Investigation of the neural basis of second language acquisition: An electroencephalography and transcranial electrical stimulation study

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論 文 内 容 の 要 旨

In this dissertation, I investigate the neural basis of second language (L2) acquisition with insights from two neuroscientific methods: electroencephalography (EEG) and transcranial electrical stimulation (tES).

In Chapter 1, I summarize key neurolinguistic findings of EEG studies, tES studies, and L2 acquisition research and propose some specific gaps in the literature pertaining to the neural basis of L2 acquisition. Namely, I first suggest that neurophysiological effects (as measured by EEG) due to stimulus modality have been understudied in native language processing and entirely overlooked in L2 acquisition studies. I then explain that while various correlational research associates the left inferior frontal gyrus (Broca's area) with language acquisition, no study has used tES to investigate the causal relationship between Broca's area and natural language acquisition. I further point out that the neurophysiological effects of L2 acquisition as induced by tES over Broca's area have not been investigated. To fill in these outstanding gaps in our understanding of the neural basis of L2 acquisition, Chapters 2–4 lay out three experiments based on both correlational (EEG) and causal (tES) methods. Chapter 5 brings together the results of these three experiments to make broader conclusions on the neural basis of L2 acquisition.

Using an event-related potential (ERP) paradigm based on EEG data, I investigate the neurophysiological effects of stimulus modality on language processing in both native and non-native Spanish speakers. Various neurophysiological modality effects elicited by morphosyntactic violation and orthographic/phonological violation processing are revealed and discussed. In native speakers, one of the most prominent effects observed was a modulation of the P600 (a parietal positivity 600 ms post violation onset elicited by grammatical violations). While it had been already been shown that higher L2 proficiency can be characterized by more nativelike language processing, it was shown here for the first time that higher L2 proficiency is marked by

greater modality-specific specialization of language processing. The question of modality-specific nativization (the process of becoming more nativelike) is also discussed, suggesting that neurophysiological nativization in the auditory modality is a stronger predictor of high proficiency.

Investigating the causal root of L2 acquisition, transcranial direct current stimulation (tDCS), a tES method that uses direct current to stimulate a cortical region, was used to stimulate Broca's area during a novel grammar acquisition task. In a longitudinal experiment, participants who were naïve to Spanish received either active stimulation or sham stimulation during Spanish verb inflection training over three sessions. While a ceiling effect confounded the observation of some long-lasting stimulation effects, it was robustly shown in the first session that Broca's area stimulation caused improved L2 verb inflection acquisition. This provides the first direct evidence that Broca's area is causally linked to L2 acquisition.

Finally, by combining the results of the first two experiments, the neurophysiological effects of Broca's area stimulation during L2 grammar acquisition were investigated. Since the first experiment demonstrated a link between high proficiency and auditory modality nativization, the auditory modality was chosen as the target modality for this final experiment. This first experiment further provided an overview of L2 learner ERPs, which could be used as a qualitative benchmark for discussing the neurophysiological effects of stimulation. The second experiment established Broca's area as a neural center involved in L2 acquisition and showed robust effects of stimulation in a single training session, thereby demonstrating the immediate efficacy of stimulation. Ultimately, this final experiment replicated the behavioral effects observed in the previous tDCS experiment, while offering new insights in light of task modality and electrophysiological correlates of more proficient L2 acquisition. First, it was shown that the behavioral effect of stimulation on novel L2 grammar acquisition in the auditory modality was smaller than that in the visual modality as observed in the previous tDCS experiment. Second, both active and sham stimulation groups exhibited qualitatively distinct ERPs from the more advanced participants in the first EEG experiment. Third, while both active and sham stimulation groups processed the novel grammar in qualitatively similar ways, the higher task performance observed in the active group was associated with greater overall cognitive efficiency, characterized by smaller magnitude and shorter-lasting potentials. Finally, the active stimulation group exhibited a distinct correctness feedback-evoked potential, indicating that effective grammar acquisition is characterized by distinctive processing of feedback.

In this dissertation, I have demonstrated from multiple investigate perspectives the importance of stimulus modality on L2 acquisition, an often-overlooked aspect of experimental design in neurolinguistics. I have also provided the first direct evidence of the causal role that Broca's area plays in L2 acquisition. Finally, I have provided the first insights into the neurophysiological effects of the first stages of L2 acquisition as induced

by Broca's area stimulation. Taken together, these results represent novel findings of fundamental importance to our collective understanding of the neural basis of second language acquisition.