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How the coevolution of language and sociality has helped to shape the human brain

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Understanding how neural circuits contribute to cognitive differences between humans and other species, including macaque monkeys, is a major issue in neuroscience. Language and tool use are the most prominent differences between humans and other primates. Many neuroimaging-based studies have explored the brain mechanisms underlying language to reveal the origin of human evolution. Leroy et al. found human-specific asymmetry in the superior temporal sulcus (STS) by analyzing the magnetic resonance images (MRI) of humans and chimpanzees [1], and resting-state functional connectivity analyses have revealed that the functional coupling between the posterior superior temporal gyrus (STG) and inferior frontal gyrus (IFG) is more prominent in humans than in macaques [2]. Based on diffusion MRI, it has also been shown that the arcuate fasciculus is much smaller or even absent in non-human primates [3]. Recently, Wang et al. [4] conducted an elegant study in which they demonstrated that specific areas for information integration may only exist in the human brain. In this investigation, the subjects (i.e. awake monkeys and humans) were exposed to auditory sequences with a fixed pattern (called habituation stimuli, e.g., AAAB, where A and B were two fixed tones) or a deviant one (called rare test stimuli), while their whole-brain BOLD fMRI signals were recorded. The stimuli were different from each other in terms of the total number of tones (e.g., going from AAAB to AB or to AAAAAB), their repetition pattern (e.g., going from AAAB to AAAA), or both (e.g., going from AAAA to AAAAAB). The authors assumed that recognition of the total number of tones indicates the ability to count, whereas recognition of the way in which the tones repeat reflects the ability to identify algebraic patterns. These two abilities, in the authors' view, are very important for the processing of language. The patterns of fMRI activation were then compared between monkeys and humans. The authors found that both species represented the number of tones in the intraparietal and dorsal premotor areas, and the tone-repetition pattern in the ventral prefrontal cortex and basal ganglia. However, only human brains showed a response to the combined changes in number and sequence, in particular bilaterally within the IFG and STS. Considering the important role of these two brain areas in language processing and social cognition, this study implied that the newly evolved circuit may underlie the unique language ability of humans. The findings consistently revealed the important role of IFG and posterior STG/STS in language evolution. However, it has been reported that the direct white matter fiber pathway via the arcuate fasciculus is

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mainly involved in repetition rather than phonology processing, which is primarily achieved through an indirect fiber pathway involving the relay station of Geschwind's area in the inferior parietal lobule [5]. Therefore, determining the brain mechanism that regulates phonology processing in human and non-human primates could help to elucidate the contributions of IFG and posterior STG/STS to language evolution in humans.

The 'triple-code' model of number processing has shown that the verb code represented by words is processed by the left perisylvian areas [6]. The unique response patterns for combined numerical and sequential tone stimuli identified in the STS and IFG of the human brain may indicate that humans are processing the numbers with the semantic information. Therefore, we conclude from Wang et al. [4] that humans process combined numbers and sequential tones using semantic working memory rather than syntactic information. The IFG, particularly the right IFG, plays an important role in cognitive flexibility. The unique response pattern found in the human IFG during the processing of the two investigated abstract properties suggests that humans have developed greater cognitive flexibility than other primates.

Language provides a means of transmitting information from one brain to another, and its acquisition, comprehension, production, change and evolution depend on social environment. The larger volume of the human brain compared to that of non-human primate brains is considered to be due to more complex social relationships, and language emerges among humans who need to deal with various interpersonal relationships in large, complex social groups comprising relatives, friends, cooperators, and adversaries. In fact, the STS region has been reported to be involved not only in language processing, but also in social perception. Electrophysiological studies in monkeys, together with neuroimaging studies in humans, have revealed that STS is an important component of the system for social perception.

More broadly speaking, a series of studies have demonstrated that, among primates, the relative size of the neocortex correlates with many indices of social complexity, including social group size, number of females in the group, grooming clique size, the frequency of coalitions, male mating strategies, the prevalence of social play, the frequency of tactical deception, and the frequency of social learning. The existence of brain areas, such as STS, which are involved in the integration of both language-related and socially important information highlights a strong link between these two domains during the course of human evolution.

In summary, language has endowed humans with the means for efficient social cooperation, and greater sociality has accelerated their evolution, while at the same time profoundly shaping the human brain.

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