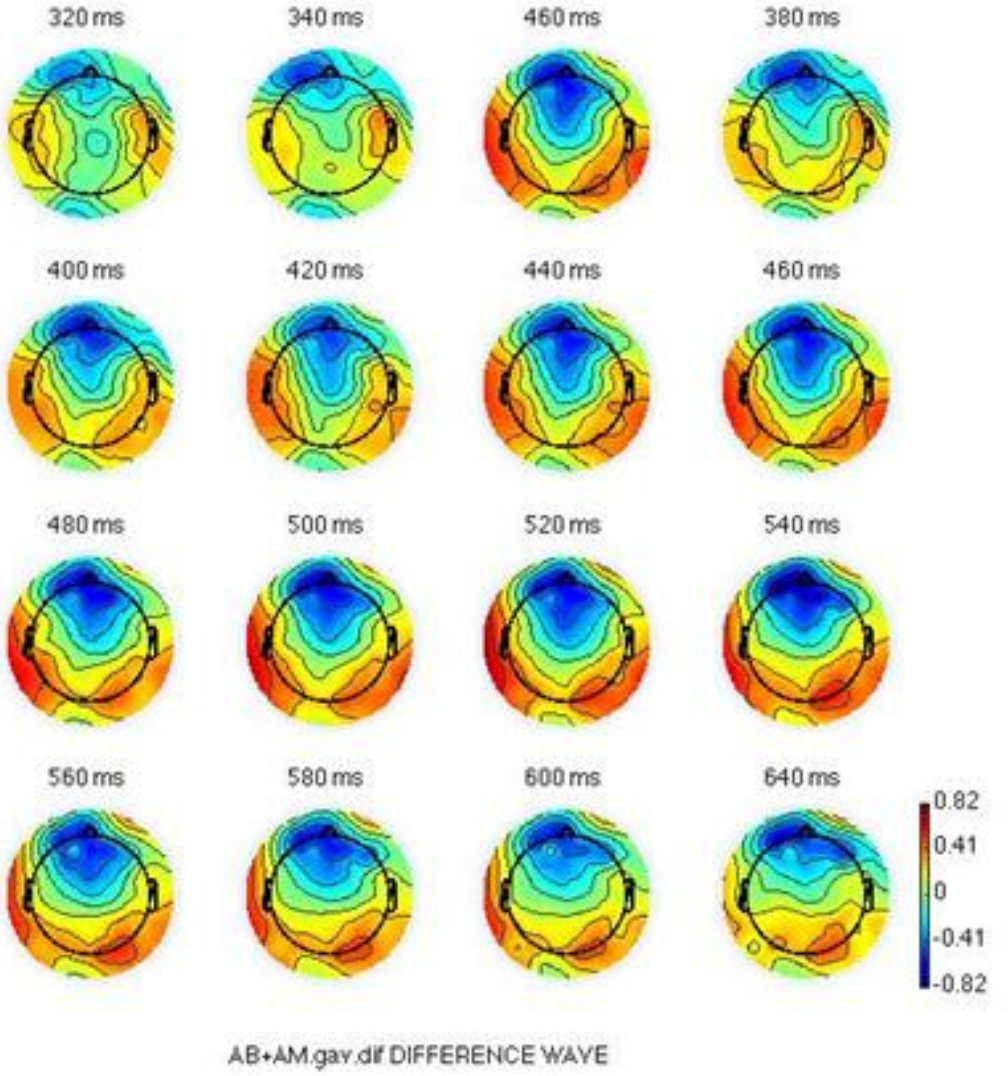
- Grand average difference waveform plot from raw EEG data:



MMN

ADULTS: (b) LATE NEGATIVITY, 300-600ms

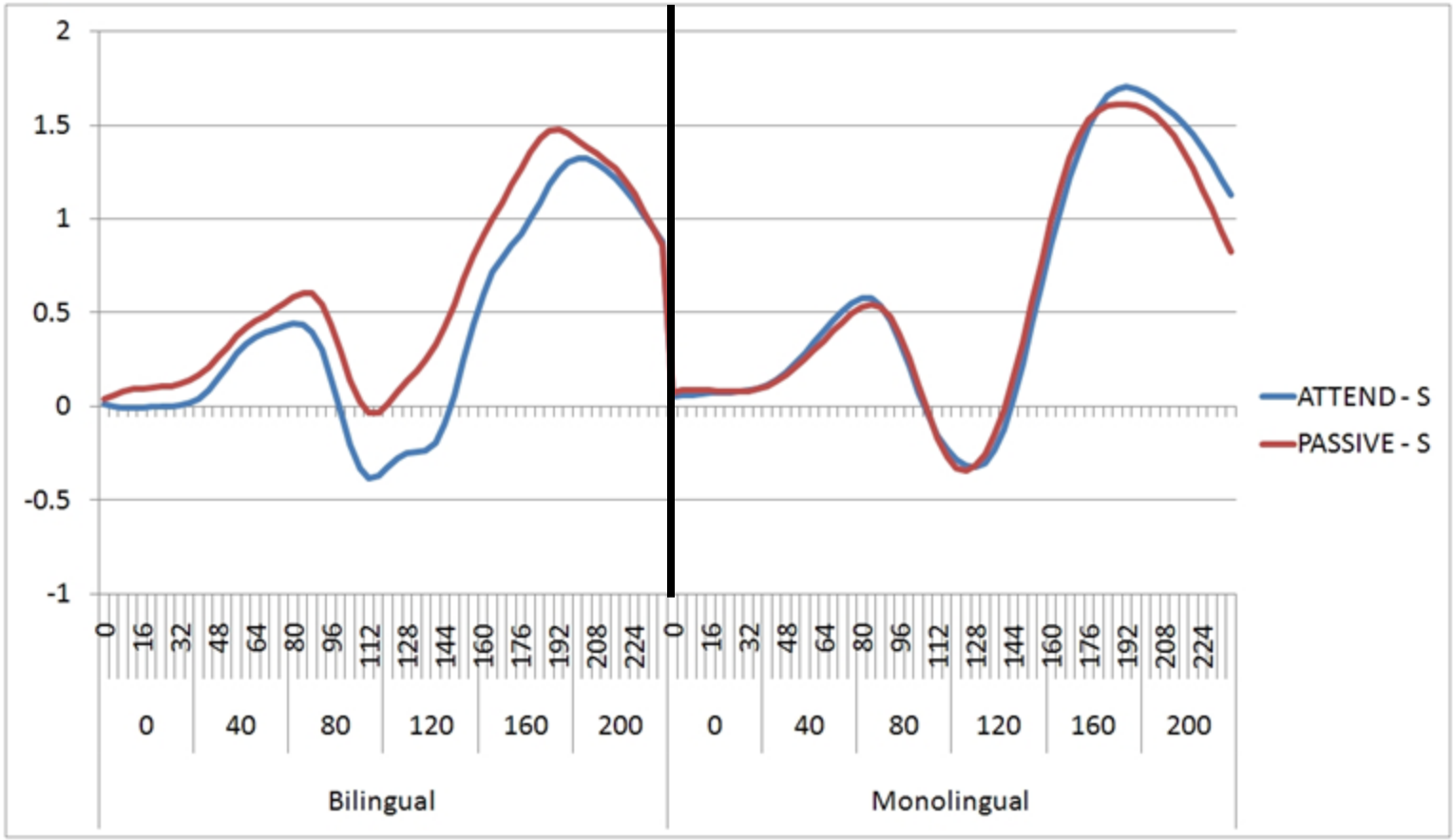
- Grand average difference waveform plot from raw EEG data:



ADULTS: (c) Processing Negativity, ~100ms

- PN: A negative shift at fronto-central sites during N1, indexing attentional resource allocation

Cz:

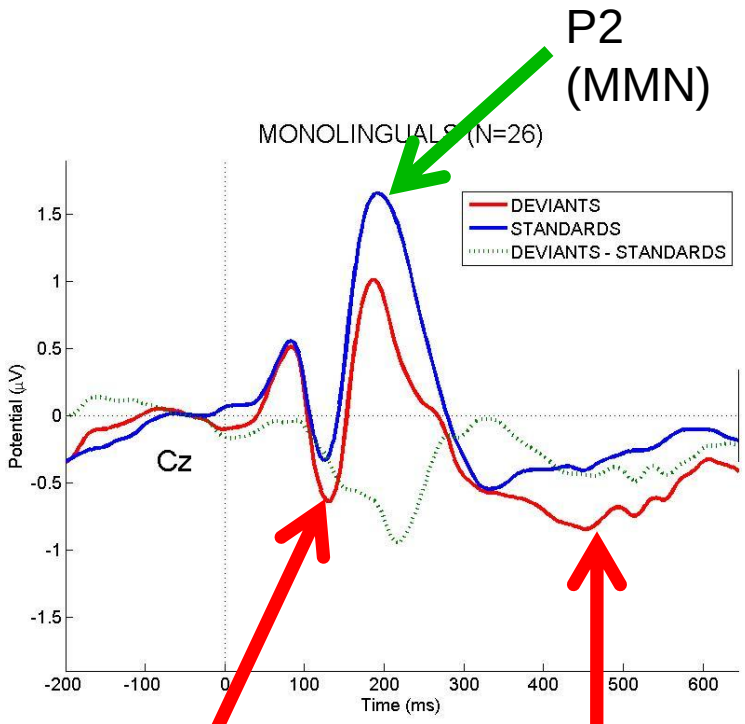


Analysis

- Temporo-spatial Principal Components
  - First, conduct a temporal PCA to isolate time regions where channels covary
  - Then, spatial PCA on each time factor, to narrow down the spatial distribution of each time component
- Advantages:
  - Data from all channels are used, but each channel is weighted by how much it contributes to the latent factor
  - No need to hand-pick electrode and time samples

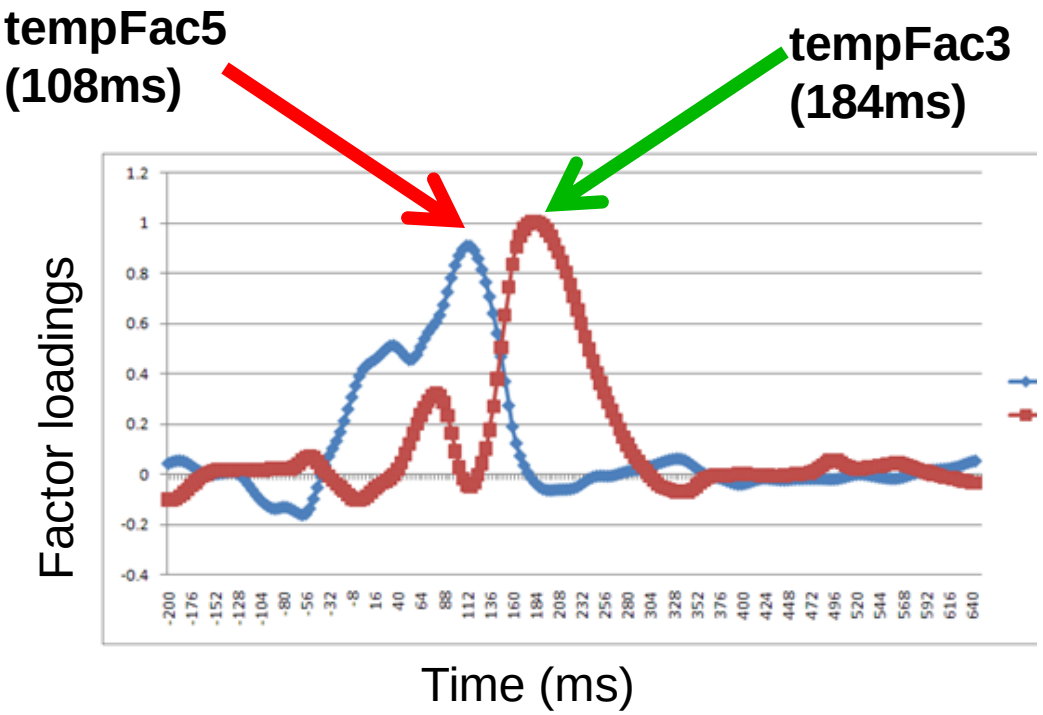
(i) Temporal PCA

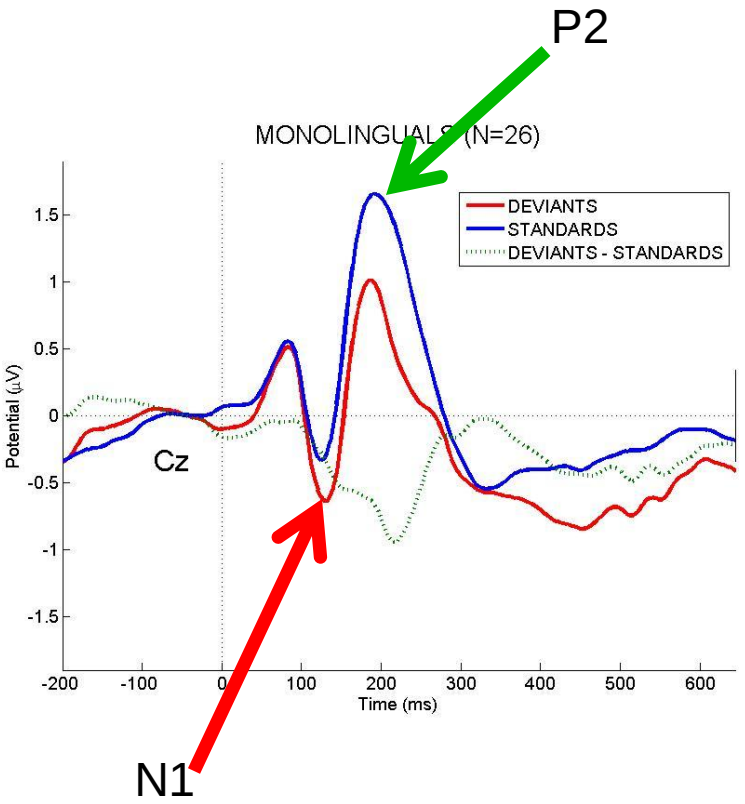
- The temporal PCA decomposes the time components of the electrical response



(i) Temporal PCA

– Two temporal factors decompose the P1-N1-P2 complex:

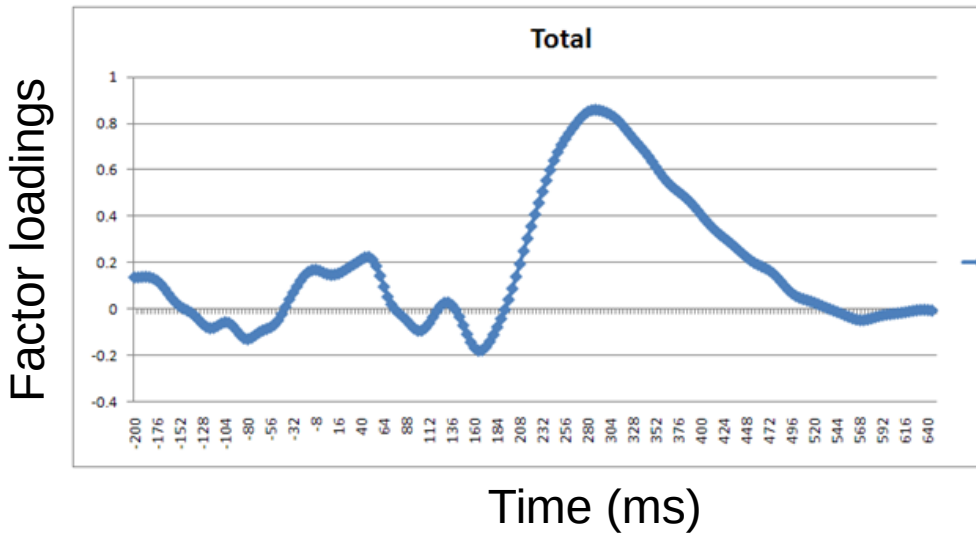


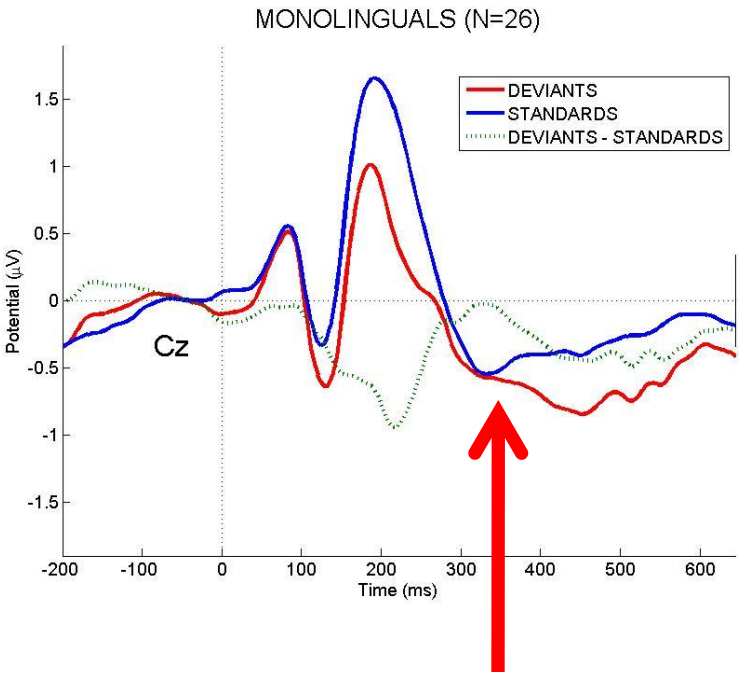


RECONSTRUCTS

(i) Temporal PCA

- A third, “Late negativity” temporal factor decomposes the last part of the response
  - **Temp2 (284ms)**





Late negativity

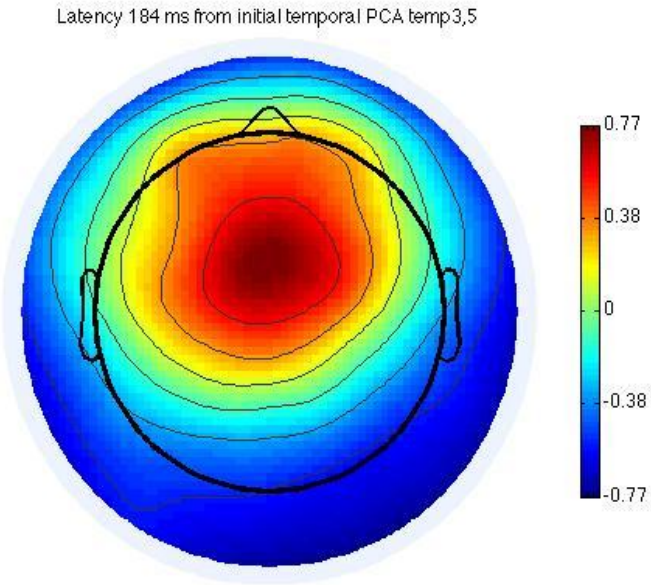
Spatial decomposition

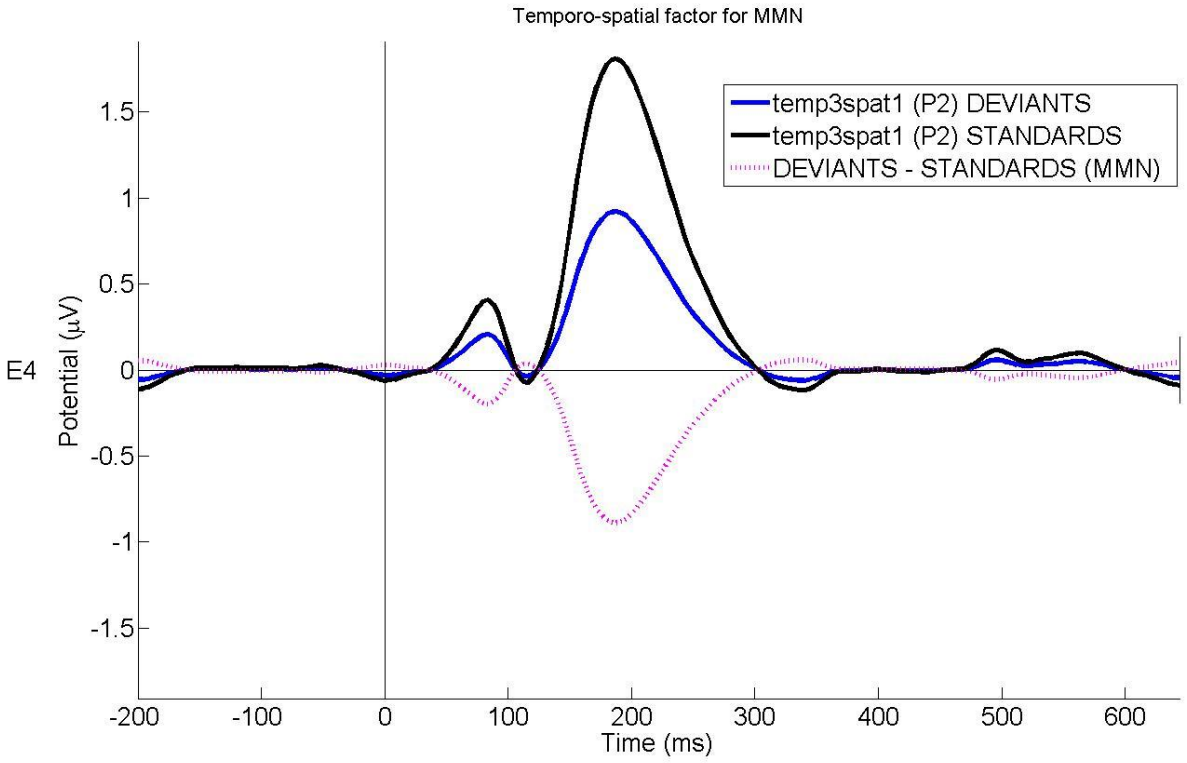
- Temporal PCA followed up by Spatial PCA on each temporal factor
- After this step, we have a single temporo-spatial factor score for each factor, subject and condition
  - These factors represent the temporal and spatial properties of the latent factor
  - Will be used as dependent measure in mixed factorial repeated measures ANOVA

(i) Temporo-spatial factor at 184 ms

- temp3 (184ms)

MMN:



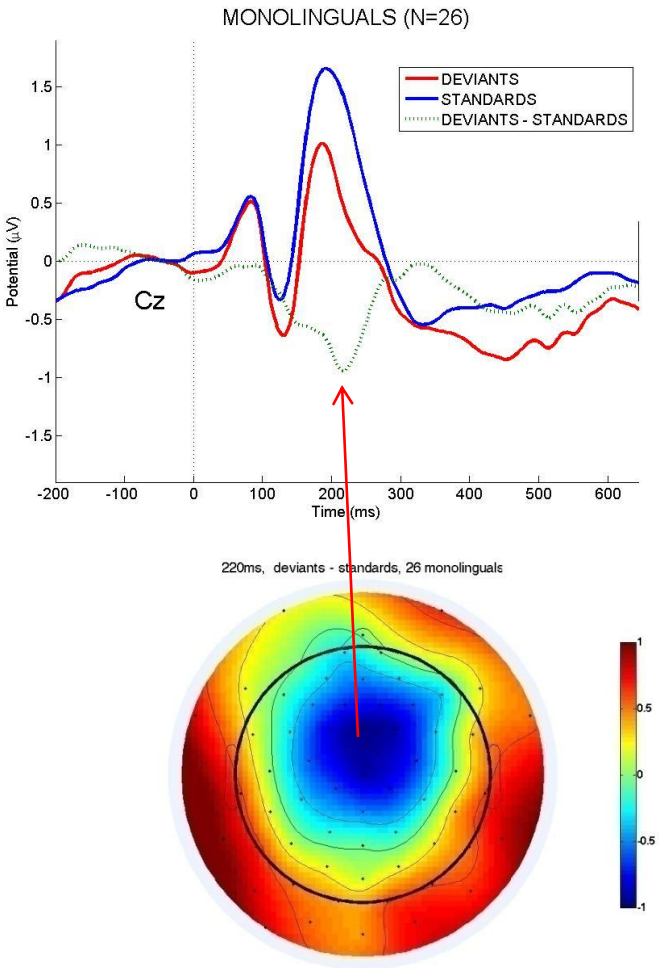


(i) Temporo-spatial factor at 184 ms

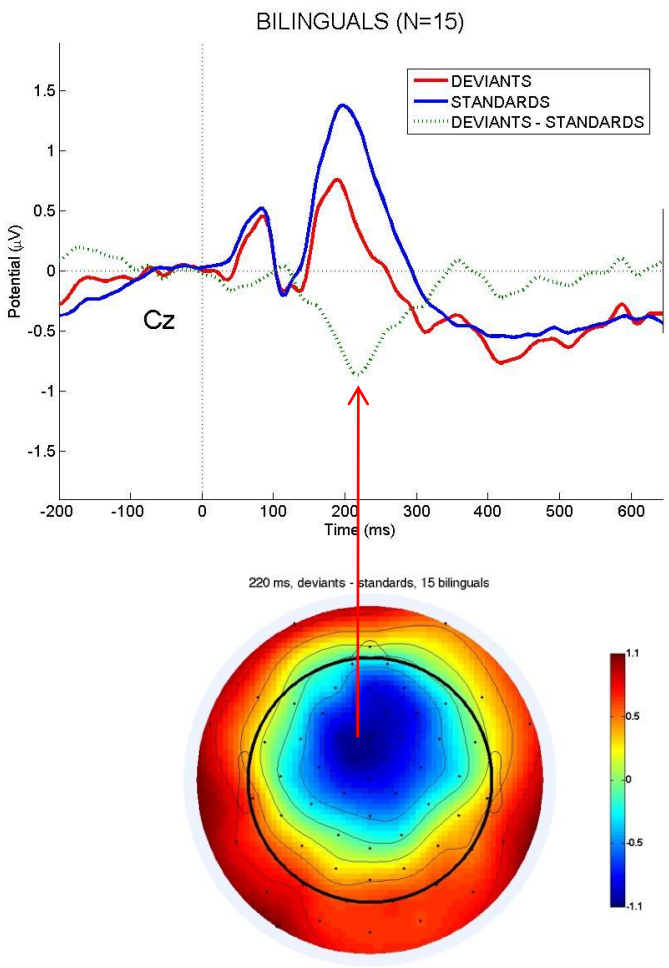
- Main effect of deviants vs. standards?
  - Yes: highly significant
  - $F(1, 38)=79.498$, $p<.00001$
- Was there an effect of ATTENTION on the MMN?
  - No, no interaction ATTENTION x STIM
  - No ATTENTION x TARGET x STIM
  - No GROUP x ATTENTION x STIM

(i) Raw ERP data

MONOLINGUALS



BILINGUALS



(i) MMN Conclusion

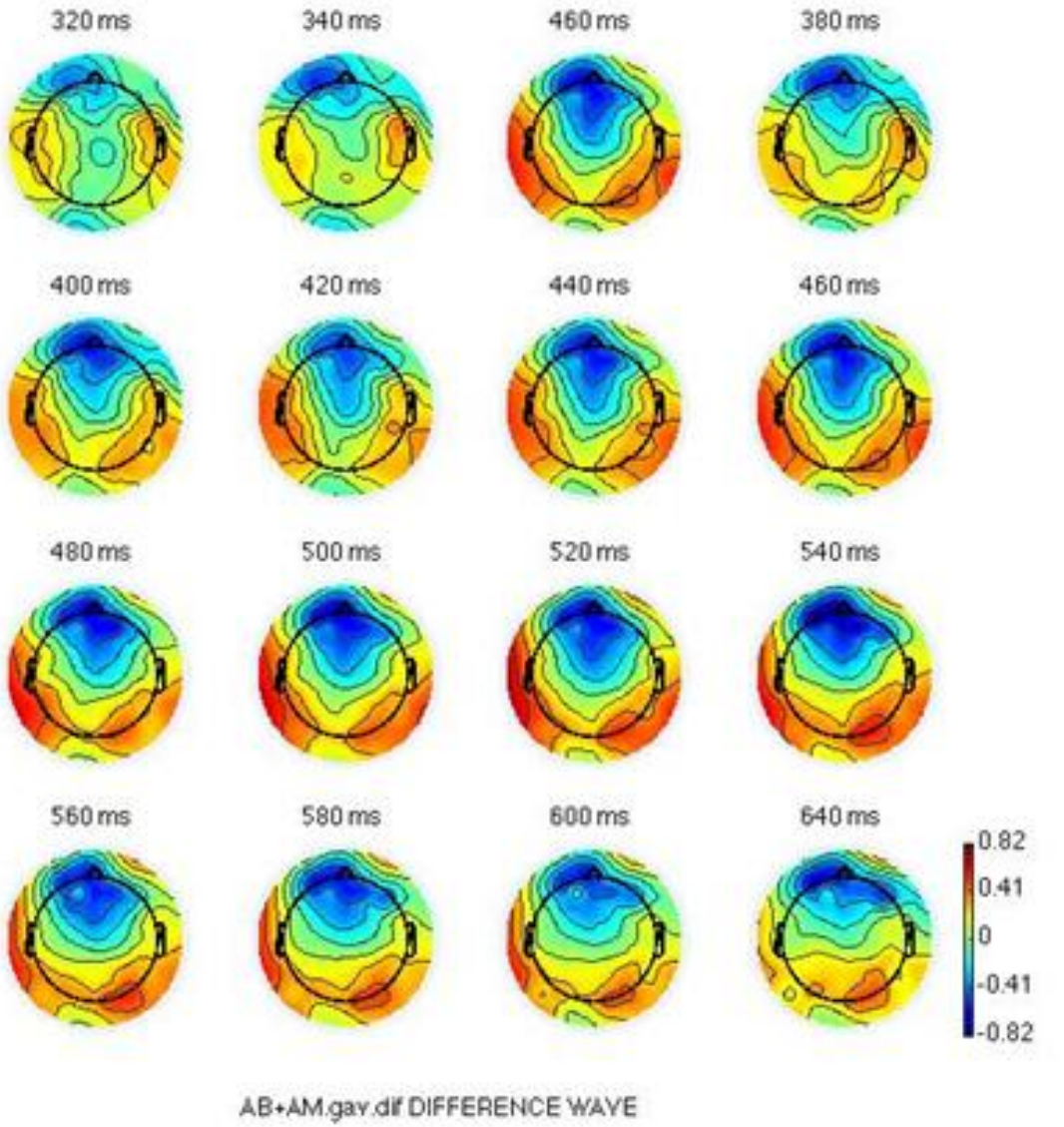
- No group difference in the adult MMN
  - Both mono- and bilinguals show the same brain response to the English vowel difference
  - There is no effect on the MMN of varying the attention conditions
- **MMN is an automatic and pre-attentive response to the same degree in both monolingual and bilingual speakers**

(ii) Temporal factor at 284ms

- Raw data:
  - 300 - 600ms

- Late negativity

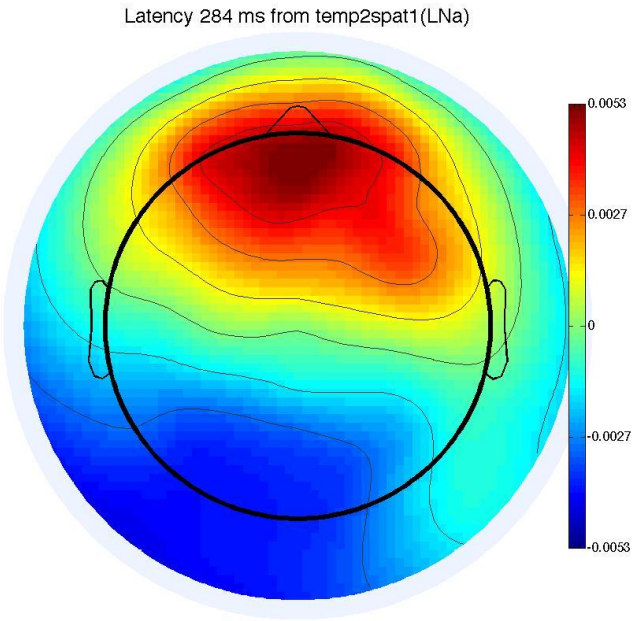
(attention related)



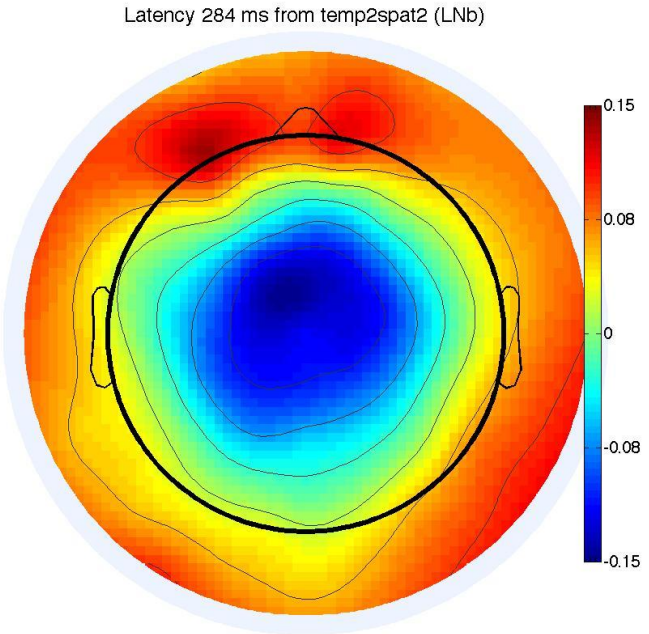
(ii) Temporal factor at 284ms: 2 spatial subfactors

- Two spatial components

(a)

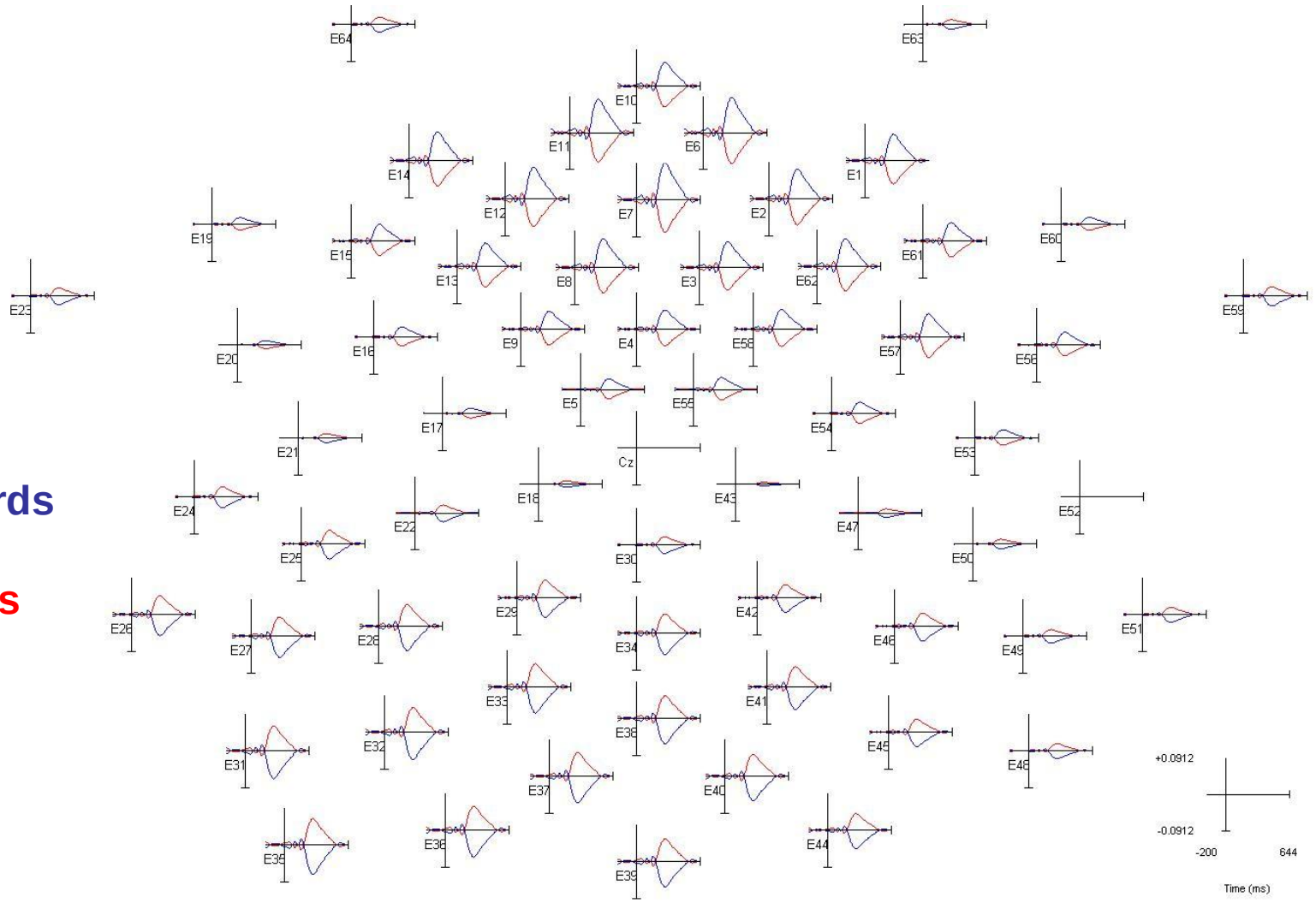


(b)



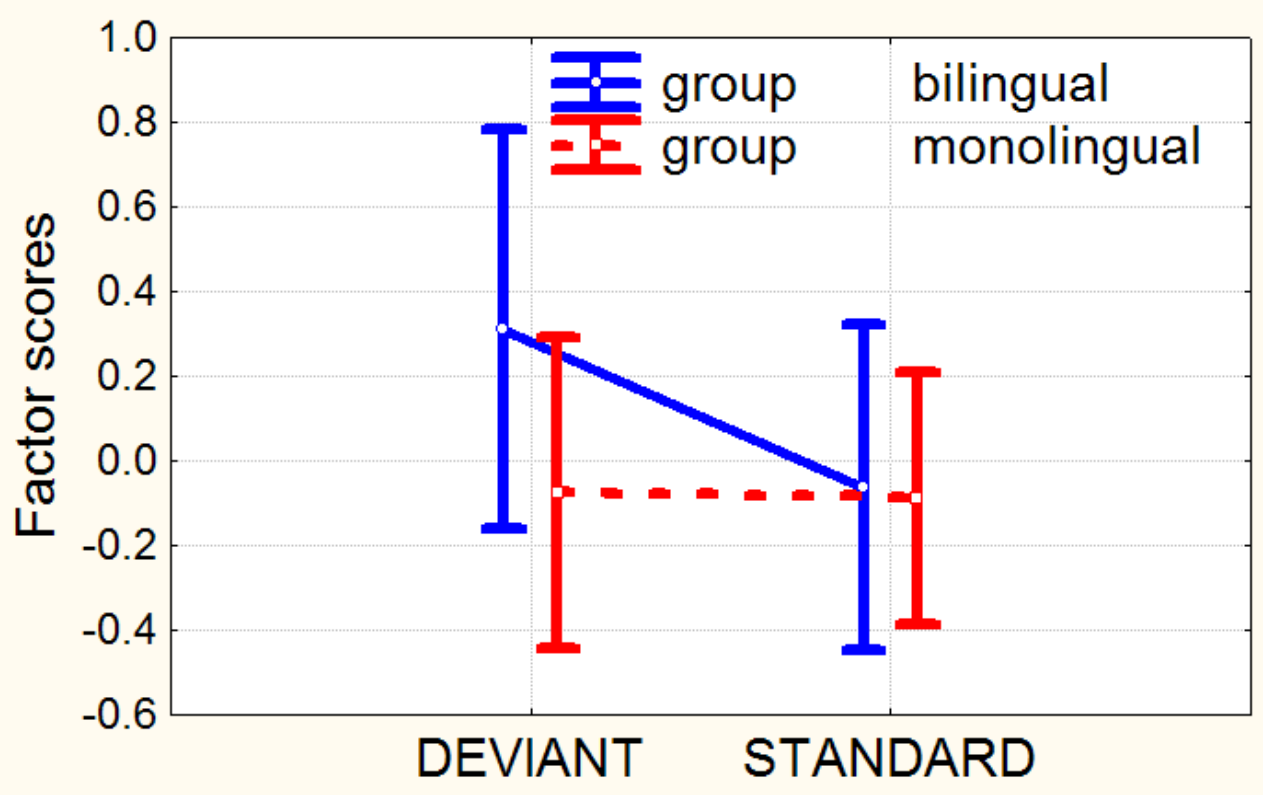
(ii)Temporal factor at 284ms; anterior spatial subfactor

Blue: Standards
Red: deviants



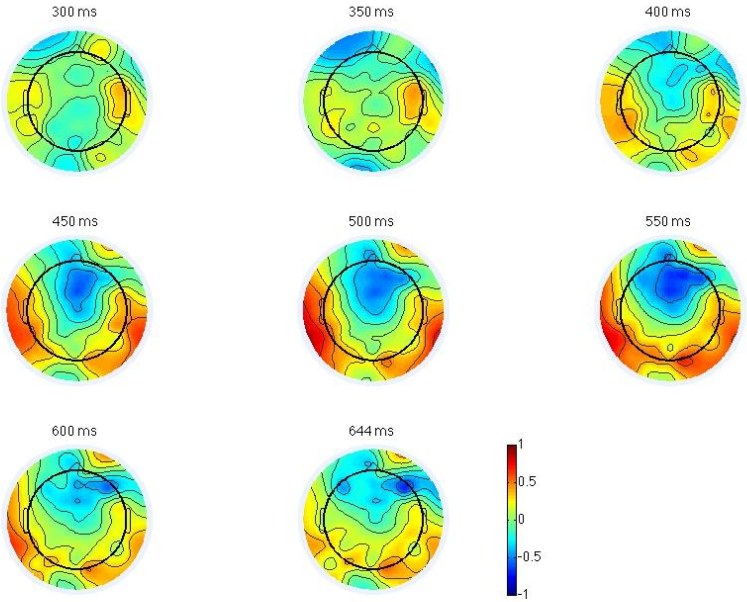
(ii)Temporal factor at 284ms; anterior spatial subfactor

- Main effect of stimulus [F(1, 38)=6.8, p=.013]
  = MMN!
- Interaction GROUP x STIM [F(1,38)=5.9, p=.02]

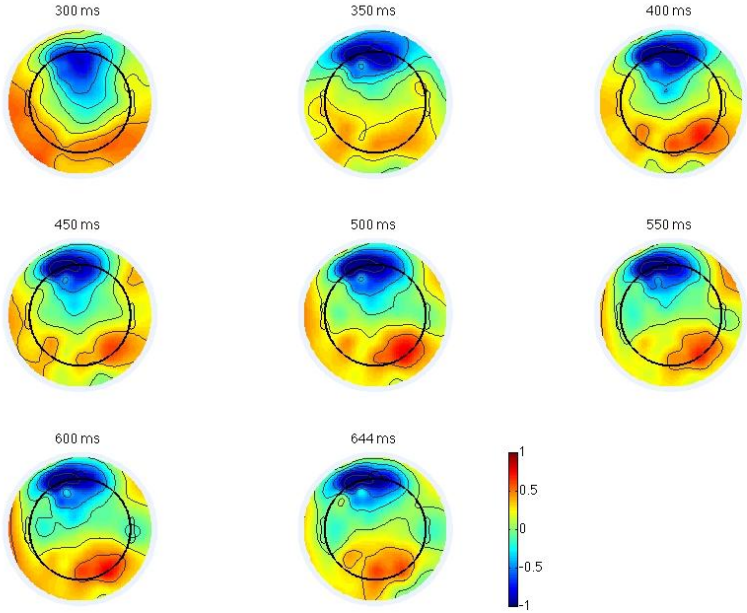


(ii)Temporal factor at 284ms; anterior spatial subfactor

- RAW DATA, Main effect of stimulus in both groups:



Monolinguals, difference plot, all attention condition



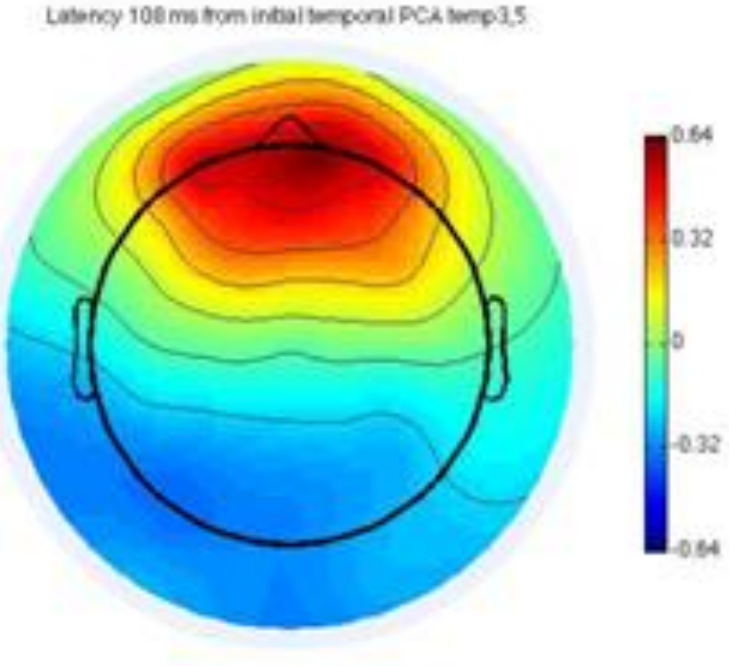
Bilinguals, all attention conditons

(ii)Temporal factor at 284ms; anterior spatial subfactor

- *What does it mean?*
  - That in this late, post-MMN time stage, bilinguals attention was drawn to the distinction between the vowels in a way that was not observed for monolinguals
  - Bilinguals show increased attentional resource allocation to the processing of the vowel distinction

(iii) Temporo-spatial factor at 108ms

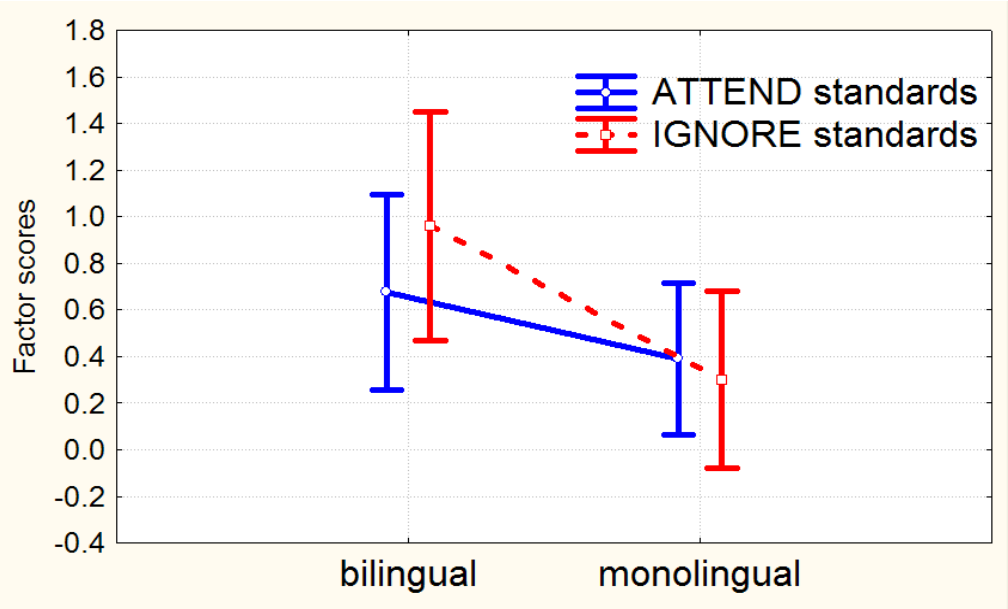
- Finally, we looked at the voltage response to the standard stimuli only under the two attention conditions



Processing Negativity: A negative shift at fronto-central sites during N1, indexing attentional resource allocation

(iii) Temporo-spatial factor at 108ms

- Repeated measures ANOVA of temporo-spatial factor scores:
  - Between: group
  - Within:
    - ATTENTION
    - TARGET
    - STIMULUS



F(1, 38)=3.8640, p=.05667

(iii) Temporo-spatial factor at 108ms

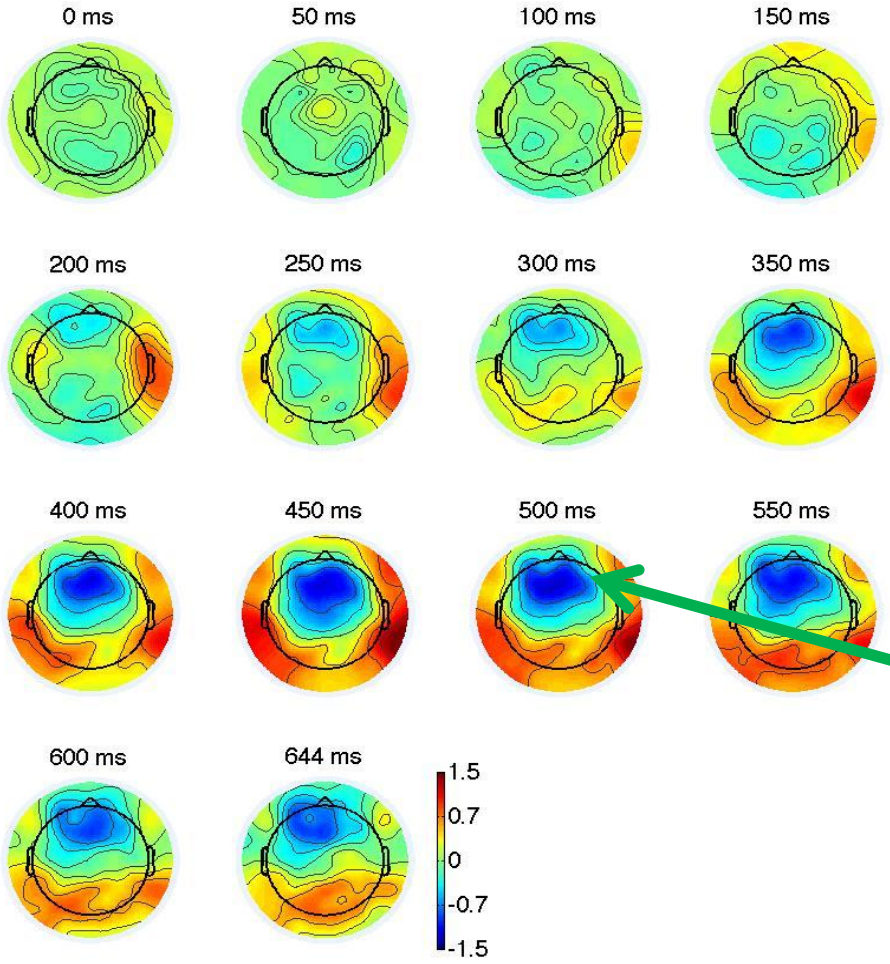
- *What does this mean?*
  - Adult bilinguals allocate more attention resources during the ATTEND than in the PASSIVE tasks in the early auditory processing of the stimuli
  - monolinguals show no such effect

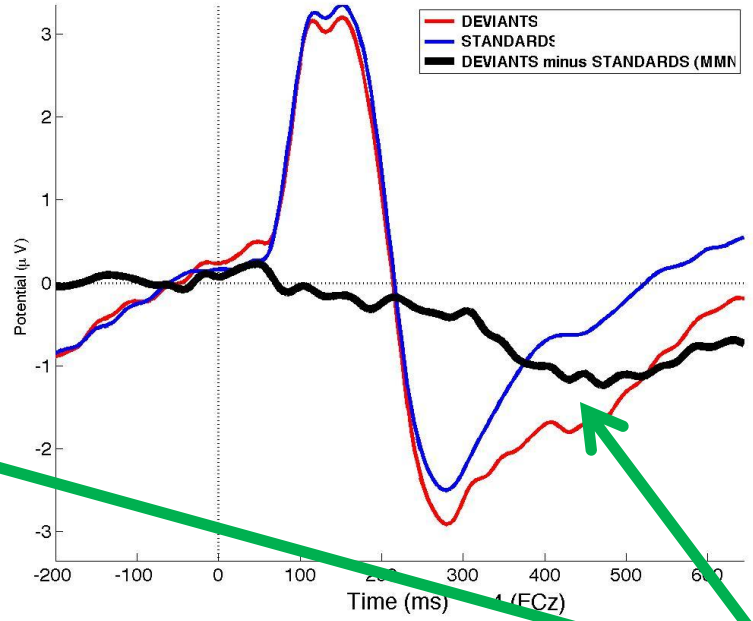
Summary, adult findings

- Both monolingual and bilinguals have same basic MMN
  - Automatic response to vowel difference
- But: Bilinguals show greater attentional resource allocation
  - Processing negativity: bilinguals only
    - More resources in the attend condition
  - Anterior late negativity: bilinguals only
    - Index of attentional processing of vowel difference

CHILD STUDY

Children's mismatch response



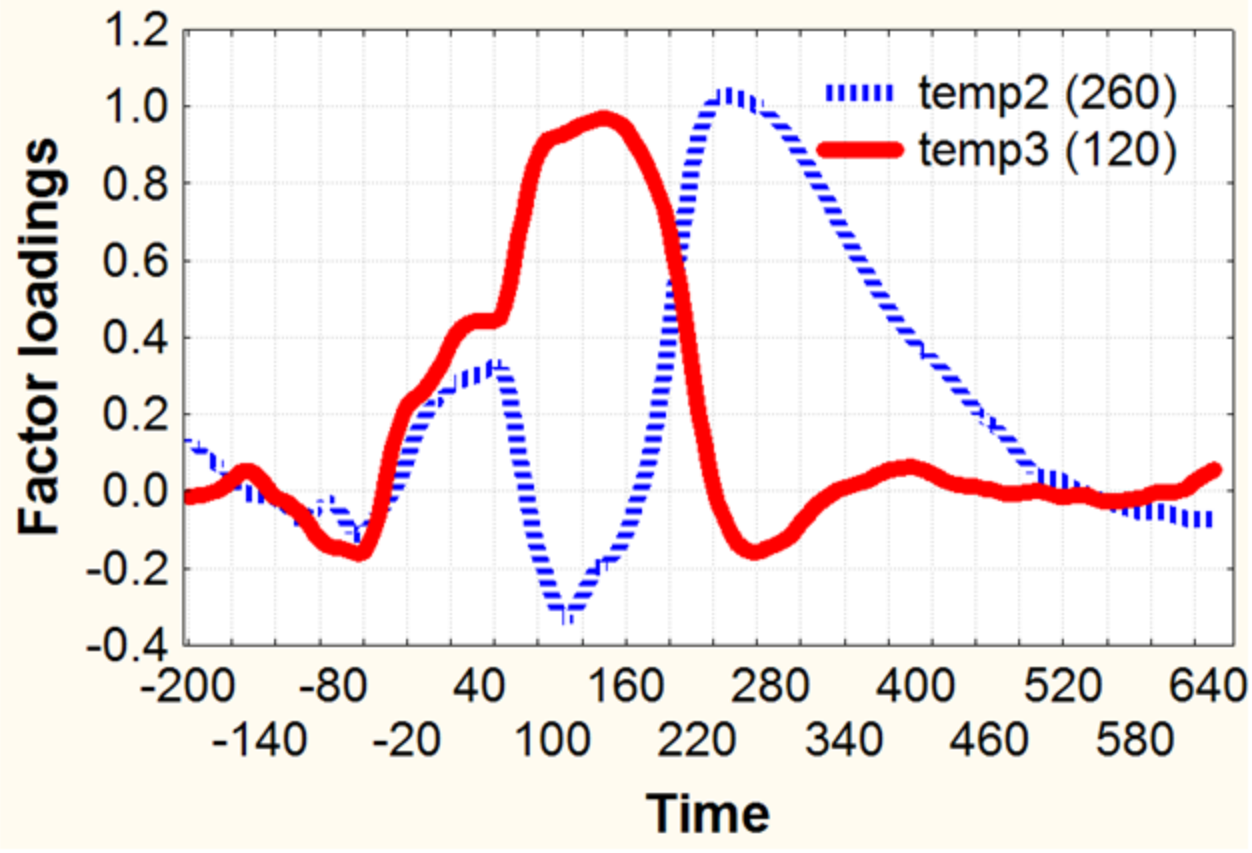


MMR

Child deviant - standard difference wave (N=30)

PCA decomposition

- Temporal PCA yielded 2 ERP-related time components:

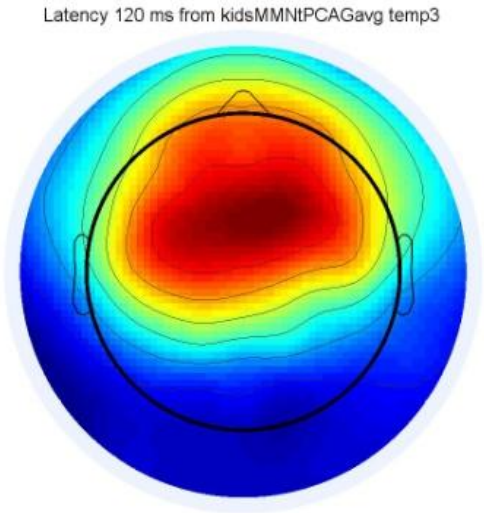


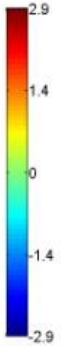
PCA decomposition

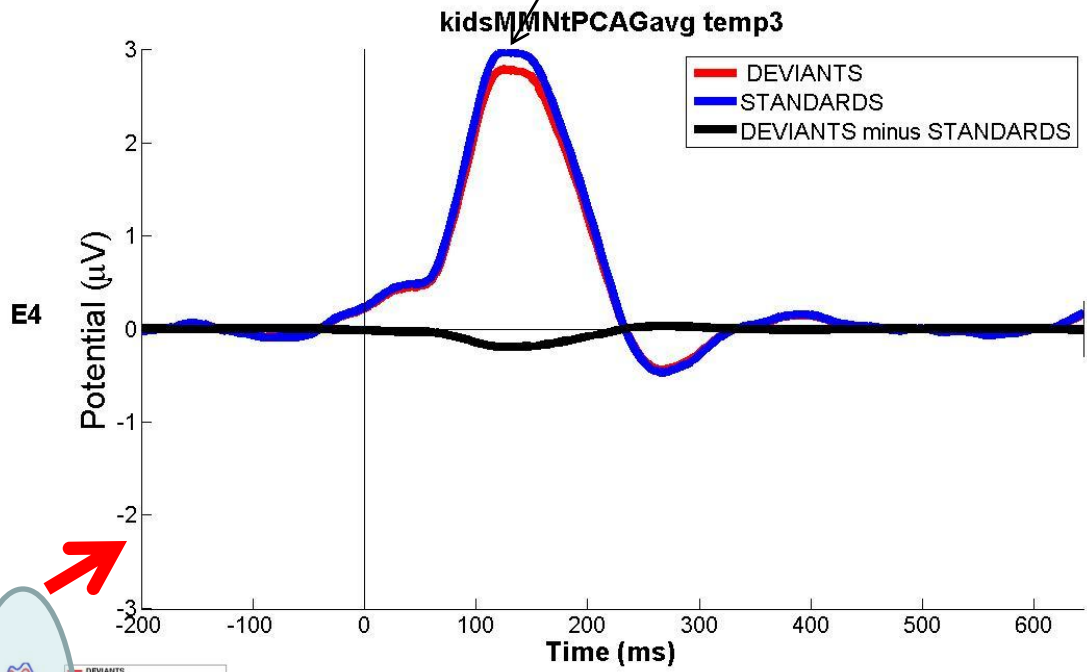
- Further spatial decomposition did not yield spatially homogeneous factors; we therefore limited analysis to the temporal PCA factors
  - Too much spatial variability in this time component in kids

Early factor:120ms

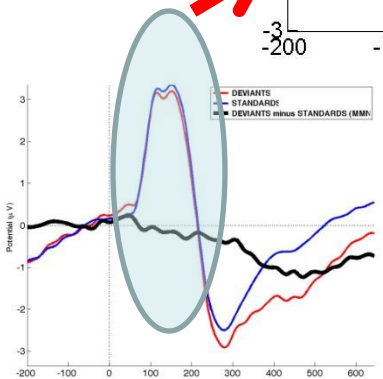
n.s.! F(1,28)=1.4, p=0.24





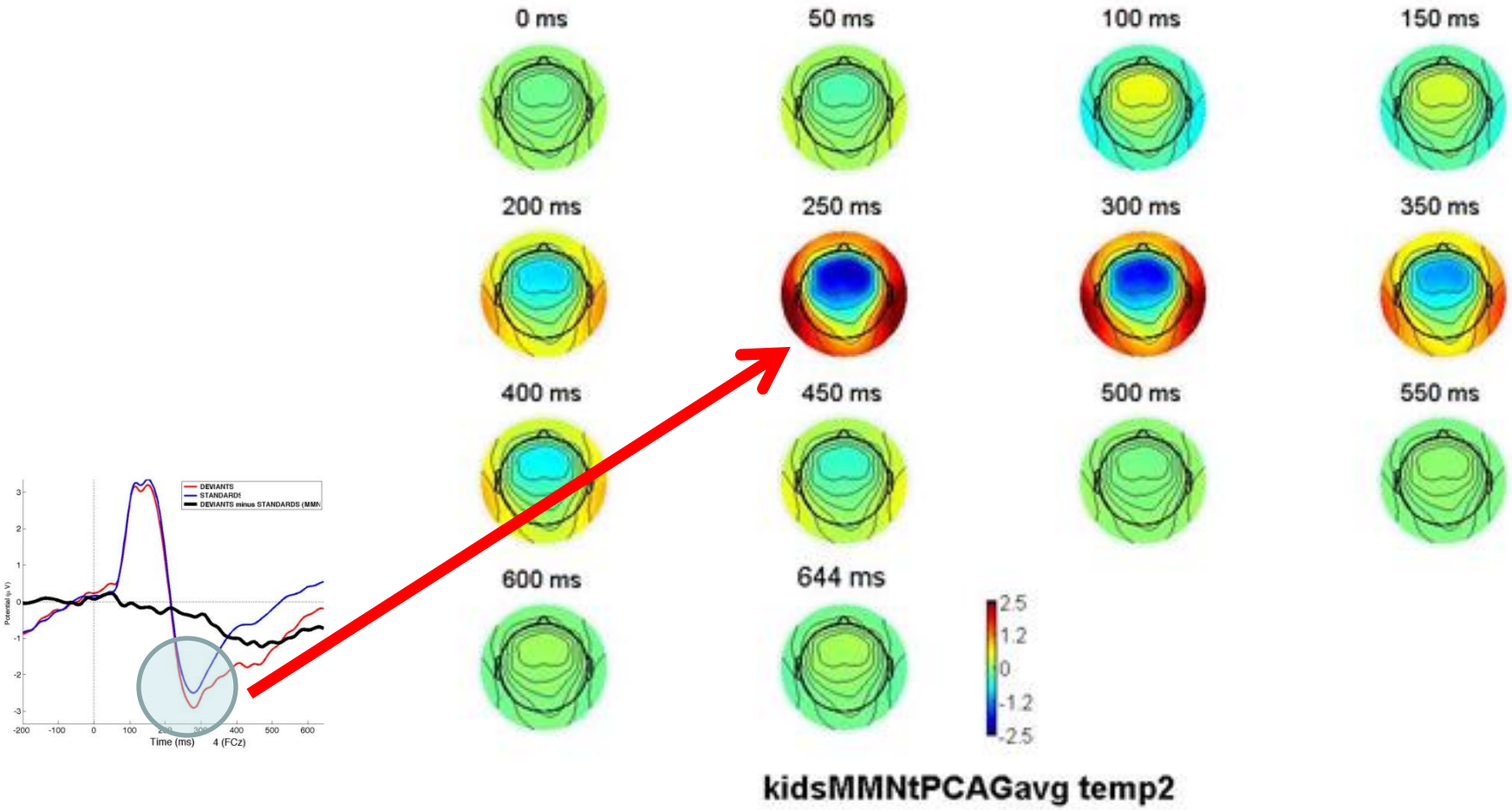


Raw data:



Late factor: 260ms

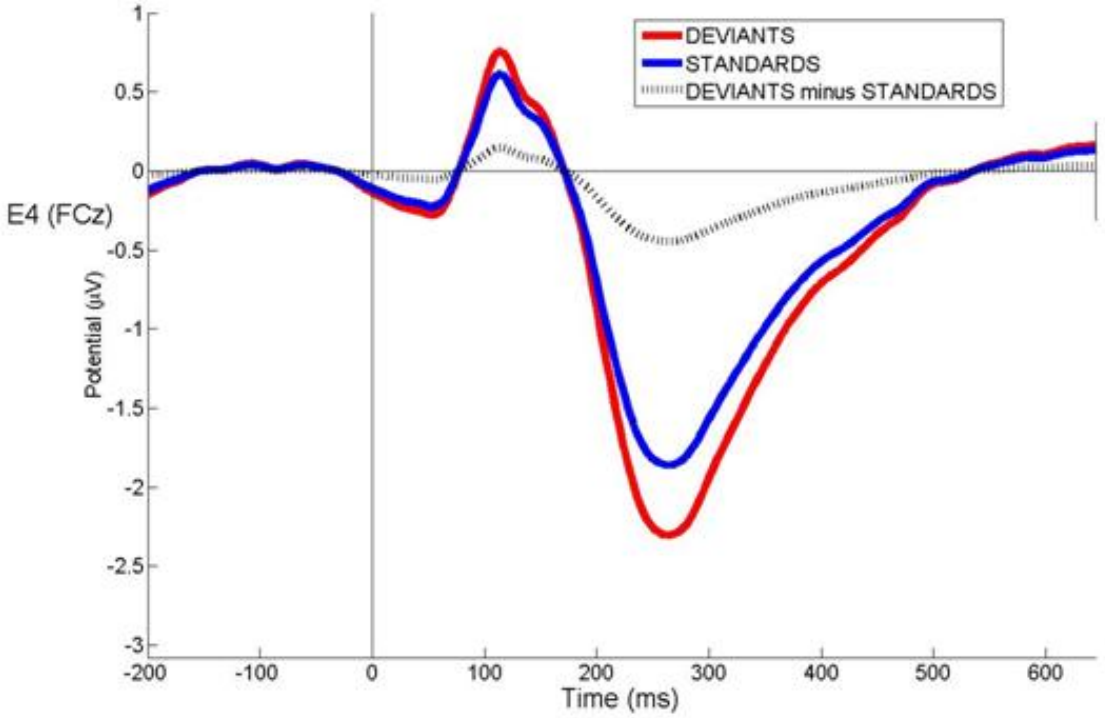
- Second component of response



Late factor: 260ms

- Significant main effect: MMN (Dev vs. Std)

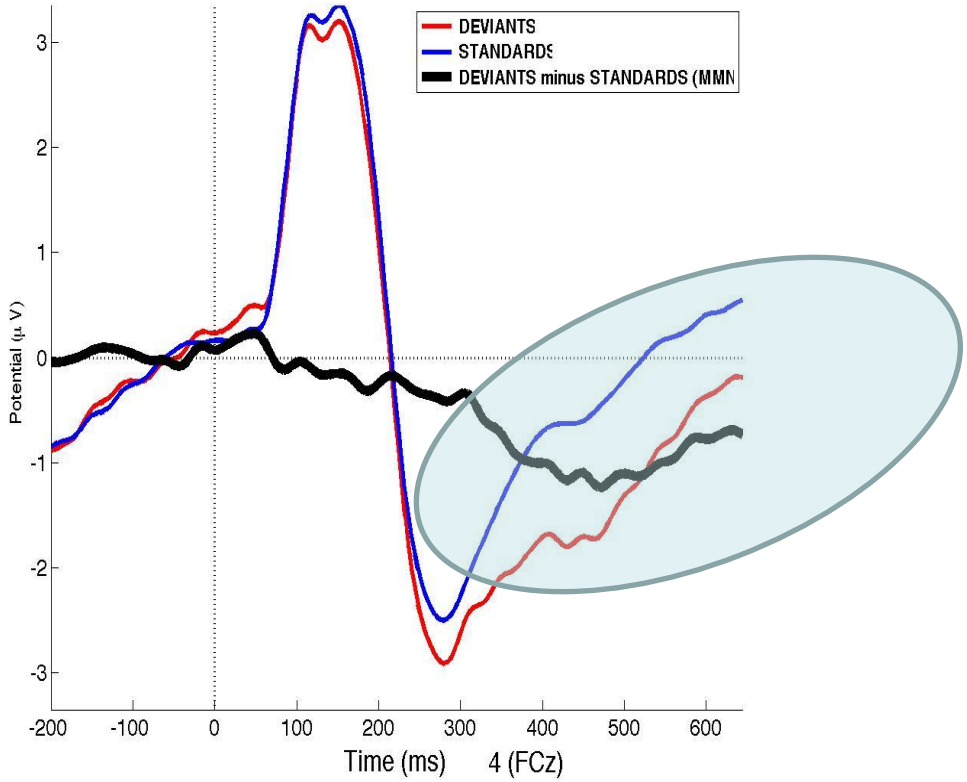
PCA factor



Stimulus effect (DEV-STD) F(1,27) = 15.5, p < .001

Rest of epoch, anterior electrodes

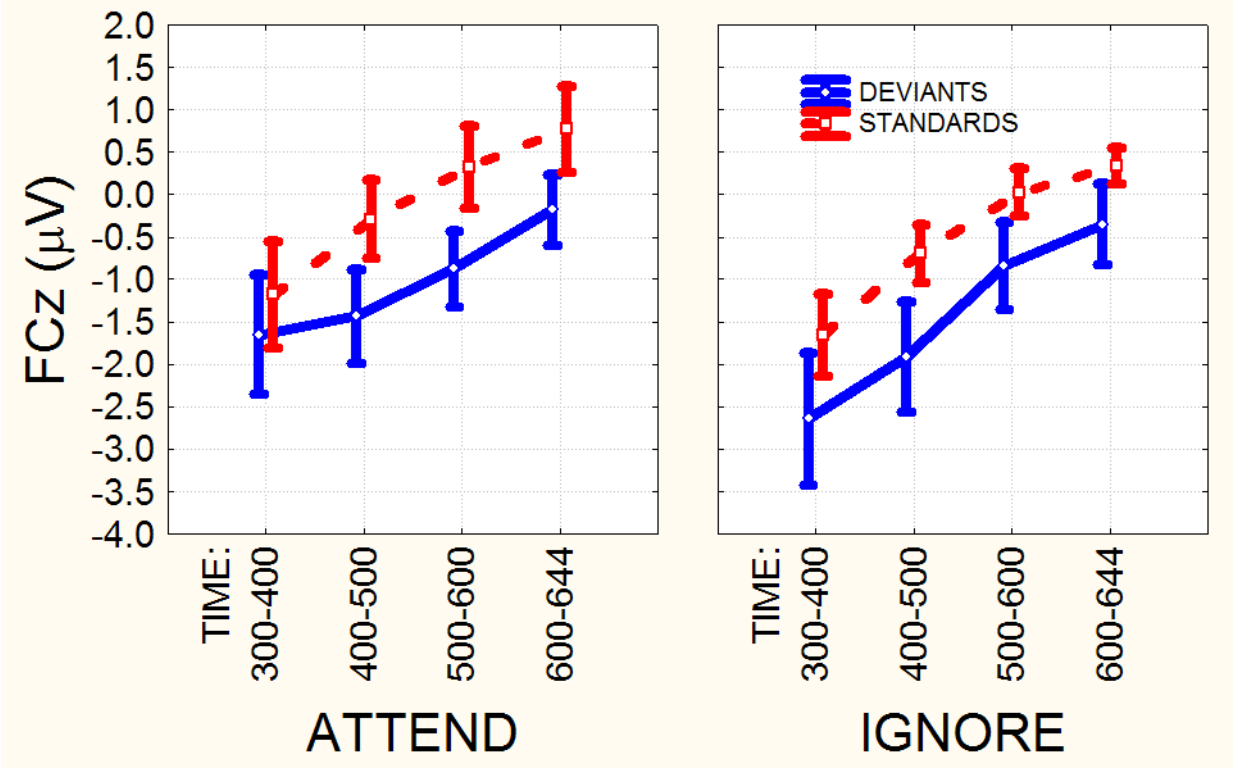
- No homogeneous temporal PCA component



Rest of epoch, anterior electrodes

- Main effect of stimulus (DEV – STD difference), no group or attention effect

Only interaction: between Time, Attention and Stim: Greater absolute amplitude in the attend condition



F(3, 84)=4.89, p=.003

SUMMARY, CHILDREN

- In the PCA analysis, children only showed a condition effect in the late part (260ms) of their auditory evoked potential
  - No difference monolingual vs. bilingual
  - No main effects or interactions involving attention
- Raw ERP analysis of rest of epoch also showed a stimulus (MMN) effect

WRAPPING UP!

- Adult bilinguals (from 5 years of age) equals adult monolinguals
- But: →Adult bilinguals showed greater attentional resource allocation to the stimuli
  - As indexed by the early *Processing* Negativity in the ATTEND condition
  - As indexed by greater stimulus effect than monolinguals in the anterior LN

The End

- The two child groups were identical
  - Three years of schooling in L2 is sufficient for leading to native-like automatic speech perception
- Adult bilinguals differ subtly from monolinguals
  - develop increased attentional resource allocation during speech perception