Decoding The Performance of a Memory Task Using Single-trial Intracranial EEG

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INTRODUCTION

- Distinct brain activity patterns are shown when successfully remembering and forgetting a specific item in a memory task, respectively.
- The memory task is divided into an encoding session to memorize presented items and a retrieval session to retrieve memorized items.
- Most of previous studies attempted to decode the performance of the memory task using brain activity measured in the retrieval session, but which cannot predict whether the memory task will succeed or fail in advance.
- Decoding the performance of the memory task before or during the encoding session can not only predict whether the memory task will succeed or fail in advance, but also help to reveal neural mechanisms of encoding the memory task.
- In this study, we investigated the possibility of decoding the performance of the memory task using intracranial electroencephalography (iEEG) data measured around the hippocampus, known to be associated with memory task during and before encoding session.

METHOD

Dataset

- The iEEG data were collected from the two patients using macro electrodes (Neuralynx, USA) implanted in the right or left hippocampus during the memory task. The numbers of electrodes were twenty for both patients.
- Figure 1 shows the schema of the experimental paradigm used in this study, which consisted of encoding, distractor, and retrieval session.
- The memory task consists of encoding, distractor, and retrieval session.
- In the encoding session, each of 120-words items was presented to the patients and they were asked to memorize them as many as possible.
- In the distractor session, the patients took a break for 10 min during which they were asked to solve a simple math task for at least 5 min.
- In the retrieval session, the patients were asked to retrieve the 120 words, where new 60 words were also presented along with the 120 words.
- The patients were asked to press the three buttons depending on their memory whether the words had been presented before (“old”; button 1), not presented before (“new”; button 2), or not sure presented before (“no idea”; button 3).

Data Analysis

- The iEEG data measured during the encoding session were band-reject filtered between 59.5 to 60.5Hz and band-pass filtered between 0.5 to 50.5 Hz.
- The filtered iEEG data were segmented -1 to 4 s based on onset time of presenting each word. After then, to decode correctly and incorrectly encoded items during a pre-task (-0.5 – 0 s) and task period (0 – 4 s) in the encoding session, respectively.
- we took advantage of the task results of the retrieval session as class labels. We assigned the correctly remembered trials as “correct”, while others (forgotten and no idea) were assigned as “incorrect”.
- We extracted power spectral densities (PSDs) using continuous wavelet transform (CWT) from five frequency bands: delta (δ: 1 – 4 Hz), theta (θ: 4 – 8 Hz), alpha (α: 8 – 13 Hz), beta (β: 13 – 30 Hz), and gamma (γ: 30 – 50 Hz). The PSDs were normalized using the Z-score of the baseline power (-1 – -0.8 s) and used as decoding features.
- The decoding accuracy was evaluated using a naïve Bayes classifier based on 10x5-fold cross-validation, where Fisher score was used to select the best subset of features to avoid an overfitting problem.

RESULT

- Figure 2 shows the event-related spectral perturbation (ERSP) maps of the two patients during the encoding session, which were obtained by averaging all channels and trials for correctly and incorrectly encoded items, respectively.
- The two conditions showed different ERSP patterns; correct items showed stronger ERS around beta band in common for the two patients (magenta rectangle in the third column) along with their unique patterns.

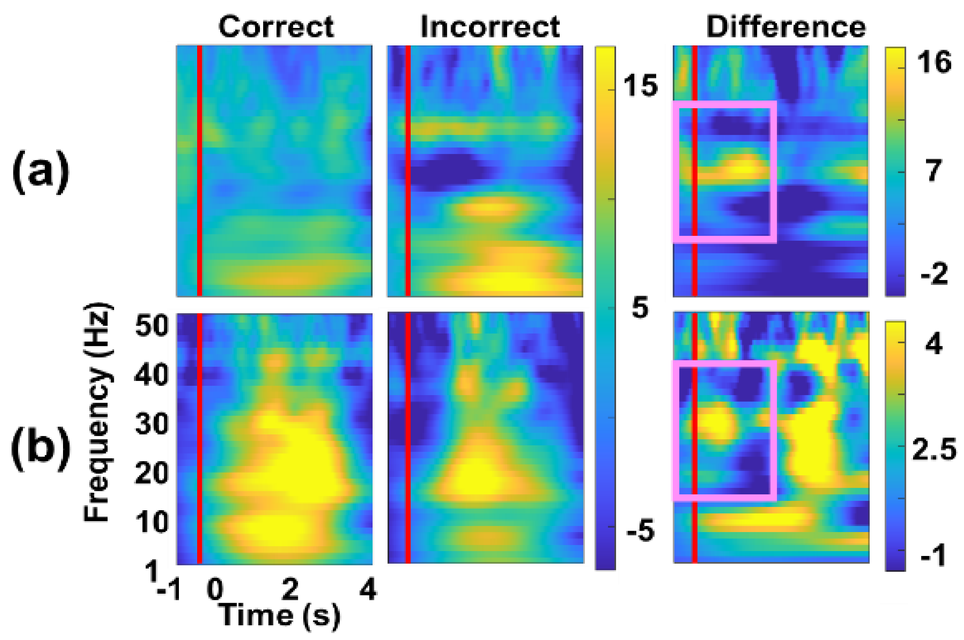

Figure.2 Event-related spectral perturbation (ERSP) maps of (a) Patients 1 and (b) Patients 2 during the encoding session. The red line indicates when the item was presented (onset time)

- Figure 3 shows the decoding accuracy for each patient. The highest decoding accuracies of the pre-task and task periods were obtained when using delta spectral powers for both patients (Patient 1: 67.5 % and Patient 2: 78.8% for the task period; Patient 1: 74.8 % and Patient 2: 73.2% for the pre-task period).
- This result demonstrated that the results of the memory task can be successfully decoded before and during the encoding session using brain activity.

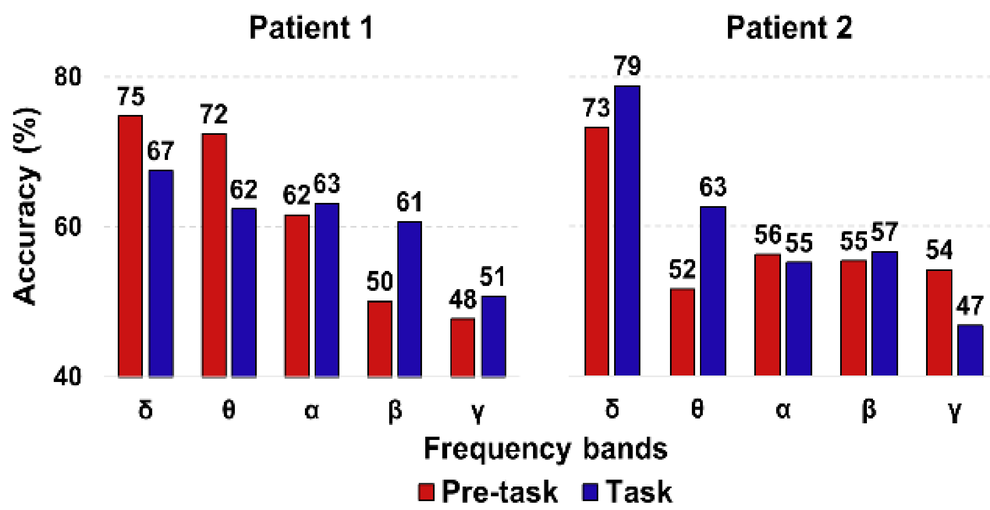

Figure.3 Decoding accuracy for each patient

CONCLUSION

- **The highest decoding accuracies of the pre-task and task periods were obtained when using delta spectral powers for both patients (Patient 1: 67.5 % and Patient 2: 78.8% for the task period; Patient 1: 74.8 % and Patient 2: 73.2% for the pre-task period).**
- In our future studies, we plan to improve the decoding performance by introducing more advanced classification algorithms based on deep learning architectures.

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