



Alpha-band Modulation Depending on the Nature of Verbal Communication

Successful Detection Using OPM-MEG

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Abstract: This study investigates the feasibility of magnetoencephalography (MEG) hyperscanning with optically pumped magnetometers (OPM). Brain activities during communication showed differences in alpha-band normalized amplitudes between the Natural and Patterned conditions, supporting OPM-MEG's potential to detect subtle neural activity changes, comparable to traditional MEG.

Keywords: optical pumped magnetometer, hyperscanning, verbal communication

Introduction

Background: To understand the neural basis of communication, two-person neuroscience (2PN) experimental designs are crucial, as communication is inherently an interactive process rather than a solo activity. The experimental setup for conducting 2PN is called hyperscanning. Among the available techniques for hyperscanning, optically pumped magnetometer magnetoencephalography (OPM-MEG) is a neuroimaging method that measures brain magnetic fields by detecting changes in light absorption resulting from the excitation of alkali metal atoms. Compared to conventional systems, OPM-MEG enables sensor placement in closer proximity to the scalp and offers lower operational costs because it does not require liquid helium.

Importance: Hyperscanning measurements using OPM-MEG have recently become feasible [1]. In the present study, we had the opportunity to conduct measurements with one of the largest OPM-MEG systems in Japan, equipped with 48 OPM-MEG sensors. We aimed to implement a practical verbal communication task and to examine whether comparisons between different conditions are possible. If it becomes feasible to detect subtle changes in brain activity associated with minimal differences in the nature of verbal communication, OPM-MEG has the potential to make significant contributions to the advancement of 2PN.

Previous studies: In superconducting quantum interference device (SQUID) MEG hyperscanning studies conducted to date, turn-taking speech tasks are frequently employed. Anada et al. [2] demonstrated that during alternating associative production of words (Natural condition), widespread desynchronization in the normalized amplitude of alpha-band activities occurred compared to sequential utterance of Japanese syllables (Patterned condition). Watanabe et al. [1] have already obtained results suggesting that, at the sensor level, the findings of Anada's Natural condition can be replicated using OPM-SQUID MEG hyperscanning.

Goals: This study aims to establish an OPM-SQUID MEG hyperscanning setup and, in particular, to replicate the differences between the Natural and Patterned conditions observed in previous studies [2] using OPM-MEG sensors. Since the study is still at an exploratory stage, we relied on descriptive analyses and visual inspection without conducting formal statistical testing.

Methods

Twelve pairs (24 participants; 10 males, 14 females, mean age 21.6 ± 2.6 years) participated in this study. The experimental protocol involving human subjects was approved by the Ethics Committees of the Faculty of Health Sciences (25-8), Hokkaido University. Written informed consent was obtained from each participant prior to the experiment. Participants' brain activity was measured using either a 48-channel OPM-MEG system (HEDscan, FieldLine) or a 306-channel SQUID-MEG system (Vectorview, Elekta Neuromag). This paper reports only the OPM-MEG data from the five cases (all females, 21 ± 1.9 years). Two experimental conditions were used: Natural and Patterned. In the Natural condition, participants took turns producing semantically related words every 5 seconds in response to a prompt displayed over their partner's video image. For example, starting from the prompt "banana," one participant responds with "yellow," followed by the other participant saying "sunflower." In the Patterned condition, the prompt displayed a Japanese alphabet (ひらがな) segment, and participants sequentially uttered three or more syllables in order. Each block comprised 16 trials, resulting in 32 trials for both the Natural and Patterned conditions. Noisy sensors were excluded from the 48 OPM-MEG sensors, and the data were bandpass filtered

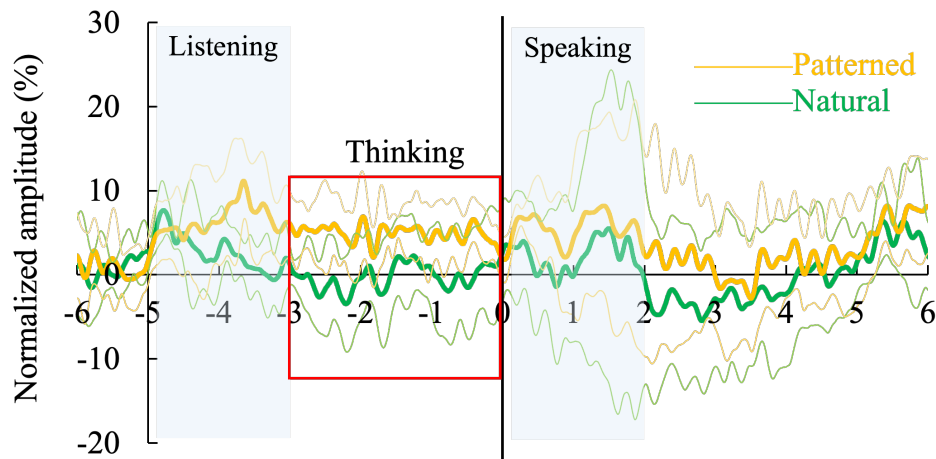


Figure 1. Time course of normalized alpha-band activity for the Patterned (orange) and Natural (green) conditions, averaged across 48 OPM-MEG sensors. Upper and lower lines around each trace represent the 95% confidence intervals. After listening to the partner's speech (Listening) and before self-speaking (Speaking), during the period of thinking of an associate word (Thinking, red square), alpha ERD is observed in the Natural condition, whereas alpha ERS occurs in the Patterned condition.

between 1–40 Hz. The Hilbert transform was then applied to obtain the envelope of the 8–12 Hz band. Using the 1-second period preceding the prompt presentation as a baseline, event-related synchronization/desynchronization (ERS/D) was calculated to derive the normalized amplitude of alpha-band activity. The mean normalized alpha amplitude value during the Thinking period (defined as the 3 seconds preceding the participant's own speech) was calculated.

Result

The grand average is shown [Figure 1]. The normalized alpha amplitude during the Thinking period in the Natural condition was $-0.2 \pm 5.3\%$ (mean \pm SD). In contrast, the normalized alpha amplitude during the Thinking period in the Patterned condition was $4.9 \pm 2.5\%$. Visual inspection revealed an overall ERS in the Patterned condition.

Discussion

The increase in alpha-band activity suggests a reduction in neural activity, so it is reasonable that alpha-band synchronization occurs in the Patterned condition, which was relatively predictable. This result is also strongly consistent with previous research [2]. Therefore, OPM-MEG, at least in terms of sensor-based analysis, can detect subtle differences in brain activity during language communication, comparable to SQUID-MEG.

Conclusions

The arrangement of the 48 OPM-MEG sensors enabled sufficient coverage, allowing subtle differences in neural activity related to verbal communication to be assessed. It is expected that further development of 2PN will occur by conducting source estimation using OPM-MEG in the future.

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