Neuroscientific Conditions of Becoming a Multilingual

—— Finding a brain region governing grammar acquisition in a new language ——

Information

Date: January 24, 2024, 11:00 – 12:00

In-person participation: Please apply via email and visit the meeting place below.

Online participation: Please apply via email, and we will let you know a Zoom ID.

Place: Aoyama H&A Building, 3F

(Shibuya 2-2-10, Shibuya-ku, Tokyo; 10 min. walk from Shibuya station, Exit B4)

https://maps.app.goo.gl/a7N28h6TpGWVAMzHA

Presenters

Department of Basic Science, The University of Tokyo

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Keita Umejima, Research Associate

Department of Linguistics and Philosophy, Massachusetts Institute of Technology

Suzanne Flynn, Professor (online presentation)

Institute for Language Experience, Experiment & Exchange (LEX Institute)

Kenshi Suzuki, Representative director

Registration

For those attending our press release, we kindly request you to fill up the following registration form and send an Email to the PR agent (kz-hiraoka@lexhippo.gr.jp) of LEX Institute before January 23, 17:00.

● Attendant information for Email registration

・Company:

・Media / Department:

・Name of each attendant and total number of attendants:

・Participation: □ In−person, □ Online (Zoom)

・Filming: □ Number of photo shooting: □ Number of video shooting:
□ Online screen capture

・Phone:

・Email:

Main points

- ◆ We found a brain region governing grammar acquisition in a new language, when native speakers of Japanese who had experience in English, Spanish, etc., were newly exposed to spoken sentences in Kazakh.
- ◆ This brain region governing grammar acquisition in a new language completely matched with the "dorsal left inferior frontal gyrus," which is the region that the research team has long identified as the "grammar center" involved in the syntactic processes of first and second languages.
- ◆ The present neuroscientific study clearly proved the "Cumulative-Enhancement model of language acquisition," which claims that the effects of acquiring multiple languages would accumulate, leading to a deeper acquisition of the languages.

Summary

Professor Kuniyoshi L. Sakai and Research Associate Keita Umejima from the Department of Basic Science, the University of Tokyo, in their joint research with Professor Suzanne Flynn from the Department of Linguistics and Philosophy, Massachusetts Institute of Technology, have identified the brain region governing the *who*, *when*, and *what* for grammar acquisition when exposed to a new language. This study has been realized with the aid of Institute for Language Experience, Experiment & Exchange (LEX Institute) / Hippo Family Club (Tokyo, Japan; Representative director: Kenshi Suzuki).

Our research group recruited participants who acquired Japanese as their mother tongue and had experience in learning English, and made them newly acquire Kazakh in an experimental setting that modeled natural language acquisition. Using an MRI scanner (Note 1), we investigated the neural processes during which the participants performed grammar tasks that involved heavy syntactic loads. As results, we successfully specified that the activations in the dorsal left inferior frontal gyrus (dorsal L. IFG) (Note 2) were enhanced "for which participants (the *who*)," "during which phase of trials (the *when*)," and "for which sentence types (the *what*)."

Professor Sakai, the corresponding author of this paper, has demonstrated that this brain region functions as the "grammar center" for a first language (L1) and second language (L2). The current findings revealed that the same grammar center also plays a critical role in the acquisition of a third language (L3) and fourth language (L4), providing neuroscientific evidence consistent with the "Cumulative-Enhancement model of language acquisition," which claims that the effects of acquiring multiple languages would accumulate, leading to a deeper acquisition of the languages. This hypothesis has been proposed by Professor Flynn, a co-author of this paper, based on her behavioral experiments on language acquisition.

Based on the method of repeatedly hearing sentences through natural speech sounds, the LEX Institute/Hippo Family Club has continued their multilingual activities for several decades. Our present discovery further promotes the findings of our joint research released in March, 2021 (https://www.u-tokyo.ac.jp/focus/ja/press/z0109_00003.html).

Contents of presentation

< Research backgrounds and issues in previous research >

Many Japanese people suffer from the consistent problem that they hardly ever are able to speak English, in spite of their continuous and intense study of English as a “foreign language” in school at different levels, as well as at colleges/universities, and other forms of language schools. Speaking multiple languages is often considered to be a "special ability." However, in many regions of Europe and other multiethnic countries in Africa and Asia, multilingual environments are a commonplace. In these environments, the effort needed for acquiring a new language is often perceived to be much less stressful. There is some previous research that has investigated L3/L4 acquisition in behavioral experiments. In addition, apart from the findings reported by our research group three years ago, neuroscientific evidence concerning acquiring a new language such as L3/L4s is still scant. The contribution of the neural substrates common to L1/L2 acquisition has also not been sufficiently identified.

< Research contents >

We recruited 31 volunteers in the age of 14-26, including students of the University of Tokyo, students of Sophia University, and members of the Hippo Family Club. All participants acquired English as their L2, and half of the participants achieved proficiency scores indicating novice or higher proficiency in their L3 (typically Spanish) in a listening comprehension test. All participants were exposed to Kazakh (a member of the Turkic language family, and a native language in Kazakhstan and neighboring countries) for the first time in the experiments, where we conducted grammar tasks (Fig. 1) utilizing speech stimuli recorded by a native speaker. Without the explicit teaching of any of the grammatical rules in Kazakh, we repeatedly presented the correct and incorrect examples for the grammaticality of a sentence, as well as for subject-verb correspondences in a sentence in the demo trials. We tested whether the participants were able to judge correctly the grammaticality of new stimulus sentences by themselves in the test trials. Approval for the experiments was obtained from the ethical review board at the University of Tokyo, and written informed consent was obtained from all participants.

Each of the Kazakh sentences we used included a main clause and a relative clause, where each clause included a subject, a direct object, and a verb. The “man” included in each sentence is either the Subject (S) or Object (O) in the main clause, and is either S or O in the relative clause; from this perspective, each sentence is classified as being one of the following four types of sentence structures. For example, under the OS condition, the “man” is an Object in the main clause, and a Subject in the relative clause (denoted by square brackets [ ] in the examples below). In the experiments, we mixed these four sentence types and presented them in a completely randomized order.

1. Example English translation under OS: “We recognized a man [who knew John well].”
2. Example English translation under OO: “We recognized a man [whom John knew well].”
3. Example English translation under SO: “A man [whom John knew well] recognized us.”
4. Example English translation under SS: “A man [who knew John well] recognized us.”

In each task trial, we presented a sentence auditorily, and then presented a noun-verb (NV) pair. We tested the GR task, which required the participants to judge whether the sentence was grammatical or ungrammatical. We also tested the SV task, which required the participants to judge whether the NV pair was matched with one of the two subject-verb (SV) pairs in the sentence structure or not. Based on the distributions of the accuracy rates in the tasks, we separated the participants into two groups: Group I (16 participants, 7 women), consisting of those who had reached accuracy rates higher than 60% in the SV task for both the OS and SO conditions, and Group II (15 participants, 7 women), consisting of those who did not. Regarding these groups, we confirmed that the more proficient the bilinguals and multilinguals were in their L2/L3s, the higher their performance became in their L3/L4s (i.e., Kazakh).

For each participant, the temporal sequence of trials was divided into four phases (*quarters*), the accuracy rates for Group I significantly increased from the first to fourth quarters in the SV task under the OS and SO conditions (Fig. 2a), as well as under the OO condition. In contrast, for Group II, the accuracy rates did not significantly change (Fig. 2b). During the fourth quarter, Group I successfully performed all conditions except for the SS condition in the SV task (Fig. 2c). In contrast, Group II was not able to acquire any of the sentence structures in any condition within the time window of our experiment (Fig. 2d).

Using functional MRI (fMRI) (Note 3), we measured the brain activations while the participants were performing the grammar tasks. The activations for Group I, when compared with those for Group II, were significantly higher in the dorsal L. IFG and bilateral STG/MTG (Fig. 3a, left), as well as in the medial regions. When we focused on the successfully performed conditions of OS, OO, and SO, activated regions were more localized in the dorsal L. IFG and L. STG/MTG alone (Fig. 3a, right).

With regards to the phases of trials, we compared the brain activations during the final fourth quarter with the initial first quarter for Group I, and observed focal activation in the dorsal L. IFG alone (Fig. 3b). In addition, we compared the activations under the OS, OO, and SO conditions, which were successfully acquired by Group I during the fourth quarter, with those under the SS condition, and again observed focal activation in the same dorsal L. IFG alone (Fig. 3c).

The fact that activation in the dorsal L. IFG was observed consistently indicates that this region, known as the "grammar center" of L1/L2, also plays a critical role in the grammar acquisition for the L3/L4.

Moreover, we quantified the activation in the dorsal L. IFG during the presentation of the "Sentence" that preceded the tasks, and, interestingly, we observed significant correlations against the accuracy rates for both the GR (Fig. 4a) and SV (Fig. 4b) tasks. In other words, if we measure the activations in the dorsal L. IFG, we can actually *predict* the accuracy rates for the subsequent experimental tasks.

The activations in the dorsal L. IFG were free from task difficulty or memory loads (so-called working memory), because larger activations were observed in the participants indicating less difficulty in performance on these tasks. The dorsal L. IFG activations thus should be reflecting successful building of sentence structures.

< Social significance and future plans >

In Japan, English skills of the Japanese people are continuously decreasing yearly, although English has been a curricular subject, beginning in the elementary school education. This is especially true with regards to the youngest participants, who are 18–20 years of age; their English scores are decreasing most significantly, shifting from "Moderate" to "Low," and further to "Very low" during the recent years (EF Education First Japan, Ltd., https://www.efjapan.co.jp/epi/regions/asia/japan/). Possible reasons for this decrease could be that many Japanese people traditionally have studied English solely by relying on memorizing individual words and learning grammar rules explicitly. It could be that we are currently exposed to massive amounts of textual information such as in the SNS with rather low or poor exposure to actual speech sounds. The results of the current research indicate that even Japanese people can acquire any new languages by simply experiencing exposure to speech in the target language. This clearly suggests the synergistic effect of acquiring multiple languages simultaneously. This suggestion is consistent with the notion of "natural acquisition" of languages, and raises questions for language education in general. For further discussion, please see "*Acquiring English without Studying: An Epoch-Making Method Based on Brain Science* (Japanese)" (Sakai, 2022, PHP Institute, Kyoto).

Another reason may derive from the underlying misconception of "teaching a foreign language." Wilhelm von Humboldt, the founder of the Humboldt University of Berlin and also a linguist, concluded in 1836 "that one cannot really teach language but can only present the conditions under which it will develop spontaneously in the mind in its own way. [...F]or the individual, learning is largely a matter of *Wiedererzeugung* [reproduction/regeneration], that is, of drawing out what is innate in the mind" (Chomsky, 1965). This idea is the basis of the "innateness hypothesis" of language acquisition proposed by the American linguist Noam Chomsky, and suggests a universal underpinning for all natural languages. For evidence from neuroscience for this hypothesis, please see "*Chomsky and Neuroscience of Language* (Japanese)" (Sakai, 2019, Shueisha International, Tokyo).

The Sakai laboratory of the University of Tokyo will continue to investigate and thus reveal the mechanisms of the human brain underlying the creative aspects of language, and the LEX institute will promote practical activities regarding multilingualism, contributing to the realization of deep and meaningful communication among people across the world.

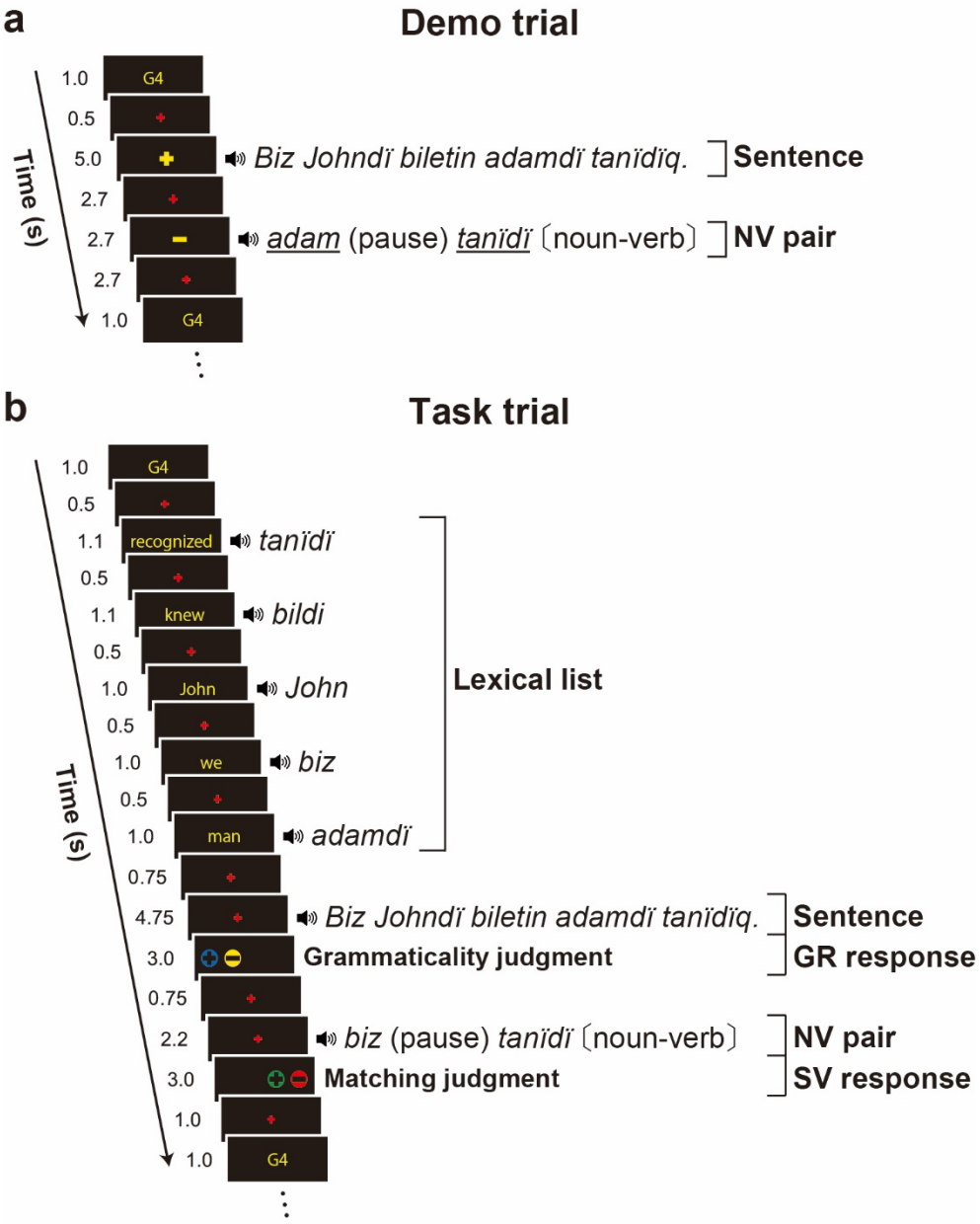

Figure 1. Temporal events in a demo or task trial.

(**a**) In the *demo* trials, a Kazakh sentence [either grammatical or ungrammatical] was presented auditorily, followed by an NV pair [either matched or mismatched with the two SV pairs in the sentence structure; underlined words denote such a mismatch]. In each NV pair, the noun (or pronoun) was presented always without a suffix for the accusative case (e.g., *adam* for *adamdi*), and the verb was presented always with a third-person singular suffix in the simple past tense. The + / − sign presented simultaneously with a sentence indicated its grammaticality/ungrammaticality, and the + / − sign with an NV pair indicated match/mismatch (see above). The sentence shown in the figure means "*We recognized a man who knew John.*" (**b**) In the *task* trials, five Kazakh words ("Lexical list" in the figure) were presented auditorily; individual words translated into English were visually presented. This Lexical list was followed by a sentence using all five words from the Lexical list. The participants chose a + / − button in a grammaticality task (GR task). An NV pair was then presented to the participants asking them to judge the correctness of matching (see above). Here again, the participants chose a + / − button in a subject-verb task (SV task).

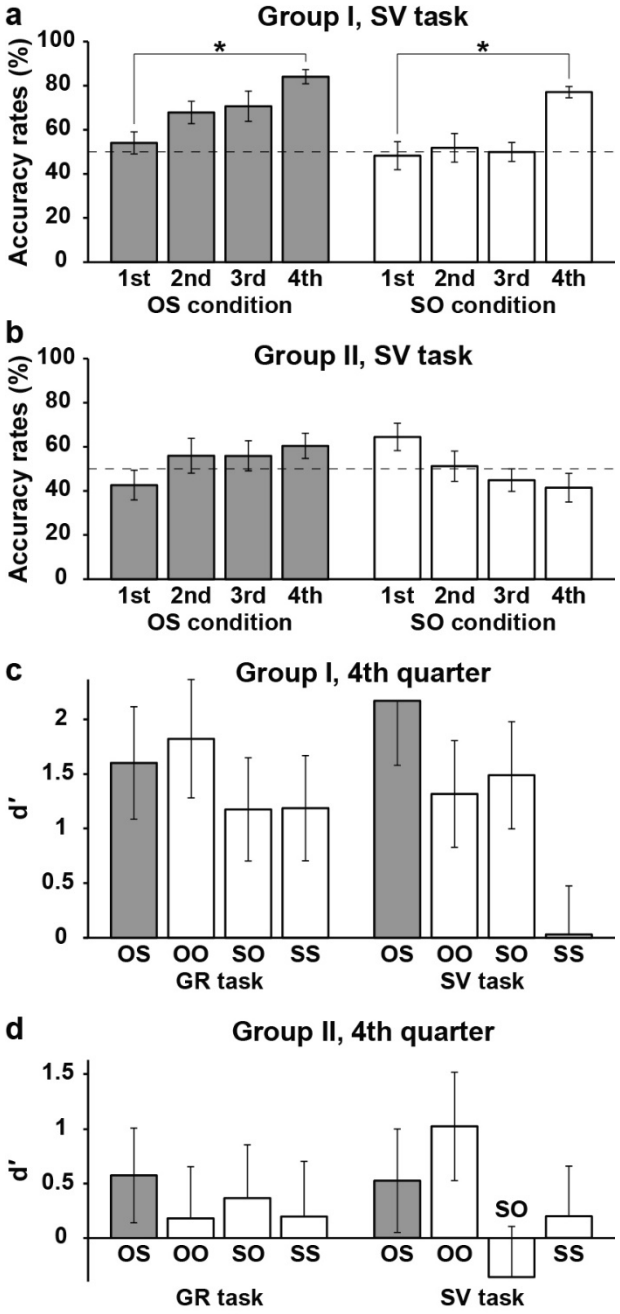

Figure 2. Proficiency improvement in Kazakh.

(**a**) Accuracy rates in the SV task during each quarter, shown for Group I, who met the criteria of more than 60% (the fourth quarter) in the SV task under both the OS (left) and SO (right) conditions. (**b**) Accuracy rates in the SV task for Group II, who did not reach the above criteria. The rates remained at chance level under the OS (left) and SO (right) conditions. (**c**) The d′-values for Group I (the fourth quarter), which were significantly above chance level at value 0 except for SS in the SV task. (**d**) The d′-values for Group II, none of which were significant. Error bars indicate standard errors of the mean (SEM) for the accuracy rates and RTs, whereas the error bars of d′-values indicate estimated variances. $*p < 0.05$.

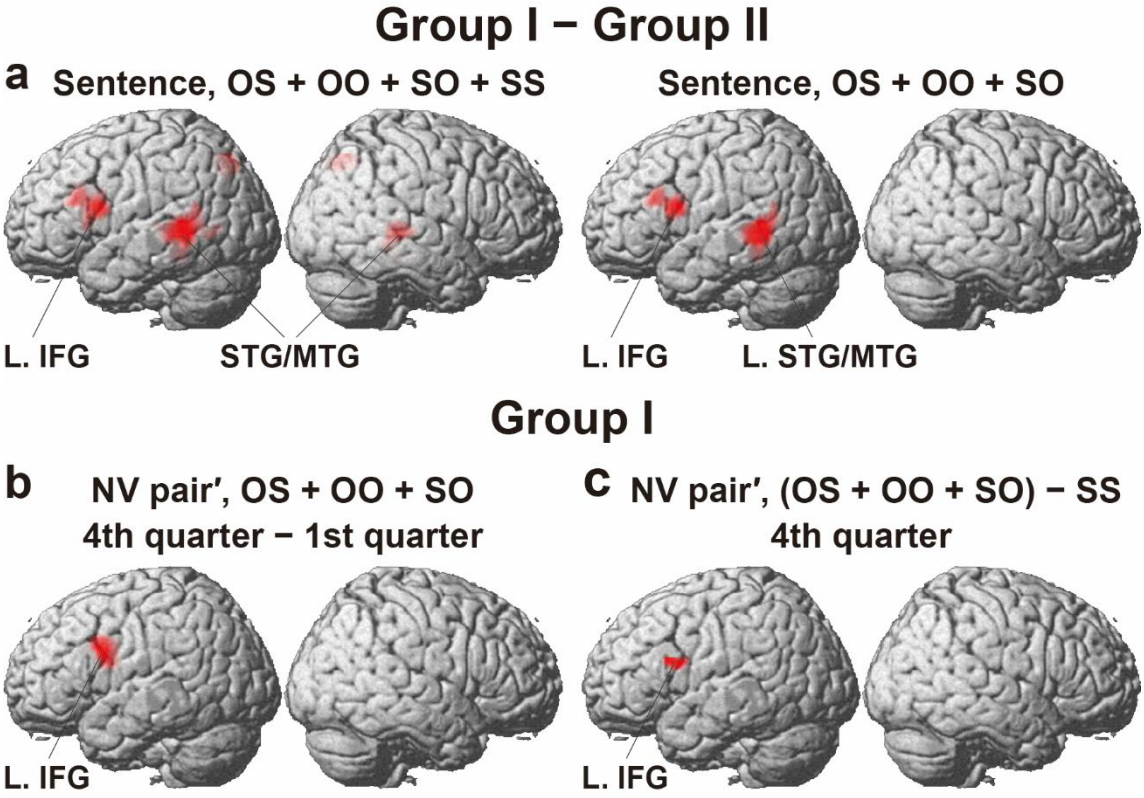

Figure 3. Activations related to groups, phases, and conditions.

(**a**) Focal activations observed in a direct comparison of the [Group I − Group II] contrast. During the Sentence events, activations were mainly observed in the left inferior frontal gyrus (L. IFG) and superior/middle temporal gyri (STG/MTG) under the OS, OO, SO, and SS conditions (left), or under the OS, OO, and SO conditions (right), consistent with behavioral results (see Fig. 3c). (**b**) L. IFG activations for Group I, observed in the [4th quarter − 1st quarter] contrast. Activations in the [NV pair − Lexical list] contrast (abbreviated as NV pair′) were averaged among OS, OO, and SO conditions. (**c**) L. IFG activations for Group I, further revealed by the [(OS + OO + SO) − SS] contrast during the fourth quarter.

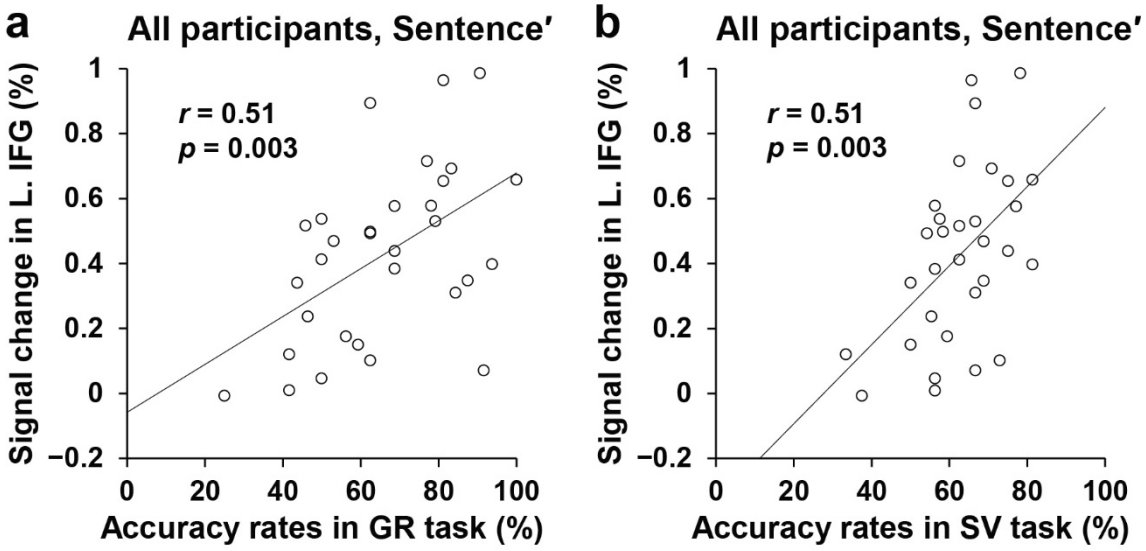

Figure 4. Brain activations related to the subsequent task performances.

(**a**) A correlation between L. IFG activations and accuracy rates in the GR task for all participants. Averaged among the four construct conditions, the rates in the GR task became higher for the participants, who showed stronger activations in the [Sentence − Lexical list] contrast (abbreviated as Sentence′). The region of interest (ROI) for this figure was determined by the activated region in Fig. 3c. (**b**) A similar correlation in the SV task. Stronger L. IFG activations also predicted higher rates in the SV task.

Related Information:
Multilingual people have an advantage over those fluent in only two languages.
UTokyo-MIT study measures brain activity while learning basic sounds, grammar rules of unfamiliar language (April 1, 2021)
https://www.u-tokyo.ac.jp/focus/en/press/z0508_00173.html

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Bibliography

Journal : Scientific Reports (Nature Portfolio Journal), published online on January 2nd.
Title : Enhanced activations in the dorsal inferior frontal gyrus specifying the *who*, *when*, and *what* for successful building of sentence structures in a new language
Authors : Keita Umejima, Suzanne Flynn, Kuniyoshi L. Sakai*
DOI : 10.1038/s41598-023-50896-6
URL : https://www.nature.com/articles/s41598-023-50896-6

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Glossary

(Note 1) MRI scanner

Magnetic Resonance Imaging (MRI) is a technology for imaging brain tissue architectures by measuring protons' responses to the local magnetic field. MRI is broadly used as a method to observe brain tissues from outside of the brain without causing any damage. For this purpose, we use the MRI scanner, which is a medical equipment with superconductive magnets that generates high magnetic fields (about 3 tesla). This MRI scanner is used for "fMRI" explained in Note 3.

(Note 2) dorsal left inferior frontal gyrus (dorsal L. IFG)

The dorsal IFG (Brodmann's area 44/45/6) are regions in the frontal lobe of the brain, present in each of the left and right hemispheres. Those regions in the left hemisphere are a part of the "language areas" involved in human's language processing, especially responsible for the function of the "grammar center." The homologues in the right hemisphere have the role of supporting the grammar center.

(Note 3) functional MRI (fMRI)

An imaging technology for measuring blood flow changes that accompany neural activations in the brain. The fMRI is broadly used from the 1990s as a method to well observe brain activations that change temporally, measured from outside of the brain without causing any damage.

Contact information

(Please ask the presenters about the research.)

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