DETERMINING THE UNDERLYING MECHANISM OF ADULT BRAIN RESPONSES TO OMISSION DEVIANTS

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- It is important for our brain to interpret incoming sounds especially for understand language and music
- We're interested to see how our brain responds to a violation of sound patterns

INTRODUCTION



- Mismatch Negativity (MMN) Response is an ERP component elicited by the brain toward an unexpected sound after a set of repetitive sounds¹
 - Response followed by a P3a response¹
 - MMN robustly evident for pitch, melodic, and timing deviants¹

INTRODUCTION



- Two leading hypotheses for the mechanism of the MMN:
 - Predictive Coding Deviant sound violates a prediction model set by brain for prior sounds eliciting a prediction error²
 - Neural Adaptation Repetitive sound patterns activate feature neurons that eventually habituate. Deviant sounds activate new feature neurons³

INTRODUCTION



RESEARCH QUESTION

What is the underlying mechanism for the MMN Response:

Predictive Coding or Neural Adaptation?





Determine whether an MMN response can be produced using an omission deviant in an oddball paradigm

- If an MMN response is found using an omission deviant, this would support the predictive coding framework
- If an MMN response is not found using an omission deviant, this would support the Neural Adaptation Hypothesis
 - An omission deviant should not activate any new feature neurons¹



STIMULI

Unexpected Silence Condition

- 90% standard C4 piano tones
- 10% deviant (tones pseudorandomly omitted with at least 2 standard tones in between)

Expected Silence Condition

- Standard C4 piano tones
- Longer SOA creating an expected silence (500 ms after tone onset)





EEG PROCESSING







 Shaded regions = 95% CI centered around the grand averages

FIGURE 1: GRAND AVERAGE ERPS TO UNEXPECTED AND EXPECTED SILENCES





MMN response is significantly different between the two conditions such that the unexpected silence elicits a more negative response (p = 0.019)

FIGURE 2A: AMPLITUDE FOR THE MMN ELICITED BY UNEXPECTED SILENCE AND EXPECTED SILENCE FOR EACH PARTICIPANT





P3a response is significantly different between the two conditions such that the unexpected silence elicits a more positive response (*p* = 0.042).

FIGURE 2B: AMPLITUDE FOR THE P3A ELICITED BY UNEXPECTED SILENCE AND EXPECTED SILENCE FOR EACH PARTICIPANT





- There is a significant MMN and P3a response elicited by the brain towards the unexpected silence
 - Supports the predictive coding framework
 - An unexpected silence elicits an MMN like an unexpected tone, but this response is not seen in the grand average ERP as expected perhaps due to the variability in the latency of the onsets of the responses





Auditory Development:

- Does an omission deviant elicit an MMN response in infants?
- Does the MMN response occur with certain cognitive impairments?

Research Methods:

- Is there a more powerful analytical tool to detect the MMN response for omission deviants?
- Is the same effect seen when looking at the oscillatory responses rather than the transient one?⁵

REFERENCES

- Trainor, L. J. (2012). Predictive information processing is a fundamental learning mechanism present in early development: Evidence from infants. *International Journal of Psychophysiology*, 83(2), 256–258. <u>https://doi.org/10.1016/j.ijpsycho.2011.12.008</u>
- Winkler, I. (2007). Interpreting the mismatch negativity (MMN). *Journal of Psychophysiology* - *J PSYCHOPHYSIOL*, 21, 147–163. <u>https://doi.org/10.1027/0269-8803.21.34.147</u>
- May, P. J. C., & Tiitinen, H. (2010). Mismatch negativity (MMN), the deviance-elicited auditory deflection, explained. *Psychophysiology*, 47(1), 66–122. <u>https://doi.org/10.1111/j.1469-8986.2009.00856.x</u>
- ^{4.} Yabe, H., Tervaniemi, M., Reinikainen, K., & Näätänen, R. (1997). Temporal window of integration revealed by MMN to sound omission. *NeuroReport*, 8(8), 1971–1974.
- 5. Chang, A., Bosnyak, D. J., & Trainor, L. J. (2018). Beta oscillatory power modulation reflects the predictability of pitch change. *Cortex*, 106, 248–260. <u>https://doi.org/10.1016/j.cortex.2018.06.008</u>



Determining the Underlying Mechanism of Adult Brain Responses to Omission Deviants



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INTRODUCTION METHODS Continued Mismatch Negativity (MMN) Response is an ERP elicited by the EEG Processing: continued

- brain toward an unexpected sound after a set of repetitive sounds1
- Response followed by a late response¹
- MMN robustly evident for pitch, melodic, and timing deviants¹
- · Two leading hypotheses for the mechanism of the MMN:
- Predictive Coding Deviant sound violates a prediction model set by brain for prior sounds eliciting a prediction error² Neural Adaptation - Repetitive sound patterns activate feature
- neurons that eventually habituate. Deviant sounds activate new feature neurons³

RESEARCH QUESTION

What is the underlying mechanism for the MMN Response: Predictive Coding or Neural Adaptation?

GOAL & HYPOTHESES

Goal: Determine whether an MMN response can be produced using an omission deviant in an oddball paradigm

Hypothesis:

- If an MMN response is found using an omission deviant, this would support the predictive coding framework
- If an MMN response is not found using an omission deviant. this would support the Neural Adaptation Hypothesis · An omission deviant should not activate any new feature neurons1

METHODS

- Segmented ERPs into 6 electrode regions
- MMN peak found between between 100-300 ms per participant
- P3a peak found between 250-400 ms per participant

Analysis:

CL

 3 x 3 x 2 Repeated Measures ANOVA was conducted for the MMN and late response for each condition (unexpected, expected, resting) and laterality (left, centre, right) .



Figure 1. Grand Average ERPs to Unexpected and Expected Silences for the 6 cortical regions (FL, FZ, FR, CL, CZ, CR) Shaded regions = 95% CI centered around the grand averages





Figure 2a: Amplitude for the MMN elicited by unexpected silence and expected silence for each participant

a) MMN response is significantly different between the two conditions such that the unexpected silence elicits a more negative response (p = 0.019).



Figure 2b: Amplitude for the P3a elicited by unexpected silence and expected silence for each participant

b) P3a response to the difference waveform were significantly more positive compared to the resting state condition (p = 0.042).

IMPLICATIONS

- There is a significant MMN and late response elicited by the brain towards the unexpected silence
- · This supports the predictive coding framework
- · The response to unexpected silence is similar to an unexpected sound
- Able to demonstrate an MMN response to omission deviants with an SOA larger than 200 ms
- · Unlike other papers, our study design compared an
- unexpected silence to an expected silence, whereas other papers compared different SOAs of omission deviants or an omission deviant to tones 4

LIMITATIONS

- The effect for an MMN response to omission deviants is largely variable. A more powerful analysis technique may be able to give a robust effect⁴
- The expected silence condition contained more silences than the unexpected condition. To make the conditions more comparable, the unexpected silence should contain 20% deviant and the expected silence should be every 5th tone (20%)

FUTURE DIRECTIONS

Auditory Development

Does an omission deviant elicit an MMN response in infants? Does the MMN response occur with certain cognitive impairments? **Research Methods:**

Is there a more powerful analytical tool to detect the MMN response for omission deviants?

Is the same effect seen when looking at the oscillatory responses rather than the transient one?5



Standard Tone (90%) Omission (10% Standard tones were C4 piano, Deviant was an omission of the

tone Expected Silence 1000 ms

Stimuli:

250 m

250 ms

Unexpected Silence

500 mr

Same C4 piano tone with a longer SOA creating an expected silence (500 ms after tone onset)

Procedure:

- Participants (n=27) were seated in a sound attenuated room and watched a silent movie with subtitles
- Presented 3 rounds of 3 blocks where the first 2 were counterbalanced between the expected and unexpected conditions, and the last was always resting state.

EEG Processina:

- 128 channel caps (11 channels removed for noise)
- · Filtered data between 1 and 8 Hz
- · Offline re-referenced to common average
- Noise above 75 microvolts removed via artifact blocking

REFERENCES