

Title	音声生成と理解における神経振動メカニズムに関する研究
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Doctoral Dissertation

Investigation on the neural oscillatory mechanisms of
speech production and comprehension

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ABSTRACT

Speech communication is a trait of human species. It is the most natural and convenient means of interpersonal interaction and information acquisition. Normally, we can quickly and accurately understand the meaning of spoken language based on our acquired linguistic knowledge. Also, we can precisely control articulatory movements via appropriate speech planning, motor programming and auditory feedback. These seemingly quite flexible and easy operations, however, require extremely complex brain network coordination. With the mutual development and continuous interactions, there is a tight link formed between the speech comprehension and production systems, called the 'speech chain'. Understanding the principles governing the neural dynamics related to the speech chain remains to be an unmet goal within neuroscience. Recent brain imaging advances have contributed abundant of anatomical and functional cortical localizations and neural pathways. However, it is not sufficient for us to form a comprehensive understanding of the organizational principles underlying the local computation and long-range communication across multi-scale brain networks. Our study aims to unravel the speech production and comprehension mystery by probing into the neural oscillatory mechanisms and reconstructing the temporal-spatial-spectral brain network dynamics in a series of listening and speaking tasks. Technically, we utilized a multi-modal data acquisition system, which includes a high-density (128-channel) electroencephalography (EEG) recorder, an eye movement tracking system, and an electret condenser microphone. Experimentally, we designed a word listening task and a sentence oral reading task to explore speech processing at different linguistic scales and along successive functional stages. Materially, we take advantage of distinctive Chinese properties

(e.g., uniformity and rhythmicity) to address some linguistic controversies that have not been settled in other languages. Computationally, we performed EEG artifact reduction, source reconstruction, effective connectivity estimation, and cross-frequency coupling (CFC) evaluation, etc. These developed methods enable us to investigate some interesting topics, such as the motor theory of speech perception, the syntactic and semantic effects in sentence phrase building, and the interactive nature of the speech perception-production loops. By incorporating prevailing theoretical and computational frameworks with our results in the brain network dynamics and CFC patterns, we proposed a neurofunctional model of speech production and comprehension (SPAC) to explain the dynamic, hierarchical and interactive organization of speech functions. The SPAC model (1) considers the active nature of the speech functions with top-down regulations from higher cognition; (2) extends the framework up to the sentence level with the consideration of syntactic and semantic effects on low-level sensorimotor processing. (3) complements earlier anatomical and functional models with spatiotemporal brain network dynamics. (4) indicates bidirectional information flows in the dorsal stream for speech production and ventral stream for speech comprehension. (5) explains with CFC mechanisms for the bridging of linguistic form diversities and representational hierarchies, as well as the bidirectional interactions between the bottom-up sensory input and top-down cognitive regulations. The SPAC model is supposed to forward our understanding of the speech chain from a more comprehensive perspective.

Key words: Speech production and comprehension, cross-frequency coupling, brain network dynamics, EEG source reconstruction, SPAC, model