

Brain responses to negation: An fMRI study with Japanese negative polarity items

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Despite its common occurrence in daily communication, negation takes numerous forms. The combinations of semantic and syntactic structures that are used to form negated sentences reveal a complex and multi-faceted phenomenon. This study aimed to investigate how the brain contends with such complexity, and specifically, the areas of the brain responsible for processing Japanese sentences with SIKA, a negative polarity item that requires negation as its syntactic licenser (see (a) below), and the focus particle DAKE, whose inclusion in an affirmative sentence results in a semantic interpretation similar to that of the SIKA-negation sentence (see (b') below). In contrast to SIKA, DAKE does not require negation as a syntactic licenser. It was essential to contrast those sentences with SIKA and DAKE, as well as their controls, to disentangle the different processing factors involved in sentence comprehension, and to locate the brain regions responsible for them. The results showed that the left Inferior Frontal Gyrus (BA 44) is responsible for processing the syntactic licensing required by Japanese negative polarity SIKA. This process differs from that of computing a semantic interpretation associated with focus particles.

An event-related fMRI method was applied to investigate brain responses while readers read sentences displayed on a screen a single word at a time. As shown in the example materials below, SIKA or the focus particle DAKE was attached to the subject noun phrase in the main clause. Both negative and affirmative counterparts of the negative sentences were included in DAKE (b and b') and control (c and c') sentences. There was no significant difference in the accuracy of the comprehension questions provided after each sentence, which suggests that the different sentence types tested were understood equally well. SIKA sentences, which demanded negation as a syntactic licenser, showed increased activation in the left Inferior Frontal Gyrus (BA 44) and the left Insula, when compared against DAKE sentences as well as negative sentences without a focus particle. Enhanced activation of the left Inferior Parietal Lobule was also observed for SIKA sentences; this is likely due to the increased load on working memory required to compute the syntactic dependency involved, within the sentences. In processing sentences with a focus particle DAKE, a semantic network that comprises the left BA 47 and Angular Gyrus was activated. This was supported by comparisons between sentences with DAKE and those without a focus particle.

Overall, the results of this study suggest that different processes involved in interpreting Japanese negative polarity SIKA was supported by different, specific regions of the brain. That is, the left Inferior Frontal Gyrus is responsible for computing syntactic SIKA-negation dependencies, while the left Inferior Parietal Lobule is recruited when working memory load increases. The interpretation of focus particles is supported by an independent semantic network. Such results imply that the parser is equipped with mechanisms binding different levels of representation during on-line comprehension. The study's further implications for parsing theory will be discussed.

Materials Examples

a. SIKA-negation

[Tenmongakusya-sika [sinbunkisya-ga kaigan-de sinwakusei-o mokugekisita] toiukoto-o sinzinakatta.]
 astronomer-SIKA reporter-NOM shore-on new planet-ACC witnessed (fact) that believed-NOT
Only the astronomer believed that a reporter spotted a new planet on shore.

b. DAKE-negation / b'. DAKE-affirmative

[Tenmongakusya-dake [sinbunkisya-ga kaigan-de sinwakusei-o mokugekisita] toiukoto-o sinzinakatta.]
 astronomer-DAKE reporter-NOM shore-on new planet-ACC witnessed (fact) that believed-NOT
 sinzimasita.]
 believed

Only the astronomer (b. did not believe / b'. believed) that a reporter spotted a new planet on shore.

c. Control-negation / c'. Control-affirmative

[Tenmongakusya-wa [sinbunkisya-ga kaigan-de sinwakusei-o mokugekisita] toiukoto-o sinzinakatta.]
 astronomer-WA reporter-NOM shore-on new planet-ACC witnessed (fact) that believed-NOT
 sinzimasita.]
 believed

Only the astronomer (c. did not believe / c'. believed) that a reporter spotted a new planet on shore.