Brain Circuits for Language Processing

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There is a tacit assumption in neuroscience from the genetic to the systemic level, which holds that the biological foundations of humans are essentially similar to those of nonhuman primates. However, the recent development of linguistics has clarified that human language is radically different from what is known as animal communication. In my talk, I will provide the experimental evidence that the fundamental language processing is indeed specialized in the human brain, focusing particularly on the function of Broca's area. Next, I will summarize new findings on the three syntax-related networks including 19 brain regions, which have been recently identified by our functional connectivity studies. For 21 patients with a left frontal glioma, we observed that almost all of the functional connectivity exhibited chaotic changes in the agrammatic patients. In contrast, some functional connectivity was preserved in an orderly manner in the patients who showed normal performances and activation patterns. More specifically, these latter patients showed normal connectivity between the left fronto-parietal regions, as well as normal connectivity between the left triangular and orbital parts of the left inferior frontal gyrus. Our results indicate that these pathways are most crucial among the syntax-related networks. Both data from the activation patterns and functional connectivity, which are different in temporal domains, should thus be combined to assess any behavioral deficits associated with brain abnormalities. I will further present cortical plasticity for second language (L2) acquisition, such that the activation of language-related regions increases with proficiency improvements at the early stages of L2 acquisition, and that it becomes lower when a higher proficiency in L2 is attained. These results may reflect a more general law of activation changes during language development. The approach to evaluate acquisition processes in terms of not only indirect behavioral changes but direct functional brain changes takes a first step toward a new era in the physics of language.

References:

Kinno, R., Ohta, S., Muragaki, Y., Maruyama, T. & Sakai, K. L.: Left frontal glioma induces functional connectivity changes in syntax-related networks. *SpringerPlus* **4**, 317, 1-6 (2015).

Kinno, R., Ohta, S., Muragaki, Y., Maruyama, T. & Sakai, K. L.: Differential reorganization of three syntax-related networks induced by a left frontal glioma. *Brain* **137**, 1193-1212 (2014).

Ohta, S., Fukui, N. & Sakai, K. L.: Syntactic computation in the human brain: The Degree of Merger as a key factor. *PLOS ONE* **8**, e56230, 1-16 (2013).

Inubushi, T. & Sakai, K. L.: Functional and anatomical correlates of word-, sentence-, and discourse-level integration in sign language. *Front. Hum. Neurosci.* **7**, 681, 1-13 (2013).

Sakai, K. L., Nauchi, A., Tatsuno, Y., Hirano, K., Muraishi, Y., Kimura, M., Bostwick, M. & Yusa, N.: Distinct roles of left inferior frontal regions that explain individual differences in second language acquisition. *Hum. Brain Mapp.* 30, 2440-2452 (2009).

Sakai, K. L.: Language acquisition and brain development. *Science* 310, 815-819 (2005).