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Research paper

Sensorimotor activation related to speaker vs. listener role during natural conversation

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HIGHLIGHTS

- Simultaneous MEG recordings from two persons during live interaction.
- Left-lateralized involvement of sensorimotor cortex during natural conversation.
- Phasic modulation of sensorimotor rhythm indexing preparation to own speaking turn.

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ABSTRACT

Although the main function of speech is communication, the brain bases of speaking and listening are typically studied in single subjects, leaving unsettled how brain function supports interactive vocal exchange. Here we used whole-scalp magnetoencephalography (MEG) to monitor modulation of sensorimotor brain rhythms related to the speaker vs. listener roles during natural conversation.

Nine dyads of healthy adults were recruited. The partners of a dyad were engaged in live conversations via an audio link while their brain activity was measured simultaneously in two separate MEG laboratories.

The levels of ~10-Hz and ~20-Hz rolandic oscillations depended on the speaker vs. listener role. In the left rolandic cortex, these oscillations were consistently (by ~20%) weaker during speaking than listening. At the turn changes in conversation, the level of the ~10 Hz oscillations enhanced transiently around 1.0 or 2.3 s before the end of the partner's turn.

Our findings indicate left-hemisphere-dominant involvement of the sensorimotor cortex during own speech in natural conversation. The ~10-Hz modulations could be related to preparation for starting one's own turn, already before the partner's turn has finished.

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1. Introduction

Although speech is an interpersonal communication tool, the brain basis of speech production and perception is typically studied in single isolated subjects, and often even with isolated speech segments, such as phonemes, syllables, and words. The main reasons for this experimental bias are certainly methodological as it is more complicated to study brain processes during connected speech, and even more complicated during natural conversation where the same experimental condition cannot be repeated to improve the signal-to-noise ratio of the measured brain activity.

Still, the interaction likely affects the brain activity that we observe in relation to both speaking and listening. In other words, dissecting a part of the interaction mechanism and studying it in isolation, out of the context, may hinder unraveling the brain basis of smooth conversational interaction.

According to Garrod and Pickering [1], dialog is the most natural form of language use because everyone who understands language and is able to speak is able to hold a dialog. In contrast, a monolog is considered to require learning. During conversation, people mutually adjust their linguistic style [2], as well as the speech rhythms and movements of head, trunk, and hands [3]. Such an alignment occurs even when the length of the verbal exchanges is only one word at a time [4].

This strong alignment between conversation partners is also reflected in turn-takings that across different languages typically

Abbreviations: MEG, magnetoencephalography; TFR, time–frequency representation.

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occur within ±250 ms with respect to the end of the previous speaker's turn [5]. This gap is likely too short to allow the partner to react to the end of the speech and start his/her own turn, meaning that the conversation partners have to be aligned at several perceptual and cognitive levels to predict the end of the partners' speech.

We were interested in finding out how cortical brain rhythms are modulated while two people are engaged in a free conversation. Previous studies have shown that the sensorimotor mu rhythm, comprising ∼10- and ∼20-Hz frequency components [6,7], is dampened before and during brisk movements. The mu rhythm is modulated by articulatory movements as well, but bilaterally in contrast to the contralaterally dominant modulations associated with hand and leg movements [8], in agreement with the bilateral innervation of the lower face. However, the results on speech-related brain-response lateralization are still quite scattered, and they may depend on the kind of "speech" used in each experiment: segments of speech (such as isolated words), connected speech [9], or real conversation with alternating speaker and listener roles.

In the present study we used a new experimental setup, recently developed in our laboratory [10,11], to measure MEG signals simultaneously from two participants engaged in a dialog. We then quantified how the speaker vs. listener role during natural conversation affects the dynamics of the sensorimotor oscillations.

2. Methods

2.1. Participants

Eighteen healthy volunteers (mean ± SEM age 27.6 ± 2.1, range 21–49; 6 female, 12 male; all right-handed: Edinburgh Handedness Inventory mean 92.6, range 71–100) participated in the experiment. The subjects were arranged into pairs (two mixed-gender pairs, two female pairs, and five male pairs); four pairs knew each other before the experiment. The study had a prior approval by the Ethics Committee of Helsinki and Uusimaa Hospital District. All subjects gave written consent before participation.

2.2. Task

Each pair had an about 7-min conversation on a given topic (4 pairs about hobbies, 5 pairs about holiday activities); no other instructions were given about the nature of the conversation.

2.3. Data collection

The MEG recordings were conducted simultaneously at the Brain Research Unit of Aalto University and at the BioMag Laboratory of the Helsinki University Hospital; these laboratories are located 5 km apart. We used a custom-made dual-MEG setup with an audio link based on Internet; the system enables recording of brain and behavioral data at the same time from two measurement sites with one-way audio delay of 50 ± 2 ms [11]. MEG was recorded at both sites with similar 306-channel neuromagnetometers (Elekta Oy, Helsinki, Finland; Elekta Neuromag at Brain Research Unit and Neuromag Vectorview at BioMag Laboratory). The subjects were engaged in conversation via the audio link, using headphones and microphones.

The 306-channel neuromagnetometer comprises 102 pairs of orthogonal planar gradiometers and 102 magnetometers. The MEG data were bandpass-filtered to 0.1–300 Hz and digitized at 1000 Hz.

2.4. Analysis

2.4.1. Audio recordings

We monitored both subjects' speech by recording the audio signals (sampled at 48 kHz) and bandpass-filtered them to 300–3400 Hz. We then computed the envelopes (absolute values of the Hilbert transforms of the signals), lowpass-filtered them at 400 Hz to avoid aliasing, and downsampled them to MEG's sam-

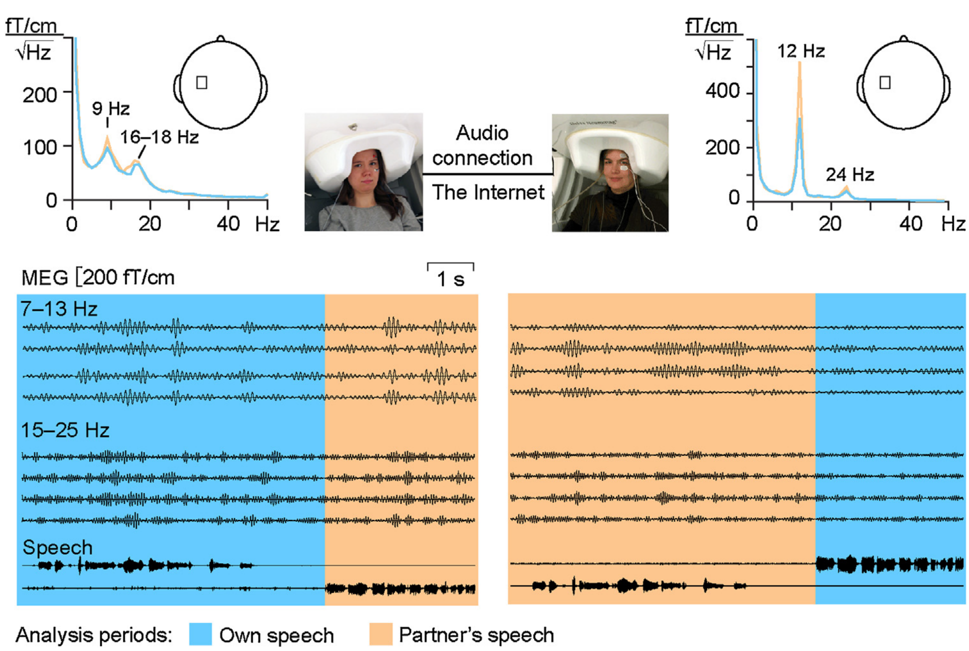

Fig. 1. Dual-MEG setup for measuring brain activity simultaneously from two subjects engaged in a conversation via an Internet-based audio connection. Above: Amplitude spectra from one MEG planar gradiometer channel over the left rolandic cortex; *blue lines* show the activity during participant's own speech and *orange lines* during partner's speech. Below: MEG data from 4 planar gradiometer channels over left rolandic cortex filtered to 7–13 and 15–25 Hz, respectively. Two lowermost traces show the speech waveforms of the participant in question (*above*), and the speech of the partner (*below*). (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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