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Beta-band Modulation in the Precuneus in AI Communication

Effects of Violated Humanness Expectations: A Magnetoencephalographic Study

Yamato KOBAYASHI [1], Hayato WATANABE [2,3], Atsushi SHIMOJO [3], Yuki UEDA [4], Noriki OCHI [5], and Koichi YOKOSAWA [3]

1. *Graduate School of Health Sciences, Hokkaido University, Hokkaido, Japan.* ***2.*** *Graduate School of Medicine, Hokkaido University, Hokkaido, Japan.* ***3.*** *Faculty of Health Sciences, Hokkaido University, Hokkaido, Japan.* ***4.*** *Department of Pediatrics, Hokkaido University Hospital, Hokkaido, Japan.* ***5.*** *Division of Laboratory and Transfusion Medicine, Hokkaido University Hospital, Hokkaido, Japan*

E-mail: *Kobayashi.yamato.z3@elms.hokudai.ac.jp*

Abstract: Is communicating with AI the same as communicating with humans? To find out, magnetoencephalograms were recorded during communication with a human or AI. The difference was shown in the precuneus; beta-band amplitudes were suppressed only when participants were instructed that the partner were human, but the actual partner were AI.

Keywords: Magnetoencephalography, Artificial Intelligence, Communication

Introduction

Recent advances in generative artificial intelligence (AI) have enabled natural dialogue, although such interactions still differ from those with human partners. Brain activity is also known to change when individuals believe they are conversing with a non-human dialogue partner [1] (Rauchbauer, et al., 2019). Therefore, we evaluated brain activities during verbal communication using both instruction (AI/human) and actual partner (AI/human) as factors. Magnetoencephalography (MEG) was adopted, as communication is inherently a dynamic process. We focused on activity in the bilateral precuneus, a region involved in self-referential processing and sensitive to social context [2] (Cavanna & Trimble, 2006).

Methods

Nine healthy, right-handed adults (8 males, 1 female; age = 20.7 ± 1.1 years, mean ± SD) participated. All procedures were approved by the Ethics Committee of the Faculty of Health Sciences, Hokkaido University (No. 24-37), and written informed consents were obtained from all participants. Participant's brain activities were measured using 306-channel planar gradiometer MEG system (VectorView, Elekta Neuromag). Participants performed a turn-taking word association task with either a human or an AI partner. In the human partner condition, one of four male experimenters (aged 21–40) acted as the partner and generated an associated word in response to each participant's word. In the AI partner condition, the participant's speech was transcribed and entered the AI (Chat GPT-4.0 mini or 4.1 mini, Open AI) by the experimenter, the AI-generated associated words in response to the participant's spoken input. In both conditions, the partner's associated words were delivered via a synthetic male voice using Amazon Polly (Amazon Web Service, Amazon) text-to-speech. Each block consisted of seven trials (Fig.1). Prior to each block, participants were instructed whether the upcoming partner would be a human or an AI. However, in some blocks, this instruction did not match the actual partner, resulting in four conditions: Instruction–Actual

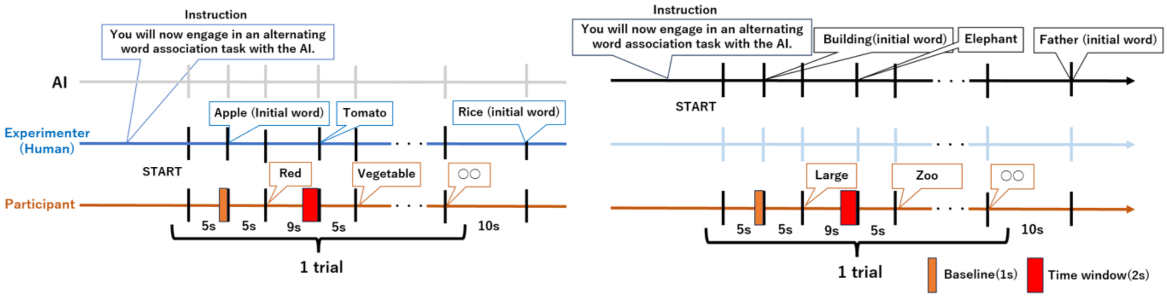

Figure 1: Schematic time sequence of one trial. Left: The participant was instructed that the dialogue partner would be an AI, but the actual partner was a human experimenter (AI-H condition). Right: The participant was instructed that the dialogue partner would be an AI, and the actual partner was also an AI (AI-AI condition).

partner; AI–AI, AI–H (human), H–AI, and H–H. Each trial began with an initial word provided by the experimenter. In each trial, participants spoke eight words. In total, each participant spoke 112 words per condition. MEG data were analyzed for two seconds before partner's speech cue, during which the participant was waiting for partner's next response.

Data analysis was performed with Brainstorm [3] (Tadel et al. 2011), which is documented and freely available for download online under the GNU general public license (http://neuroimage.usc.edu/brainstorm). MEG data were filtered with 1–40 Hz band-pass, and noisy segment was removed. Sources of brain activities were estimated using minimum norm estimation (MNE) with 15,002 vertices on the cortex of the template brain (unconstrained). The noise covariance matrix was calculated using a 300 second window of MEG data recorded in an empty room. The Hilbert transform was applied to extract amplitude of theta (5−7Hz), alpha (8−12Hz), and beta-band (15−29Hz) rhythms. Event-related synchronization/desynchronization (ERS/D) was calculated for amplitude normalization, with the baseline defined as the mean amplitude within one-second preceding the presentation of the initial word. Mean ERS/D values during the time window of two seconds prior to partner speech were averaged across the vertices in the left and right precuneus, respectively. A three-way repeated measures analysis of valiance (3-way RM ANOVA) was carried out for the normalized amplitude: Instruction (AI/human) × Actual Partner (AI/human) × Hemisphere (left/right).

Results

A significant result was observed only in the beta-band rhythm (15–29 Hz). A 3-way RM ANOVA revealed a significant interaction between Instruction and Actual Partner on the normalized amplitude of beta-band rhythm ($F(1, 8) = 6.389$, $p = 0.035$). However, neither the simple main effect of Instruction nor that of Actual Partner was statistically significant (all $ps > .05$). Notably, descriptive statistics indicated that the Human-Instruction/AI-Actual Partner condition showed a lower normalized amplitude of beta rhythm (1.599 %) compared to the other conditions (mean 3.320%, see figure 2.)

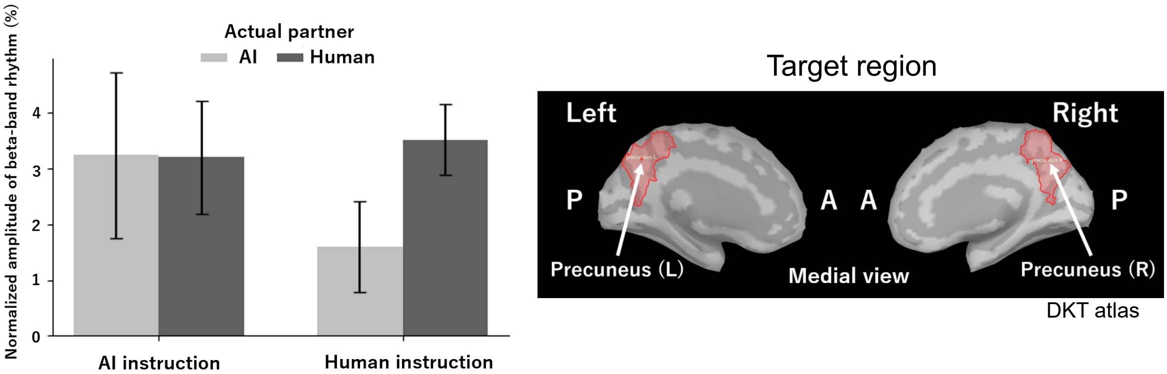

Figure 2: Interaction between Instruction and Actual Partner based on mean beta-band rhythm in the precuneus region. In the Human Instruction condition, the AI as the Actual Partner led to a lower normalized amplitude of beta-band rhythm.

Discussion

In the bilateral precuneus, beta-band amplitude was suppressed only when participants expected a human partner but interacted with an AI. No such suppression was observed when both the expectation and the actual partner were AI. It is plausible for AI to give human-like responses, but unlikely for human to respond like AI. If this asymmetry explains the present results, the precuneus may be involved in expectation, particularly in relation to humanness.

Conclusions

Communication with AI is thought to be still not the same as that with humans. The differences should be caused by both expected identity and the real identity of actual dialogue partner. Neuroimaging will be useful methods to reveal the mechanism.

Acknowledgements

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