Temporal perspective-taking in discourse comprehension: Asymmetry between past and future revealed by EEG effective connectivity

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This study investigated the neural substrates of temporal perspective-taking in discourse comprehension by analyzing scalp EEG responses to visually presented two-sentence discourses. In the stimuli, the event time was manipulated in the first sentence to be in the past, present, or future (e.g., last Sunday, today, next Sunday). In the initial phrase of the second sentence, the event day was referred to by Japanese indexicals: the proximal *kono-hi* (this day) or the distal *sono-hi* (that day). Because verbal communication typically occurs in the here and now, the proximal *kono-hi* canonically refers to the present (today). Thus, when *kono-hi* refers to the past or future, a psychological shift in temporal perspective toward the past or future is expected.

Behavioral results showed that indexical expressions referring to the past were judged significantly less acceptable than those referring to the future. Furthermore, *kono-hi* referring to the past and future was judged less acceptable than *sono-hi* in the same conditions, indicating that temporal perspective-taking toward the past and future is associated with increased cognitive load. In contrast, for references to today, *sono-hi* was less acceptable than *kono-hi*, suggesting that adopting a distal perspective toward the present is costly.

Scalp EEG data were analyzed time-locked to the onset of the indexical expression. A significant theta-band suppression (600–750 ms) was observed for *kono-hi* referring to the past and future relative to references to today (Fig. 1A), and a significant gamma-band enhancement (550–750 ms) in the left frontal region was observed selectively for *kono-hi* referring to the past relative to references to today and the future (Fig. 1B). The theta suppression may reflect temporal perspective-taking toward the past or future, whereas the gamma enhancement specific to the past suggests a distinct neural process underlying shifts between present and past [1]. This finding further implies that perspective shifts to the past and future rely on different neural mechanisms at least in part. For references to today, a significant alpha-band suppression (400–550 ms) was observed for *sono-hi* relative to *kono-hi* (Fig. 1C), which may reflect attentional control demands for possible anomaly.

To examine effective connectivity in the brain, scalp EEG data were projected to the source level, and partial directed coherence (PDC) was computed among 19 regions of interest (ROIs) identified in previous fMRI studies on temporal self-projection and linguistic time perception [2, 3]. We evaluated the effect of perspective-shift as PDC difference between the proximal references to the past or future and those to the present. No notable contrast in PDC difference was observed between the past and future conditions in the theta band (Fig. 2A, B), but a prominent contrast was observed between them in the gamma band (30–50 Hz) in the 400–500 ms time window (Fig. 2C, D). In this window, right temporal regions (BA 22, 40, 42) functioned as prominent receiver nodes for increased information flow in the connectivity for *kono-hi* referring to the future (Fig. 2D). Regarding the PDC difference in the reference to today, significantly reduced information flow was widely observed in the 300–400 ms time window for *sono-hi* relative to *kono-hi* (Fig. 2E).

According to fMRI studies, temporal self-projection is often assumed to be symmetric between the past and future, but our results reveal frequency-specific neural dynamics that differ between them. Furthermore, right temporal regions may play a critical role in successful perspective-taking toward the future.

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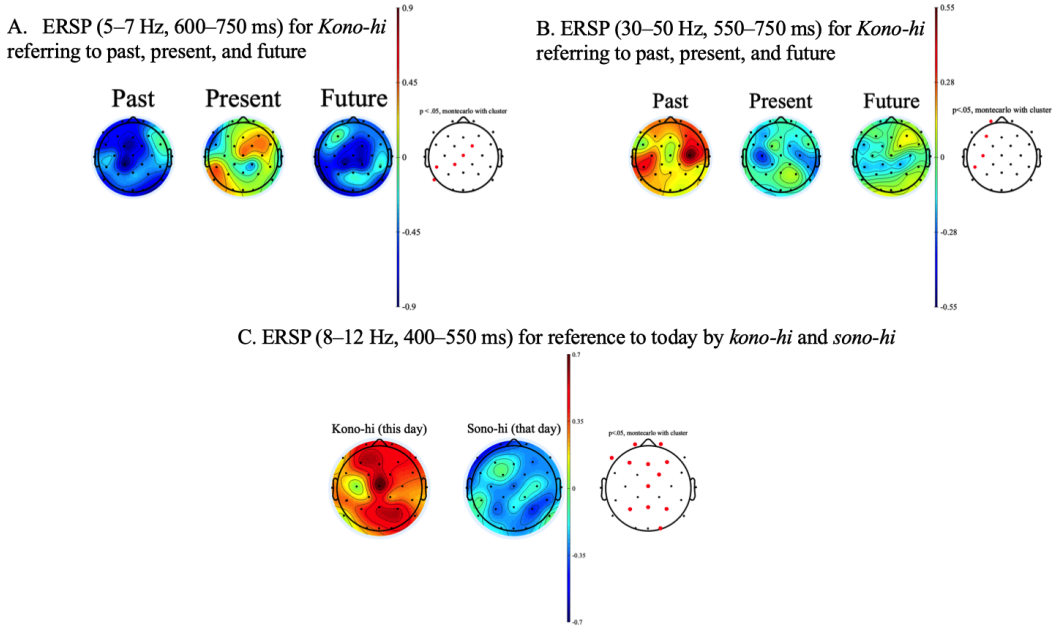

Figure 1: (A, B) Scalp ERSP for *kono-hi* (past, present, future) in the theta and gamma bands. (C) Scalp ERSP for present reference (*today*): *kono-hi* vs. *sono-hi* in the alpha band.

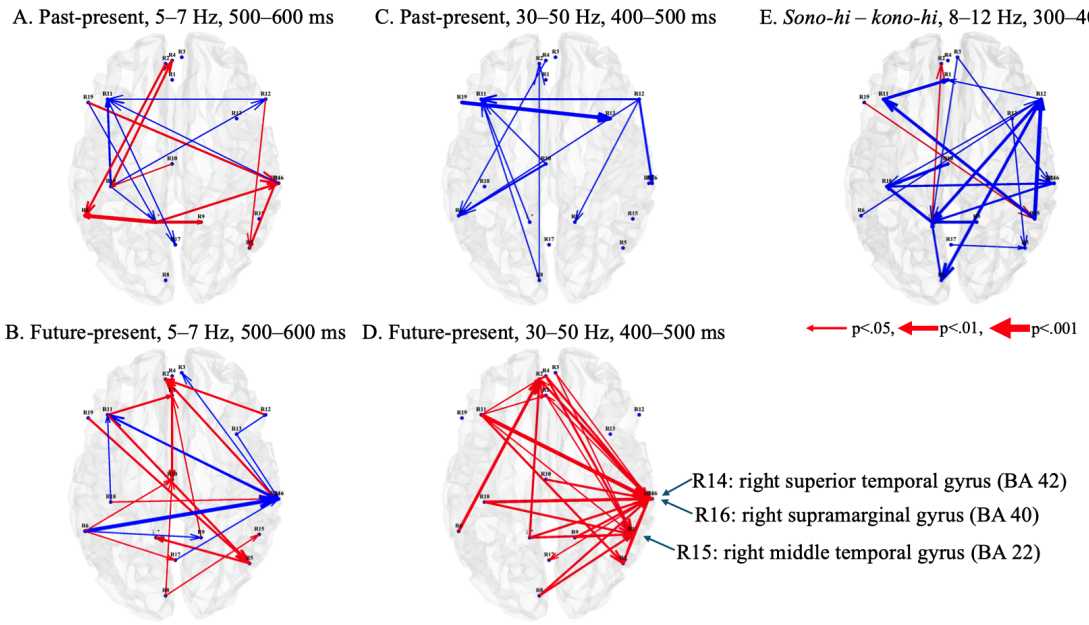

Figure 2: Significant PDC differences among 19 ROIs for *kono-hi* (past/future vs. present; A–D) and present reference (*sono-hi* vs. *kono-hi*; E). Red and blue arrows indicate increased and decreased information flow, respectively.

Example discourse

First sentence:
{先週の日曜/今日/来週の日曜}は 父の誕生日 {だった/だ/だ}.

{Last Sunday/Today/Next Sunday}-top father's birthday {was/is/is}.

'{Last Sunday/Today/Next Sunday} {was/is/is} my father's birthday.'

Second sentence:

{この日/その日}を、母はすっかり忘れて{いた/いる/いる}. (EEG recorded at underlined part)

{This day/That day}-acc mother completely forget about {was/is/is}.
'My mother {had/has/has} completely forgot about {this day/that day}.'