



How the Brain Processes Unspoken Words

An MEG Study of Japanese Empty Nouns

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Abstract: This MEG study examined the neural processing of Japanese ENs. A spatio-temporal cluster-based permutation *t*-test revealed significant activation from 720–762 ms in RSTS, RMTG, RITG/S, and RIL, indicating the brain distinguishes different types of ENs.

Keywords: Neurolinguistics, Magnetoencephalography, Empty Noun, Japanese

Introduction

Linguistic theory has proposed the existence of empty nouns (ENs)—unpronounced elements with distinct syntactic properties [1]. Their lack of phonological form makes them ideal probes into the computational mechanisms of language and the interface between syntax and other components. Behavioral studies have shown that ENs are processed during real-time comprehension [2], and distinct processing patterns across EN types have been reported [3]. In our previous work [4], we demonstrated that ENs in Japanese are behaviorally distinguishable. However, their neural basis remains unclear. This study uses MEG to examine how different EN types are computed during sentence comprehension.

Methods

We recruited 26 right-handed native Japanese speakers (13 male; mean age = 21.46, SD = 1.52), all with normal vision and no history of neurological or psychiatric disorders. Written informed consent was obtained. Three types of sentence stimuli were used (see (1)); regions were separated by vertical lines. Capitalized elements (e.g., NAKAMURA) were theoretical labels and not shown to participants. Conditions (1a) and (1b) included different types of ENs within subordinate clauses; (1c) contained no EN. In (1a), the EN shares lexical content with the matrix subject but is unpronounced; in (1b), it functions like a pronoun. All three conditions had identical lexical content in regions 1–5, with the EN type determined by the verb in region 6 [5]. Each condition included 30 targets and 90 fillers. Stimulus durations (500–1000 ms) were based on prior reading data [4]. After each sentence, participants performed a probe recognition task (e.g., identifying whether “Nakamura” appeared).

(1) a. Copy Type EN

Nakamura-ga | senshū | kayōbi-ni | [NAKAMURA kaisha-de | Takahashi-o | shikari]-sugi-ta.
Nakamura-NOM | last week | Tuesday-DAT | at an office | Takahashi-ACC | scold-too much-PST
“Nakamura scolded Takahashi too much at an office last Tuesday.”

b. Pronoun Type EN

Nakamura-ga | senshū | kayōbi-ni | [PRONOUN kaisha-de | Takahashi-o | shikari]-sobire-ta.
Nakamura-NOM | last week | Tuesday-DAT | at an office | Takahashi-ACC | scold-fail | to-PST
“Nakamura failed to scold Takahashi at an office last Tuesday.”

c. No EN condition

Nakamura-ga | senshū | kayōbi-ni | kaisha-de | Takahashi-o | shikari-tsuketa.
Nakamura-NOM | last week | Tuesday-DAT | at an office | Takahashi-ACC | scold-PST
“Nakamura scolded Takahashi at an office last Tuesday.”

MEG data was recorded at Kyushu University Hospital using an Elekta Neuromag system (1000 Hz, 0.3–330 Hz band-pass). Structural MRIs were acquired with a 3.0-T scanner (Achieve; Philips) for source localization. The data were processed in MNE-Python [6]; environmental noise was removed using oversampled temporal projection and MaxFilter. Data were band-pass filtered (0.1–80 Hz, notch at 60 Hz), and artifacts removed via ICA. Epochs were time-locked to verb onset (–200 to 1200 ms). Source estimates were obtained using an LCMV beamformer and morphed to fsaverage. A spatiotemporal cluster-based permutation *t*-test was performed within predefined language-related ROIs (aparc atlas) [7], separately for each hemisphere. Brain responses were analyzed across three-time windows (200–500, 500–800, 800–1200 ms), based on prior findings that N400 and P600 reflect different stages of linguistic processing [8].

Result

The cluster-based permutation test conducted for the 500–800 ms time window revealed a significant cluster in the right temporal lobe, centered on the right superior temporal sulcus (RSTS), middle temporal gyrus (RMTG), inferior temporal gyrus/sulcus (RITG/S), and right insular lobe (RIL) between 720–762 ms after verb onset as shown in Figure 1. This effect was observed in the comparison between sentences containing ENs, where the sentence type with pronoun-like properties (1.b) elicited significantly greater activation than the type containing a copy (1.a) (Bonferroni-corrected $p = 0.014$, averaged $t = 2.2$). No significant cluster was found for any other contrasts and time windows.

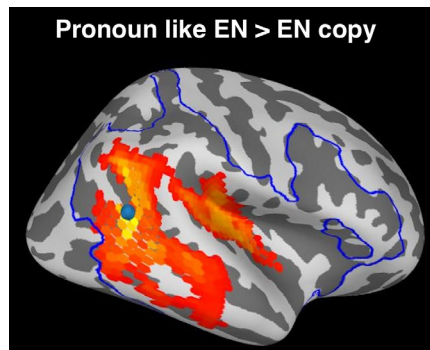


Figure 1: Significant cluster is shown in orange and red colors, indicating stronger responses to pronoun-like ENs than copy-type EN. Blue line indicates predefined ROIs.

Discussion

The result suggests that different types of ENs are processed in distinct brain regions and at different time points. Prior studies report that damage to the right temporal cortex impairs pronoun processing [9], raising the possibility that the pronoun-like EN in this study elicited activation in this region. However, a concern remains: there were no significant differences between the condition without an EN (1.c) and those with ENs (1.a, 1.b). If the observed brain regions reflect ENs properties per se, such differences would be expected. This suggests that the neural effects may not be driven solely by the presence of ENs and should be interpreted with caution.

Conclusions

This study shows that the brain distinguishes between different types of ENs during sentence comprehension. Significant activation from 720–762 ms was observed in right-lateralized temporal regions (RSTS, RMTG, RITG/S, and RIL), providing neural evidence for the dissociation of EN types in Japanese.

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