



# Neural correlates of prediction in language comprehension

## An MEG study on Japanese classifier-noun processing

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**Abstract:** This study investigates the predictive processing in language comprehension by leveraging Japanese classifier-noun expressions to examine whether the prediction effect can be dissociated from the semantic integration. The results revealed that the N400 effect was associated with semantic integration, whereas no clear effect was observed with the prediction effect.

**Keywords:** prediction, semantic integration, language comprehension, MEG, N400 effect

### Introduction

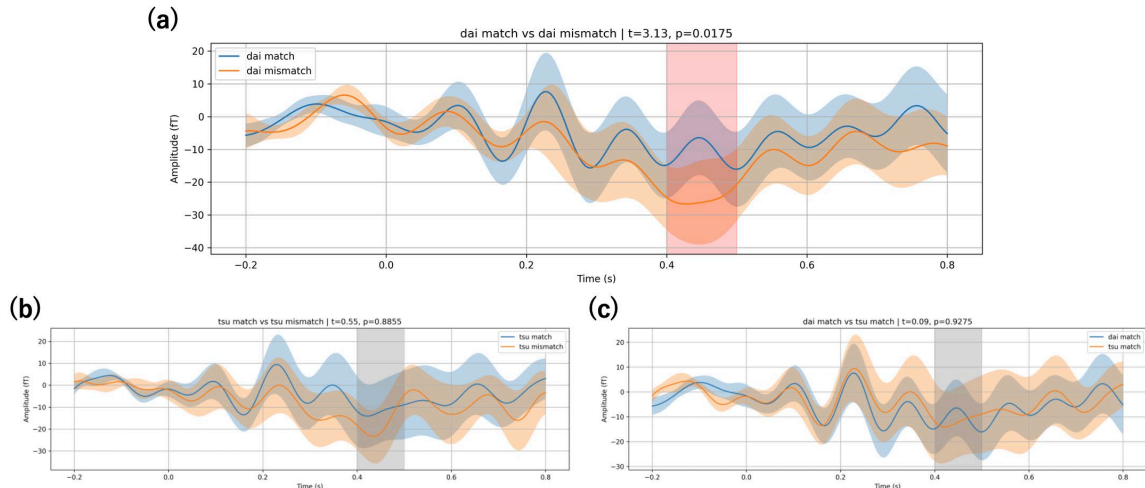
One of the core features of language comprehension is the ability to predict upcoming words based on the previous context. Recent research has been investigating such ability and trying to understand what exactly predicting processing is ([1] among many others). Some researchers have tried to dissociate the predictive processes from other processes and localize this process in the brain. The present study uses Japanese classifiers with nouns, which dissociate plausibility and the prediction to understand the predictive processing by conducting magnetoencephalography (MEG) experiments. Since previous studies ([2],[3]) using MEG were not designed to examine the effect of prediction and the semantic integration separately, we use Japanese classifier noun combination to dissociate them and trying to explore further into the nature of prediction in language comprehension. Our results revealed that the semantic integration effect can be observed as the N400 effect, whereas there was no statistically significant effect for the prediction effect. In conclusion, we need further investigation of the prediction processing in language comprehension.

### Methods

**Material:** Japanese is one of the languages that has a classifier system; for example, ‘two cars’ is expressed as *ni dai-no kuruma* (lit three bodies of car). In this experiment, we used two different types of classifiers, namely, *tsu* (piece) and *dai* (body). The classifier *tsu* is most widely used with different types of nouns, which imposes less restriction regarding the semantic interpretation, whereas *dai* is used only with a large machinery such as cars, hence it restricts semantic types of associated nouns. This makes it possible to construct a stimuli set that controls for both the target noun frequency and the bigram frequency of classifier-noun combinations (*yot-tsu-no seihin* (‘four pieces of products’) and *yon-dai-no basu* (‘four bodies of bus’) having the same bigram frequency), and at the same time contrasts the transition probabilities from the classifier to the noun (the probability of *seihin* (‘products’) given *yot-tsu* (‘four pieces’) being significantly lower than the probability of *basu* (‘bus’) given *yon-dai* (‘four bodies’)). A total of 216 stimuli sentences were created for this experiment. **Data acquisition:** Thirty native Japanese speakers participated in the experiment. MEG data were recorded using a whole-head 306-channel MEG system (Elekta-Neuromag) comprising 102 magnetometers and 204 planar gradiometers, while participants read sentences presented word-by-word on a transparent screen in a magnetically shielded room. Each trial began with a 500 ms fixation cross, followed by a classifier, noun, and verb (e.g., *yon-dai-no basu-ga hashitteiru* (lit ‘four bodies of bus are driving’)), each shown for 500 ms with no inter-stimulus interval. MEG signals were sampled at 1000 Hz with an analog filter of 0.0–330 Hz. **Preprocessing:** Environmental noise was reduced using Elekta’s temporal signal space separation (tSSS) method. Data were processed with MNE-Python (version 1.9.0, [4]). Raw signals were band-pass filtered from 0.2 to 9 Hz, and artifacts from eye movements and cardiac activity were removed via ICA with visual inspection. Epochs were extracted from –200 to 800 ms relative to the onset of the noun and baseline-corrected using the –200 to 0 ms pre-stimulus interval. Trials were excluded if peak-to-peak amplitudes exceeded 2500 fT (magnetometers) or 2500 fT/cm (gradiometers), or fell below 1 fT or 1 fT/cm. Participants with fewer than 30 valid trials per condition were excluded from further analysis. **Statistical analysis:** Statistical analysis was conducted to detect the N400 component, which is known to reflect sensitivity to semantic expectancy violation. The analysis focused on the time window from 400 to 500 ms, and the sensors used for analysis were magnetometers from the “Left-frontal” and “Left-temporal” regions, known to be involved in language processing, as defined by the VectorView sensor layout in MNE. For each participant, epochs were first averaged within each condition, and then spatially averaged across the predefined sensor group. These values were subsequently used for comparisons between conditions. Nineteen participants who met the minimum valid trial criterion were included in the analysis. For each pair of conditions, paired two-tailed t-tests were performed with a significance level of  $\alpha = 0.05$  (corrected by FDR).

## Results

A statistical comparison was conducted for three condition pairs within the 400-500 ms time window following stimulus onset. In the comparison between the *dai*-match and *dai*-mismatch conditions, the *dai*-mismatch condition showed a significantly greater negative amplitude than the *dai*-match condition ( $t(18) = 3.13, p = 0.0175$ ; Fig (a)). No significant difference was found between the *tsu*-match and *tsu*-mismatch conditions ( $t(18) = 0.55, p = 0.8855$ ; Fig (b)). The comparison between the *dai*-match and *tsu*-match conditions also revealed no significant difference ( $t(18) = 0.09, p = 0.9275$ ; Fig (c)).



**Figure 1.** Grand-average MEG from left frontal and temporal sensors. Shaded: 400–500 ms window; bands:  $\pm 1$  SEM. (a) *dai*-match vs. mismatch, (b) *tsu*-match vs. mismatch, (c) *dai* vs. *tsu*-match.

## Discussion

In this study we tested different types of classifier-noun combinations, which can ideally dissociate the semantic integration from the prediction effect. We hypothesized that the prediction effect should be expected between *tsu*-match and *dai*-match conditions since *tsu* can be used for much more general terms than that of *dai*. We also hypothesized that the difference between *dai*-match and *dai*-mismatch conditions should derive semantic integration effects; the *dai*-mismatch condition should observe semantically incongruent effect, compared to the *dai*-match condition. Our results showed that the semantic integration effect had a statistically significant effect, while the prediction effect did not show statistically significant effect for the N400 component. This might be a case in which the N400 effect is dedicated to the semantic integration, whereas the prediction effect might serve for a different effect in different component, which leaves us with the question for the further investigation.

## Conclusions

This study scrutinized the nature of the predicting processing in language comprehension by leveraging different types of noun-classifier combination in Japanese. Our results confirmed the N400 effect for semantic integration effect, but not for the prediction effect, which suggests a different processing mechanism might take place for this effect.

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## References

- [1] Altmann, G.T.M. and J. Mirković. Incrementality and Prediction in Human Sentence Processing. *Cognitive Science*, 33: 583-609. 2009. <https://doi.org/10.1111/j.1551-6709.2009.01022.x>
- [2] Dikker, S., and L Pylkkänen. MEG evidence for lexical preactivation. *Brain and Language*. Vol.127:1, 55-64. 2013. doi: <https://doi.org/10.1016/j.bandl.2012.08.004>.
- [3] Maess, B., F. Mamasli, J. Obleser, L. Helle, and A. Friederici. Prediction Signatures in the Brain: Semantic Pre-Activation during Language Comprehension. *Frontiers in Human Neuroscience*. 10:591. 2016. doi: 10.3390/fnhum.2016.00591
- [4] Gramfort, A., Luessi, M., Larson, E., Engemann, D. A., Strohmeier, D., Brodbeck, C., Goj, R., Mainak, J., Brooks, T., Parkkonen, L., and Hämäläinen, M. S.. MEG and EEG data analysis with MNE-Python. *Frontiers in Neuroscience*, 7(267):1–13, 2013. doi:10.3389/fnins.2013.00267.