

Temporal Dynamics on Decoding Target Stimuli in Rapid Serial Visual Presentation using Magnetoencephalography

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Table of Contents

1 Introduction

2 Experiment and Methods

3 Results and Discussion

4 Conclusion and Acknowledgements

Table of Contents

1 Introduction

- Background
- Motivation
- This work

2 Experiment and Methods

3 Results and Discussion

4 Conclusion and Acknowledgements

Background

- Rapid serial visual presentation (RSVP) has been widely used in brain-computer interface (BCI) as a high efficient paradigm.
- RSVP uses odd-ball effect to detect target stimuli in rapid serial.
- RSVP-BCI has been applied in many areas such as data categorization, face recognition, speller and website evaluation.



Figure: Paradigm of RSVP

Motivation

- RSVP-BCI is largely rely on the accuracy of event-related response using single trial.
- The temporal dynamics of the discriminate power is still unclear.
- The underlying neural activity is still unclear.

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Motivation

- Investigate **discriminate power dynamic**.
- Investigate **neural activity**.

This work

- Perform RSVP experiment with MEG scanning and paired MRI imaging.
- Investigate the temporal dynamic of discriminate power using MVPA method under different frequency bands.
- Investigate the underlying neural activity using paired analysis of MEG and MRI.

Table of Contents

1 Introduction

2 Experiment and Methods

- Experiment Design
- MEG and MRI acquisition
- Cortical Neuronal Activation Estimation
- MEG Preprocessing
- MVPA

3 Results and Discussion

4 Conclusion and Acknowledgements

Experiment Design

- Recruited 10 college students (7 males and 3 females, aged 23.79 ± 3.6).
- Each participant perform 10 blocks, during a block, 100 street view pictures were shown in random order at 10Hz .
- The chance of target pictures (odd ball) was set to 4%.



Figure: Target picture



Figure: Non-target picture

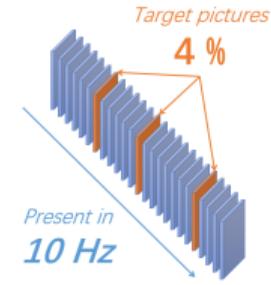


Figure: Time line

MEG and MRI acquisition

- MEG data were scanned with a whole-head CTF MEG system with 272 channels.
- MRI data were scanned with a $3.0T$ MRI scanner.
- The MRI Center of Institute of Biophysics, Chinese Academy of Sciences.

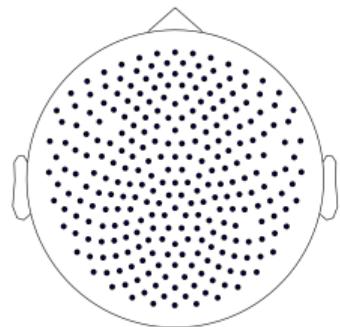


Figure: 272 MEG sensors

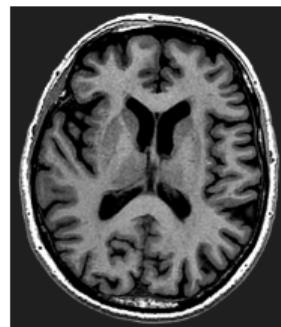


Figure: MRI image

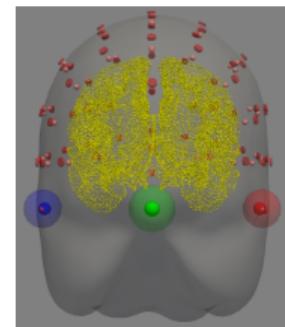


Figure: Alignment

Cortical Neuronal Activation Estimation

- The subject-specific cortical surfaces were build based on the MRI data using *freesurfer* software.
- A forward model was calculated to project the MEG data into cortical surfaces using the '*oct6*' space.

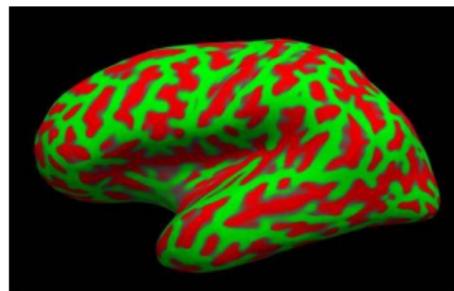


Figure: Surface

Table: *oct6* space

Spacing	Value
Sources per hemisphere	4098
Source spacing (mm)	4.9
Surface area per source (mm ²)	24.0

MEG Preprocessing

- The MEG data were preprocessed using *MNE* software.
- Suppressing artificial noise using ICA method. The artificial sources were zeroed out from raw data.
- The bands used in this research were Delta, Theta, Alpha bands, and two custom bands: U07 and U30 band.

Table: Filter bands

Filter Name	Freq band
Delta	1 – 4Hz
Theta	4 – 7Hz
Alpha	8 – 12Hz
U07	0.1 – 7Hz
U30	0.1 – 30Hz

MVPA

- Feature extraction was applied to training data, using xDAWN algorithm. Number of components was set as 6.
- Support Vector Machine (SVM) with RBF kernel was used as classifier.
- The MVPA was applied in a 10-fold cross-validation protocol. In each folder, we use one run as testing data and others as training data.

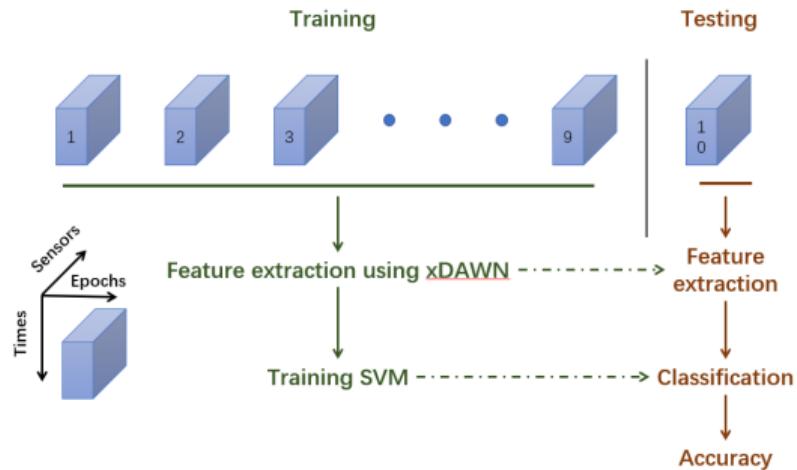


Figure: Cross validation process

Table of Contents

1 Introduction

2 Experiment and Methods

3 Results and Discussion

- MEG Signal Visualization
- Cortical Neuronal Activation
- Cortical Neuronal Activation
- MVPA Scores
- MVPA Scores

4 Conclusion and Acknowledgements

MEG Signal Visualization

We plot the evoked response of target pictures:

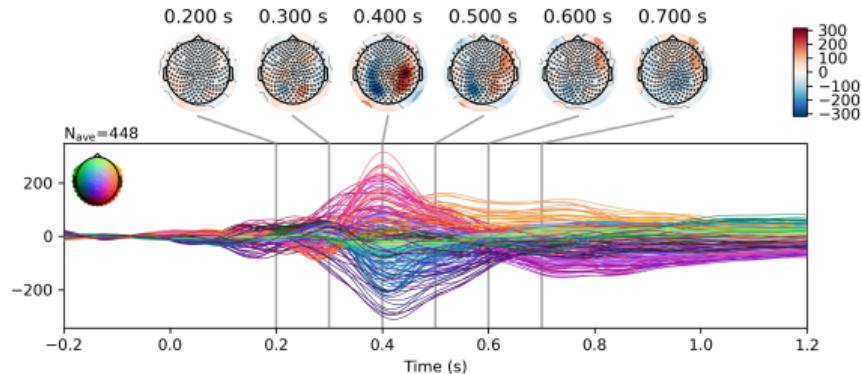


Figure: Evoked of U07 band

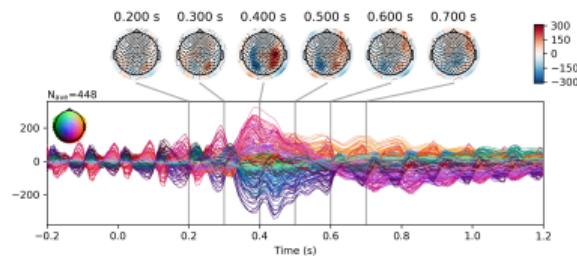


Figure: Evoked of U30 band

Cortical Neuronal Activation

The activity in surfaces:

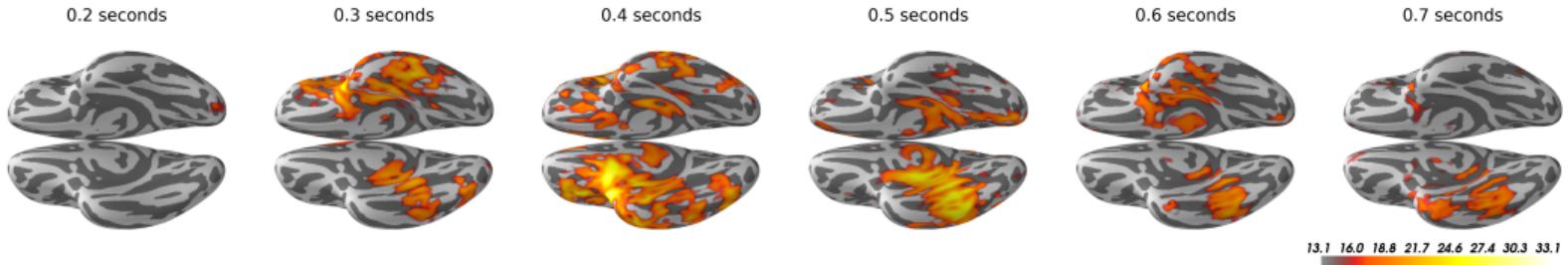
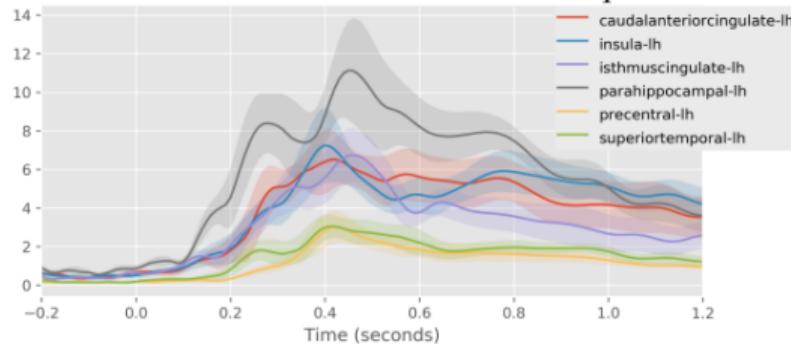


Figure: Activity in surfaces

Cortical Neuronal Activation

The activity in surfaces:

a) Neural activation time series in left hemisphere



b) Neural activation time series in right hemisphere

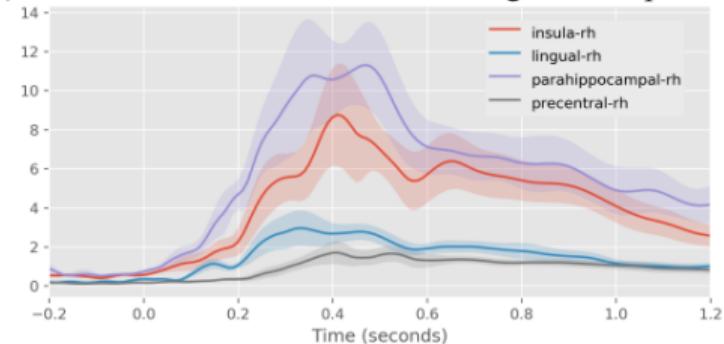


Figure: Activity in surfaces

MVPA Scores

We use following scores to measure the discriminating power:

Table: MVPA Scores

Name	Meaning	Higher means
Recall	$\frac{TP}{TP+FN}$	More target being selected
Precision	$\frac{TP}{TP+FP}$	Less non-target being selected
f1	$\frac{2 \cdot P \cdot R}{P+R}$	Better target selection
Accuracy	$\frac{TP+FP}{TP+TN+FP+FN}$	Higher overall accuracy

MVPA Scores

The band of *U07* yields highest classification scores:

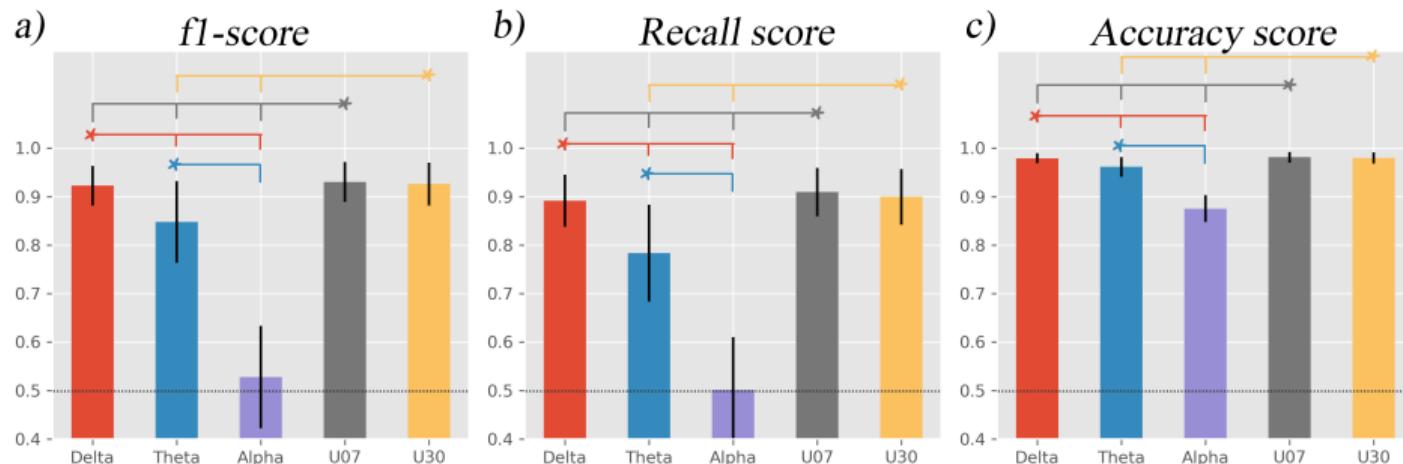


Figure: Scores across different bands

MVPA Scores

The sources in temporal resolution:

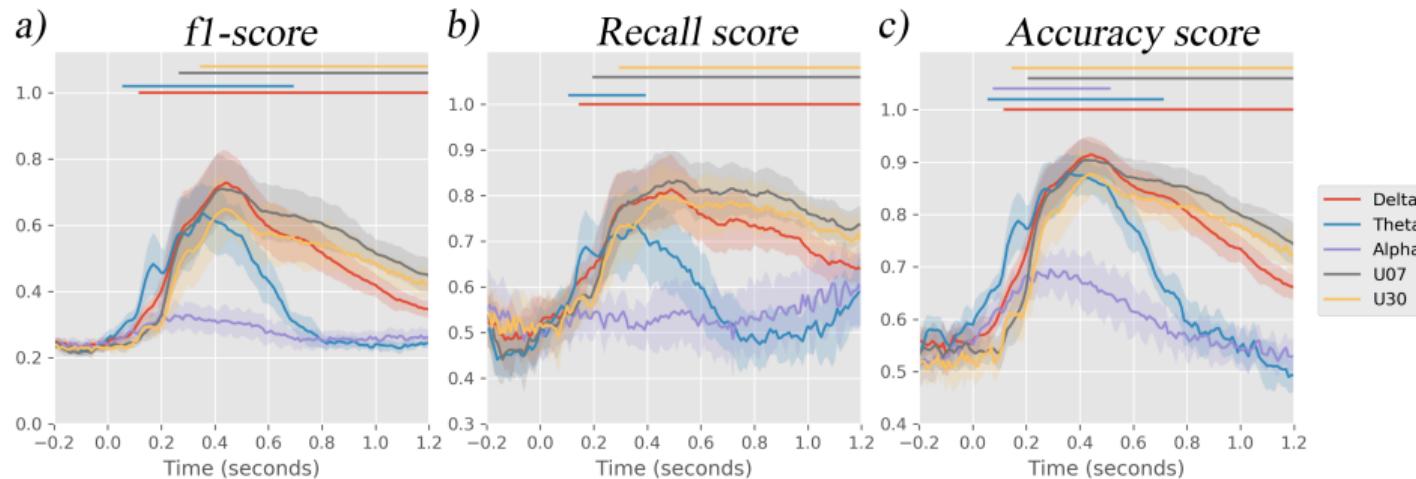


Figure: Scores in temporal resolution

Table of Contents

1 Introduction

2 Experiment and Methods

3 Results and Discussion

4 Conclusion and Acknowledgements

- Conclusion
- Acknowledgements

Conclusion

- The temporal dynamic of RSVP target response was investigated using MEG signal with different frequency bands.
- The MVPA results showed that the *U07* band signals (0.1 – 7Hz) yielded highest decoding accuracy, and further uncover the decoding power dynamic reached its peak at around 0.4 second after target stimuli onset.
- The cortical neuronal activation identified the regions activated by target pictures, like *bilateral parahippocampal cortex*, *precentral gyrus* and *insula cortex*.

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