Looking for the Phonological Mapping Negativity (in all the wrong places)

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June 24 2021

Section 1

Introduction

Introduction

Four years ago...

Introduction

Can event-related potential data inform information flow order in speech perception?

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Can event-related potential data inform information flow order in speech perception? i.e. what the extent of top-down mediation is during speech perception.

Event-related potentials

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Event-related potential components are measured with electroencephalography (EEG) equipment.

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- Interactive models of speech perception e.g. **TRACE** (McClelland & Elman 1986)

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- Interactive models of speech perception e.g. **TRACE** (McClelland & Elman 1986)
- Feed-forward / modular models of speech perception e.g. **Cohort** (Marslen-Wilson 1984)

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- Elman, J. L., & McClelland, J. L. (1988). Cognitive penetration of the mechanisms of perception: Compensation for coarticulation of lexically restored phonemes. Journal of Memory and Language, 27(2), 143-165.

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- McQueen, et al. (2009). No lexical–prelexical feedback during speech perception or: **Is it time to stop playing those Christmas tapes?**. Journal of Memory and Language, 61(1), 1-18.

Elman & McClelland (1988)

Compensation for coarticulation: (Mann & Repp 1981)

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- e.g. Christma/s-ʃ/ more often solved as Christma/s/.
- Effect stronger at phoneme boundary.

Elman & McClelland (1988)

Christma/**s-**ʃ/ /**t-k**/apes

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Christma/**s-**ʃ/ /**t-k**/apes

Cool, huh?

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The original goal of my thesis was that to **design** a handful of **ERP experiments to investigate lexical feedback** and top-down processes of speech perception. But how?

Event-related potentials

- Mismatch Negativity (**MMN**)

* Originanly named Phonological Mismatch Negativity

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- **N400**
- **P600**

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MMN

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In the auditory domain, a deviant stimulus can be identified by differences in pitch, duration, stress and frequency range (Erlbeck et al. 2014)

MMN

However, the MMN was also found to be sensitive to phonological mapping (Pulvermuller 2001)

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- MMN to the presentation of mismatching Finnish words
- No MMN in control group

N400

The N400 (Kutas & Hillyard 1980) is part of the normal brain response to words and other meaningful stimuli.

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nurse

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- Hundreds of studies
- Other paradigms include cloze-probability mismatch (e.g. Connolly and Phillips 1994)

Phonological Mapping Negativity

The Phonological Mapping (or Mismatch) Negativity, **PMN** is an event-related potential component hypothesized to index phonological mismatch and mapping

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Others (e.g. Newman et al.) report that the PMN is a **marker of acoustic and pre-lexical information**.

Connolly and Phillips (1994)

Event-Related Potential Components Reflect Phonological and Semantic Processing of the Terminal Word of Spoken Sentences:

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- The piano is out of

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- The piano is out of tune

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Event-Related Potential Components Reflect Phonological and Semantic Processing of the Terminal Word of Spoken Sentences:

- The piano is out of tune (no mismatch)

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- The piano is out of tune (no mismatch)
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- The piano is out of pizza

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- The piano is out of tune (no mismatch)
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- ...

Newman et al. (2003)

Phoneme deletion task to study the PMN:

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Delete /k/ from the word “clap”

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- aap

Newman et al. (2003)

Phoneme deletion task to study the PMN:

Delete /k/ from the word “clap”

- lap
- aap
- dog

Phonological Mapping Negativity

Lewendon et. al (2020) suggest that the possibility exists that the PMN is an extension of either the Mismatch Negativity (MMN) or N400 components

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Lewendon et. al (2020) also report that the majority of the literature on the PMN is characterized by contradictory findings and methodological limitations, e.g.

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  - Some studies report discovering the PMN in frontal and central sites, others in parietal / mid-line / evenly spread across the scalp.

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  - Few trials (usually < 40)

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  - Few participants (usually < 10)
  - Few trials (usually < 40)
  - Confounding variables

Research questions

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- **Is the PMN in response to acoustic, phonetic, phonological, lexical mapping and mismatch, none or a combination of all?**

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- **Is the PMN in response to acoustic, phonetic, phonological, lexical mapping and mismatch, none or a combination of all?**
- **Is any other ERP component found in response to acoustic, phonetic and phonological mismatch in place of / together with the PMN?**

Research questions

Why the PMN..

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Why the PMN.. and why now?

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- The PMN (placed in between phonetic and lexical processing) might play a key role in future investigations into architectures of grammar and speech perception

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Why the PMN.. and why now?

- The PMN (placed in between phonetic and lexical processing) might play a key role in future investigations into architectures of grammar and speech perception
- Clinical studies have recently used the PMN as a marker of phonological processing abilities in patient populations (Robson et al. 2017). However, it is not clear what processes the PMN really indexes.

Section 2

Methods

Experimental design

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Three ERP experiments designed to investigate the elicitation of the PMN in contexts with no lexical activation.

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Experiments **1**, **2** (and **3**) were designed to simultaneously work independently while also being fully comparable.

Equipment & Processing

Hardware:

Equipment & Processing

Hardware:

- 64 active pin-type **BioSemi** electrodes for the scalp

Equipment & Processing

Hardware:

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- 6 (EX1 to EX6) face electrodes

Equipment & Processing

Hardware:

- 64 active pin-type **BioSemi** electrodes for the scalp
- 6 (EX1 to EX6) face electrodes
- BioSemi hardware (e.g. receiver)

Equipment & Processing

Software:

Equipment & Processing

Software:

- Praat (w/ Vocal Toolkit)

Equipment & Processing

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Equipment & Processing

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- Neurobehavioral Systems' **Presentation**

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- EEGLAB (Delorme & Makeig 2004)

Equipment & Processing

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- MATLAB (2018b; 2019a; 2019b)
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- ERPLAB (Lopez-Calderon & Luck, 2014)

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- MATLAB (2018b; 2019a; 2019b)
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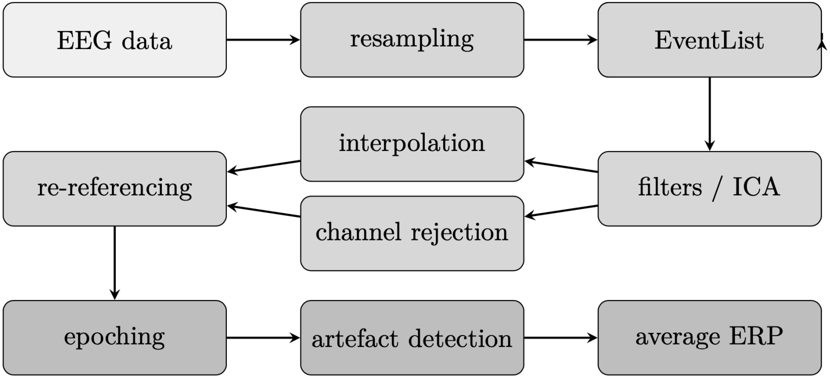
- R (4.1) (R Core Team 2021)

Equipment & Processing

EEG pre-processing:

Equipment & Processing

EEG pre-processing:



Equipment & Processing

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- 0.01 - 40 Hz band-pass filter

Equipment & Processing

EEG pre-processing:

- Offline average reference
- 512 Hz sampling frequency
- 0.01 - 40 Hz band-pass filter
- 50 Hz notch filter for AC hum

Equipment & Processing

Statistical analyses:

Equipment & Processing

Statistical analyses:

- Exploratory channel-level multivariate testing with package `ERP` (Causeur et al. 2020) and the Adaptive Factor Adjustment (AFA) procedure (Sheu et al. 2016)

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- Exploratory channel-level multivariate testing with package `ERP` (Causeur et al. 2020) and the Adaptive Factor Adjustment (AFA) procedure (Sheu et al. 2016)
- Mean amplitude modelling with mixed-effect models & package `lme4` (Bates et al. 2015)

Equipment

Data visualisation:

Equipment

Data visualisation:

- Grand-Average / difference ERP plots with `ggplot2` (Wickham 2016)

Equipment

Data visualisation:

- Grand-Average / difference ERP plots with `ggplot2` (Wickham 2016)
- Cubic spline interpolation scalp maps with package `akima` (Akima and Gebhardt 2020)

Reproducibility

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Slides for this talk are available on GitHub at the following repository:
`mcanzi/2021_UNIKON`

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My thesis has been submitted and will be available through open access following thesis defense (in August) and corrections.

Section 3

Experiment 1

Procedure

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- During EEG data collection, stimuli were played to participants during a passive listening task, however..

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- Participants were tested on their knowledge of the experimental stimuli in a computerized task
- During EEG data collection, stimuli were played to participants during a passive listening task, however..
  - In 33% of total trials (400 total trials), the first syllable of the second nonce-word of each pair would be manipulated to break expectations

Procedure

Before training, EEG data was recorded with subjects listening passively to the presentation of matching and mismatching nonce-word pairs. This was done in order to estabilish a baseline.

Stimuli

pitabu

Stimuli

pitabu dipida

Stimuli

pitabu dipida

pitabu

Stimuli

pitabu dipida

pitabu **ba**pida

Stimuli

pitabu dipida

pitabu **ba**pida

pitabu

Stimuli

pitabu dipida

pitabu **ba**pida

pitabu **bu**pida

Stimuli

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- Stimuli concept from Astheimer and Sanders (2011), who controlled for transitional probabilities, resemblance to real words, etc.
- Vowel, syllable and word length were controlled (each syllable was 200 ms long)
- Speaker and pitch contours were the same for all stimuli.

Participants

22 Participants (F = 13) took part to the experiment.

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- 22 right-handed adults

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- 22 right-handed adults
- 22 BrE speakers

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- Age (M = 20, 18-25)

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Participants

22 Participants (F = 13) took part to the experiment.

- 22 right-handed adults
- 22 BrE speakers
- Age (M = 20, 18-25)
- Normal or corrected to normal vision and hearing
- No reported use of psychoactive medications

Results: **Baseline**

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No effects of interest were found

Results: **Baseline**

No effects of interest were found

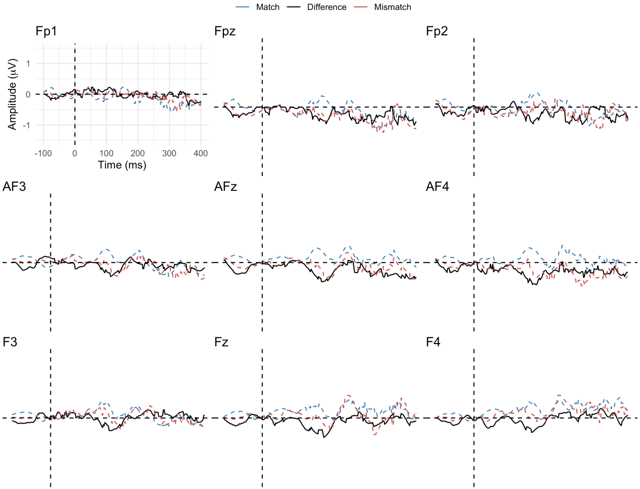
- Few trials

Results: **Baseline**

No effects of interest were found

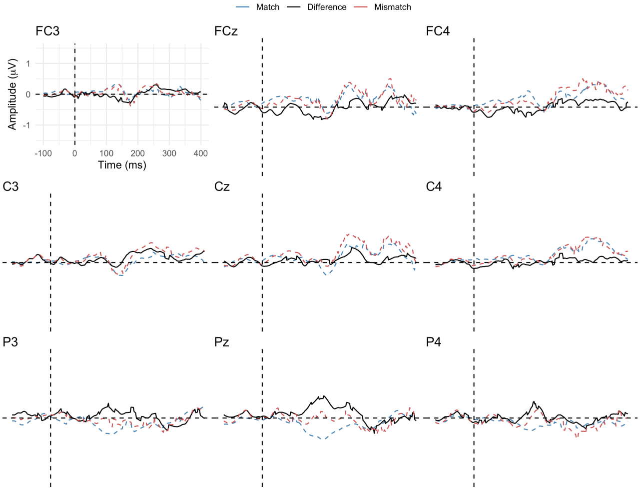
- Few trials
- Low SNR

Results


Match
Difference
Mismatch
Fp1
Fpz
Fp2
AF3
AFz
AF4
F3
Fz
F4
Amplitude (μV)
1
0
-1
-100
0
100
200
300
400
Time (ms)

Results

Results



Match
Difference
Mismatch
FC3
FCz
FC4
C3
Cz
C4
P3
Pz
P4
Amplitude (µV)
1
0
-1
-100
0
100
200
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400
Time (ms)

Results: **PMN**

Cubic-spline interpolation scalp maps. Mean amplitude betweeen 280 and 320 ms post-stimulus onset.

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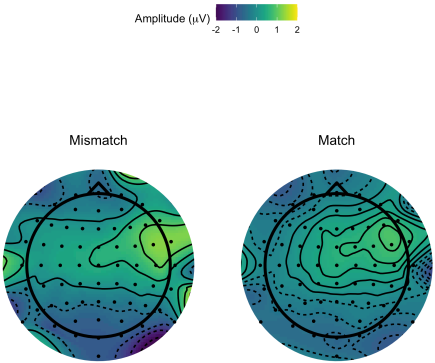

Results: **PMN**

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We fitted a LMEM to mean amplitude measured between 280 and 320 ms PSO.

Results: **PMN**

We fitted a LMEM to mean amplitude measured between 280 and 320 ms PSO. Varying intercepts allowed for `Subject`

- No main effect of `Condition` [$F(_{1,1797}) = 0.01$, $p = .89$)]

Results: **PMN**

We fitted a LMEM to mean amplitude measured between 280 and 320 ms PSO. Varying intercepts allowed for `Subject`

- No main effect of `Condition` [$F(_{1,1797}) = 0.01$, $p = .89$)]
- No interaction of `Condition` & `Region` [$F(_{10,1797}) = 1.39$, $p = .17$)]

Results: **Other effects**

- Small negative effect between 150-200 ms for mismatch condition (frontocentral) (**MMN?**)

Results: **Other effects**

- Small negative effect between 150-200 ms for mismatch condition (frontocentral) (**MMN?**)
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Results: **Other effects**

- Small negative effect between 150-200 ms for mismatch condition (frontocentral) (**MMN?**)
- Bigger positive effect between 500-700 ms for mismatch condition (centroparietal) (**P600?**)
- In case of a significant interaction between `Condition` and `Region`, pairwise contrasts were carried out with package `emmeans` (Lenth et al. 2018)

Discussion

No instance of **PMN** (in any of its expected forms) was found

Discussion

Possible explanations:

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- PMN is more ”higher-level” than previously theorized

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  - Passive listening
  - Possible P3a contamination?

Section 4

Experiment 2

Methods

Methods

- Designed to be (fairly) comparable to experiment one

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    - Same stimuli as Exp 1

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  - Same stimuli as Exp 1
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- Designed to be (fairly) comparable to experiment one
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- Includes active, behavioural tasks

Methods

- Designed to be (fairly) comparable to experiment one
  - Same stimuli as Exp 1
  - No lexical activation
- Includes active, behavioural tasks
- More streamlined

Stimuli

Same nonce words as **Experiment 1**

Procedure

di +

Procedure

di + (500 ms pause) +

Procedure

di + (500 ms pause) + pi +

Procedure

di + (500 ms pause) + pi + (500 ms pause) +

Procedure

di + (500 ms pause) + pi + (500 ms pause) + da

Procedure

di + (500 ms pause) + pi + (500 ms pause) + da

(4 s pause)

Procedure

di + (500 ms pause) + pi + (500 ms pause) + da

(4 s pause)

dipida

Procedure

However, in 33% of total trials

di

Procedure

However, in 33% of total trials

di pi

Procedure

However, in 33% of total trials

di pi da

Procedure

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di pi da

bapida

Participants

20 participants (F = 12) took part to the experiment:

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- 20 right-handed adults

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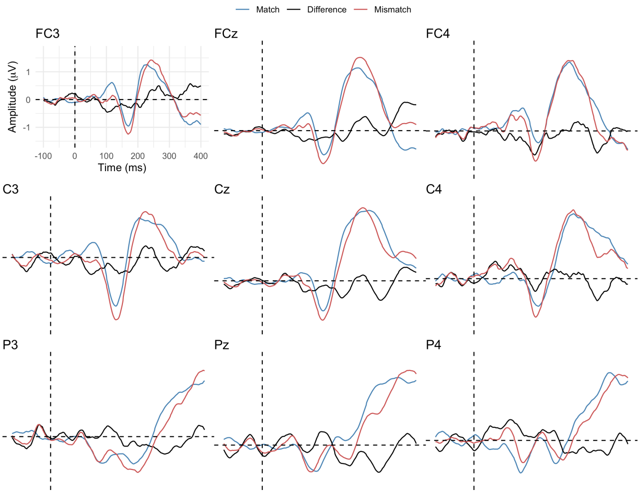
- No reported use of psychoactive medications
- 0 took part to both Exp 1 and Exp 2

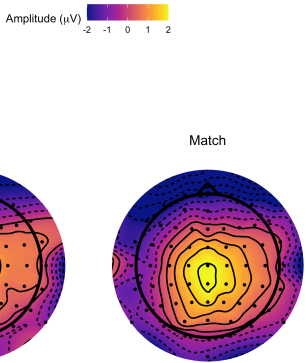
Results

Results


Match
Difference
Mismatch
FC3
FCz
FC4
C3
Cz
C4
P3
Pz
P4
Amplitude (µV)
1
0
-1
-100
0
100
200
300
400
Time (ms)

Results: **PMN**

Cubic-spline interpolation scalp maps. Mean amplitude between 280 and 320 ms post-stimulus onset.



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We fitted a linear mixed-effect regression model to mean amplitude measured between 280 and 320 ms PSO. Varying intercepts allowed for `Subject`

- No main effect of `Condition` [$F(_{1,1965.6}) = 0.0001$, $p = .98$)]
- Significant interaction of `Condition` & `Region` [$F(_{10,1948.2}) = 0.8$, $p = .001$)]. However..

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- Significant interaction of `Condition` & `Region` [$F(_{10,1948.2}) = 0.8$, $p = .001$)]. However..
- Only significant main effect on Condition between match ($M = 0.51\ \mu V$) and mismatch ($M = -0.04\ \mu V$) at parieto-occipital scalp sites.

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Section 5

General Discussion

PMN?

Contrasting findings in PMN literature cause:

- Difficulty in determining whether an observed response matches the PMN (in function and topographical distribution)

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- Difficulty in determining whether an observed response matches the PMN (in function and topographical distribution)
- Easy to mistake any component in a similar range as the PMN

PMN?

Contrasting findings in PMN literature cause:

- Difficulty in determining whether an observed response matches the PMN (in function and topographical distribution)
- Easy to mistake any component in a similar range as the PMN
- Bulk of the (very limited) literature on the PMN attributed to one research group

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The PMN appears to be linked to lexical processing more than to the processing of pre-lexical information (including acoustic and phonetic information).

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- Goes against later interpretations (e.g. Newman et al. 2003)
- How much of the PMN is in response to phonological information specifically?
    - Issues with uses of PMN in clinical settings

Other findings

Earlier responses (150-200 ms) and later P600-like effects reinforce:

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Earlier responses (150-200 ms) and later P600-like effects reinforce:

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- Early, acoustic / phonetic mismatch
- P600 as an index of sequence violation

Could the PMN be a later instance of the MMN?

Future directions

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- Explore other responses to stimulus presentation in Exp 1 and 2

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- Explore other responses to stimulus presentation in Exp 1 and 2
- Determine whether they are to acoustic, phonetic, phonological features of stimuli..
  - Done in Exp 3. Data collection interrupted by COVID-19
- Try different paradigms that isolate phonological and lexical processing

Methodological limitations

If we consider the non-observation of the PMN as a cause of methodological limitations:

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If we consider the non-observation of the PMN as a cause of methodological limitations:

- PMN most likely not reliable enough as a marker for clinical experiments
- Not a good candidate for experiments investigating information flow order in speech perception

PMN: **All the right places**

PMN: **All the right places**

Replication

Thank you!

Special thanks to my supervisors **Dr Wendell Kimper** and **Dr Patrycja Strycharczuk**

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