Neural correlates of understanding time-reversed *cheeps*: an ERP study

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Introduction

When listening to speech in ecological conditions, our cognitive system must often cope with transient signal perturbations such as sudden breaks, mispronunciations or interfering noises.

Aim of the study: examine the neural processes responsible for the early detection of a sudden acoustic perturbation in a connected-speech context and how these processes interact with later stages involved in speech reconstruction and comprehension.

Determine whether the Mismatch Negativity (MMN) elicited in response to unexpected acoustic changes in an auditory stream can also be elicited by an acoustic degradation in a speech context.

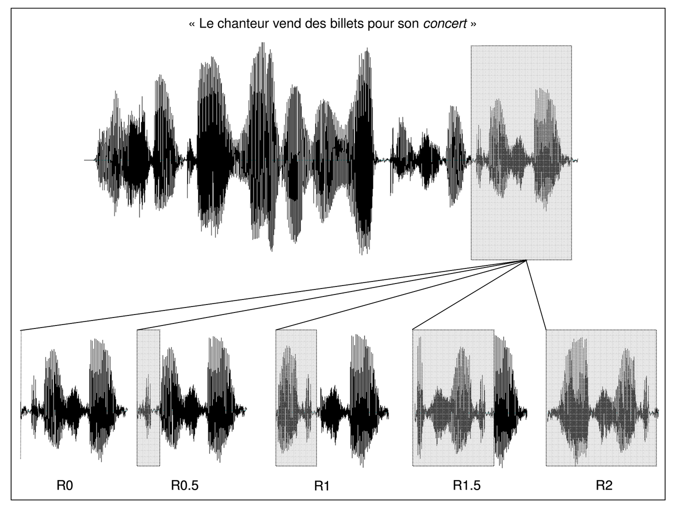
How? Explore the temporal dynamics of cortical responses, as evaluated by the recording of event-related potentials (ERPs), associated with the processing of increasingly altered (time-reversed) portions of target speech embedded in sentences.

Methods

- **Participants**

17 healthy right-handed French native participants with no hearing or language impairment

- **Stimuli**
  - ❖ /ba/ syllable (intact or time-reversed) presented as standard or deviant in an oddball sequence
  - ❖ 200 sentences – final bisyllabic word manipulated along 2 dimensions:
    - **Cloze Probability CP**
    - **Size of the Temporal Reversion**



Temporal Reversion	R0 (no reversion)		R0.5 (half 1st syllable)		R1 (1st syllable)		R1.5 (1st syllable and half 2nd)		R2 (whole word)	
CP	low	high	low	high	low	high	low	high	low	high

- **Task**

(1) oddball: watch a video while ignoring the /ba/ sounds (to elicit an MMN)

(2) sentence repetition: listen to the sentences and repeat them as accurately as possible

- **EEG**

32 electrodes – referenced to linked mastoids – [1-30 Hz] – segmentation [-100; 900 ms]

- **ERPs analysis**
  - ❖ ERPs time-locked to target word onset
  - ❖ Early time-window: 40-ms-window centered at peak latency between 200 and 300 ms
  - ❖ Late time-window: [350 – 550 ms]

- **Statistical analysis**
  - ❖ One sample *t*-tests
  - ❖ Repeated-measures ANOVAs (Reversion x CP x Spatial Domain x Lateralization)
    - Reversion: R0, R0.5, R1, R1.5, R2
    - CP: low, high
    - Spatial Domain: Frontal (F3, Fz, F4), Central (C3, Cz, C4), Parietal (P3, Pz, P4)
    - Lateralization: Left, Central, Right

Results

Figure 1: auditory oddball

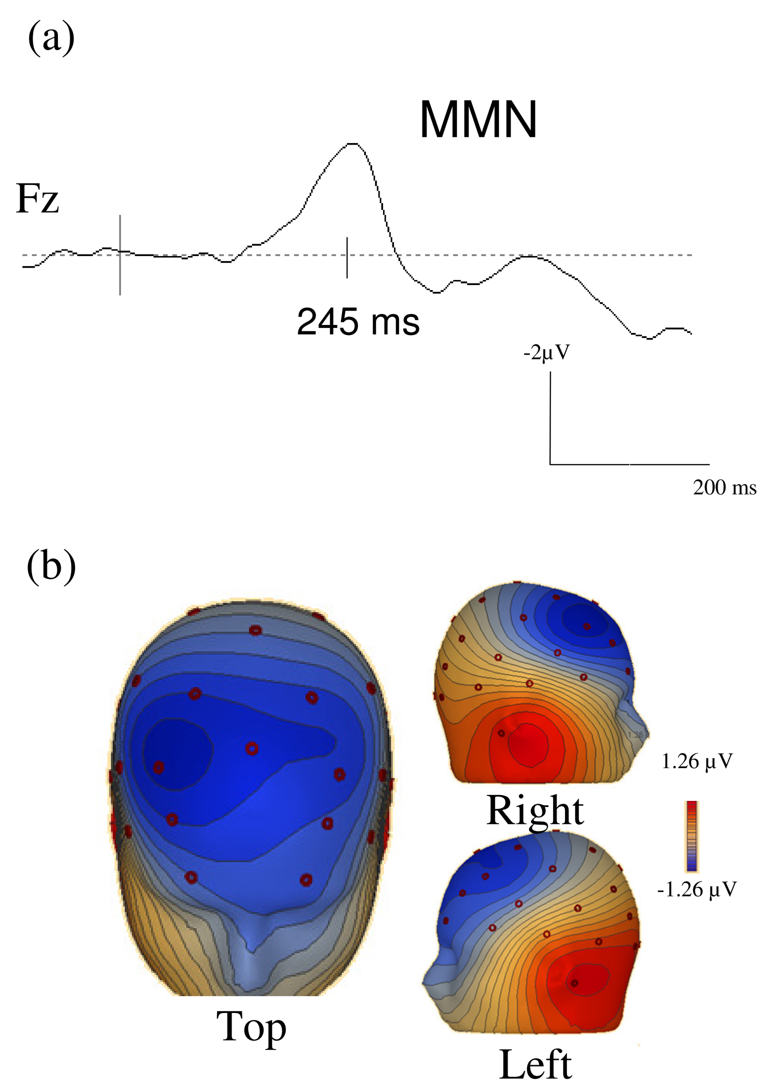


Figure 2: sentences - early time-window

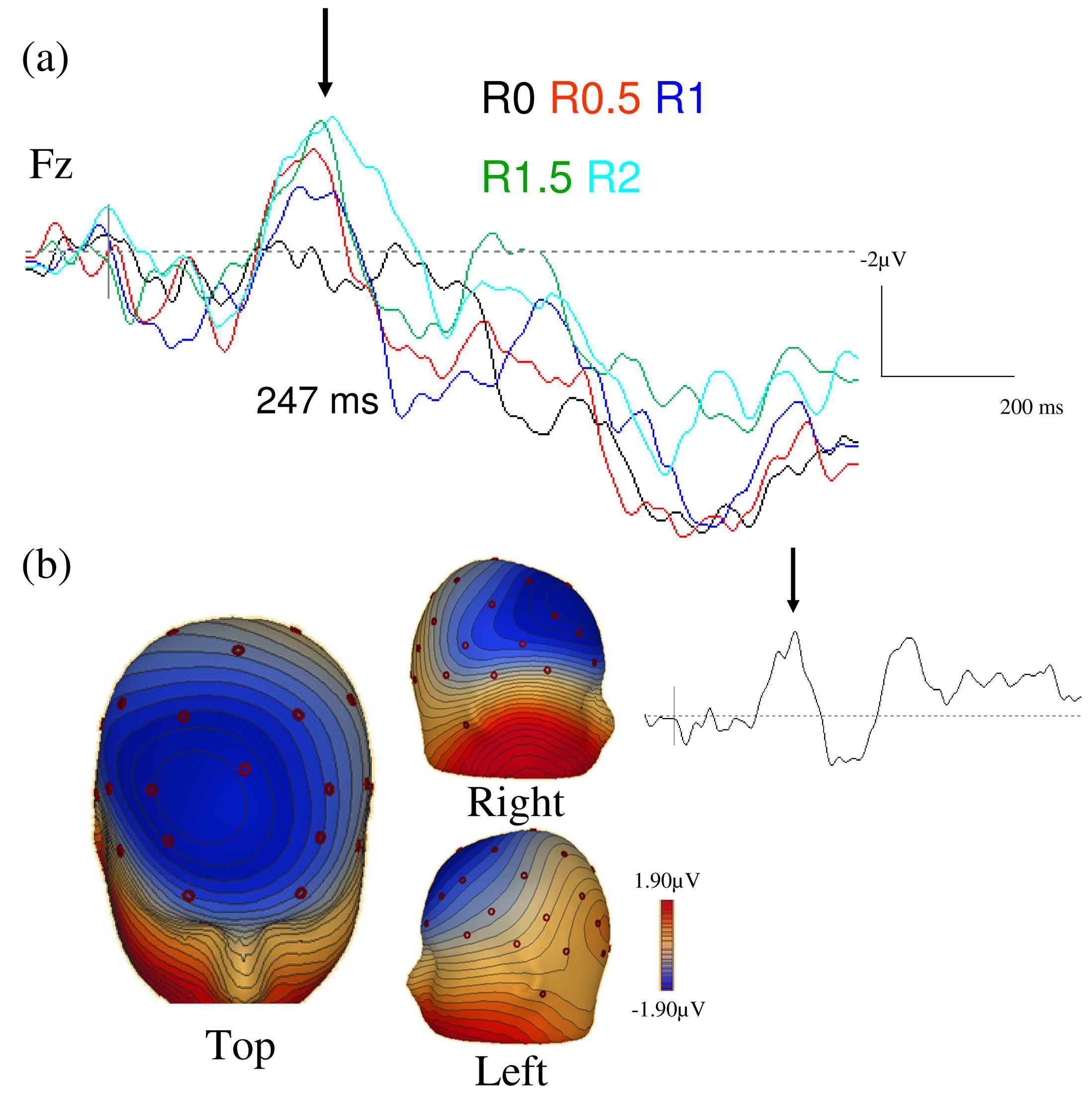
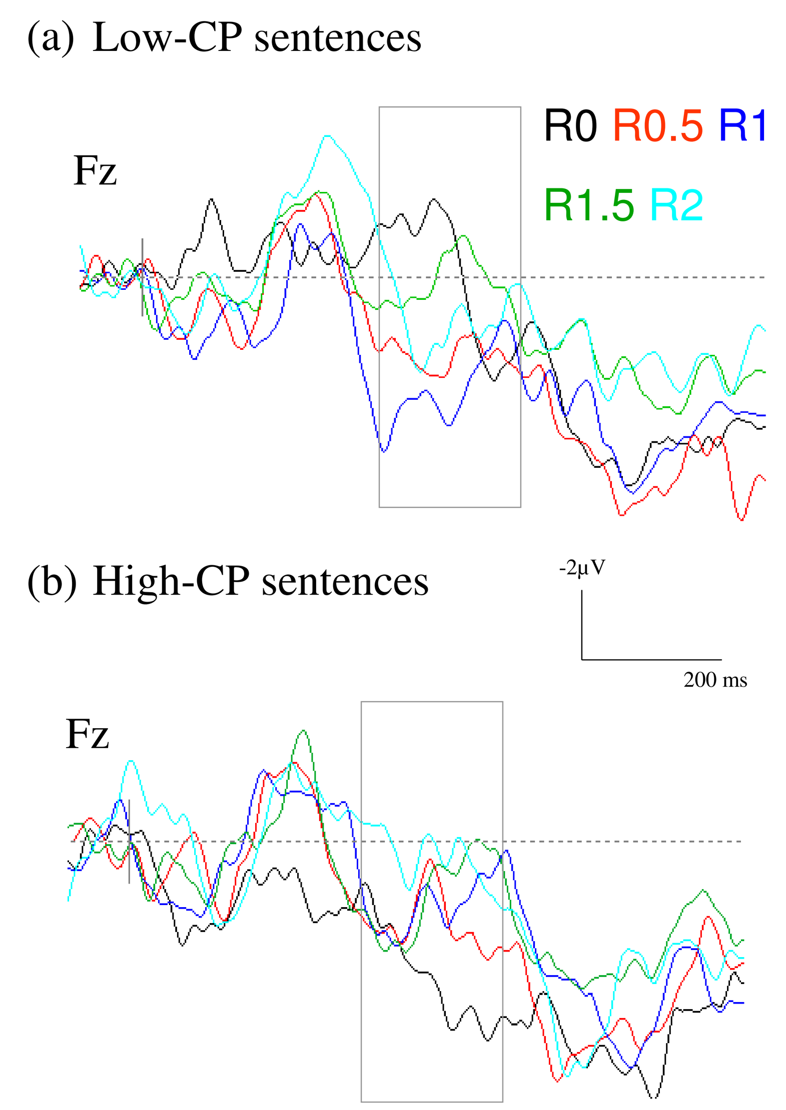


Figure 3: sentences - late time-window



- Early time-window (± 20 ms at peak latency):
  - Mean ERP amplitude significantly differed from zero ($p < .01$) in all conditions except R0-high-CP.
  - **Effect of Reversion** ($p = .019$): early negative wave elicited for degraded words independently of the actual size of the reversion (Figure 2).
  - **No effect of Cloze Probability**, no interaction.
  - **Comparable spatio-temporal features between MMN** (Figure 1) **and early negative wave to distorted target words** (Figure 2): similar latencies and amplitudes ($p > .05$), comparable topographical distribution (frontal areas, slight right hemisphere advantage)

- Late time-window:
  - N400 to low-CP intact target words – **positive shift (reduced N400) for low-CP degraded words** (Figure 3a)
  - positive wave for high-CP intact words – **negative shift for high-CP degraded words** (Figure 3b)
  - **Reversion x CP interaction** ($p = .007$): effect of CP only in the R0 condition (mean amplitude is more negative for low-CP than high-CP intact words)
  - **Reversion x CP x Spatial Domain interaction** ($p = .025$): positive and negative shifts for reversed low-CP and high-CP words respectively particularly over frontal electrodes

Conclusions

- The detection of a sudden acoustic degradation in a speech context elicits a frontal negativity early after the onset of the perturbation and independently of its actual size.
- This early negative wave resembles the MMN in terms of spatio-temporal features.
- We suggest that the MMN may be an acoustic response that can have direct implications in normal speech comprehension, particularly when encoding difficulties caused by transient degradations.
- The detection of such transient distortions in speech would allow the system to trigger online compensatory mechanisms that can help with the final comprehension of an acoustically imperfect message.