

Neural Mechanisms of Acupuncture stimulation on Cognitive reserve using fNIRS

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- Cognitive reserve (CR) exerts a dual effect on working memory, acting as a neuroprotective booster in healthy individuals but posing a cognitive burden in cognitively impaired groups.
- The right DLPFC serves as a key neural correlate of CR, showing a compensatory increase in activation in patients with high CR, unlike the lower activation pattern seen in healthy controls.
- A significant positive correlation between network assortativity and CR suggests that 'rich-club' network structures provide the neural substrate for brain resilience and efficient information processing.

INTRODUCTION

Dementia is a clinical syndrome characterized by a progressive decline in various cognitive domains. Since there is still no treatment for dementia, early diagnosis and prevention are the best approaches.

In this context, the cognitive reserve (CR) concept has received considerable attention in dementia research with regard to prognosis. It originates from discrepancies between the degree of brain pathology and clinical manifestations. Generally, CR has been measured through CR proxy, such as education, occupational complexity, questionnaire, and bilingualism.

Meanwhile, in East Asia, acupuncture is one of the most widely used alternative interventions for neurological disorders. The effect of acupuncture therapy has been explored using various neuroimaging methods such as fMRI, MRI, and fNIRS. A systematic review dealing with 13 AD-related neuroimaging studies found that acupuncture may modulate the default mode network, the central executive, and the frontoparietal networks in the brains of AD patients. However, on the macroscale, the acute neural mechanisms of acupuncture stimulation in relation to CR according to disease status are largely unknown. In this study, we try to investigate the mechanisms of acupuncture stimulation on cognitive reserve in normal aging and cognitively impaired groups using fNIRS.

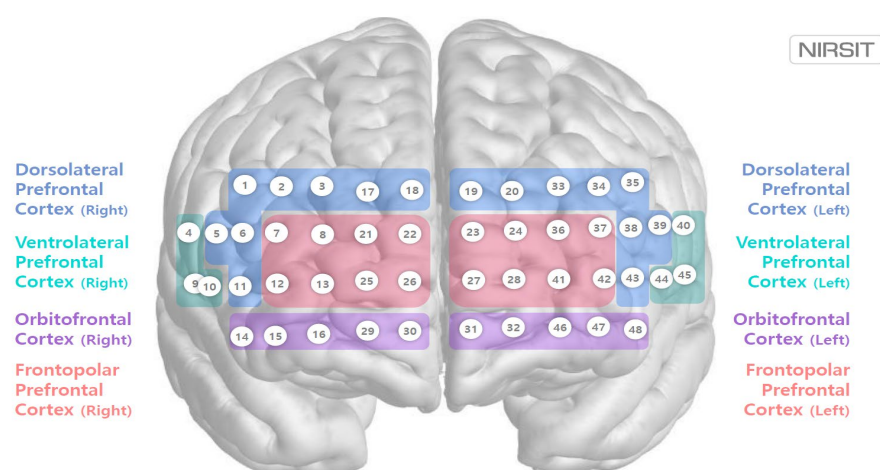


Fig. 1. 48 ROIs of Frontal areas using fNIRS

METHODS

Design: A randomized, placebo-controlled trial

Participants: Cognitively unimpaired (HC, N=39) and cognitively impaired group including dementia and MCI (N=29) measured for CRIq (Cognitive Reserve Questionnaire)

Intervention and controls: The study group received acupuncture stimulation at the genuine acupoint known to be effective in cognitive decline, and the control group received acupuncture stimulation at the sham acupoint.

CR index: CRIq, CR_education, CR_working activity, CR_leisure time

Modality: resting state fNIRS and task fNIRS(working memory task)

Neuroimaging Methods: We acquired 5 min resting state fNIRS data before and after acupuncture stimulation and also task fNIRS data (corsi block task). For network analysis, the frontal lobe was divided into 48 regions of interest (ROIs), and global network metrics—such as global efficiency, clustering coefficient, assortativity, and betweenness centrality—were calculated(Fig. 1).

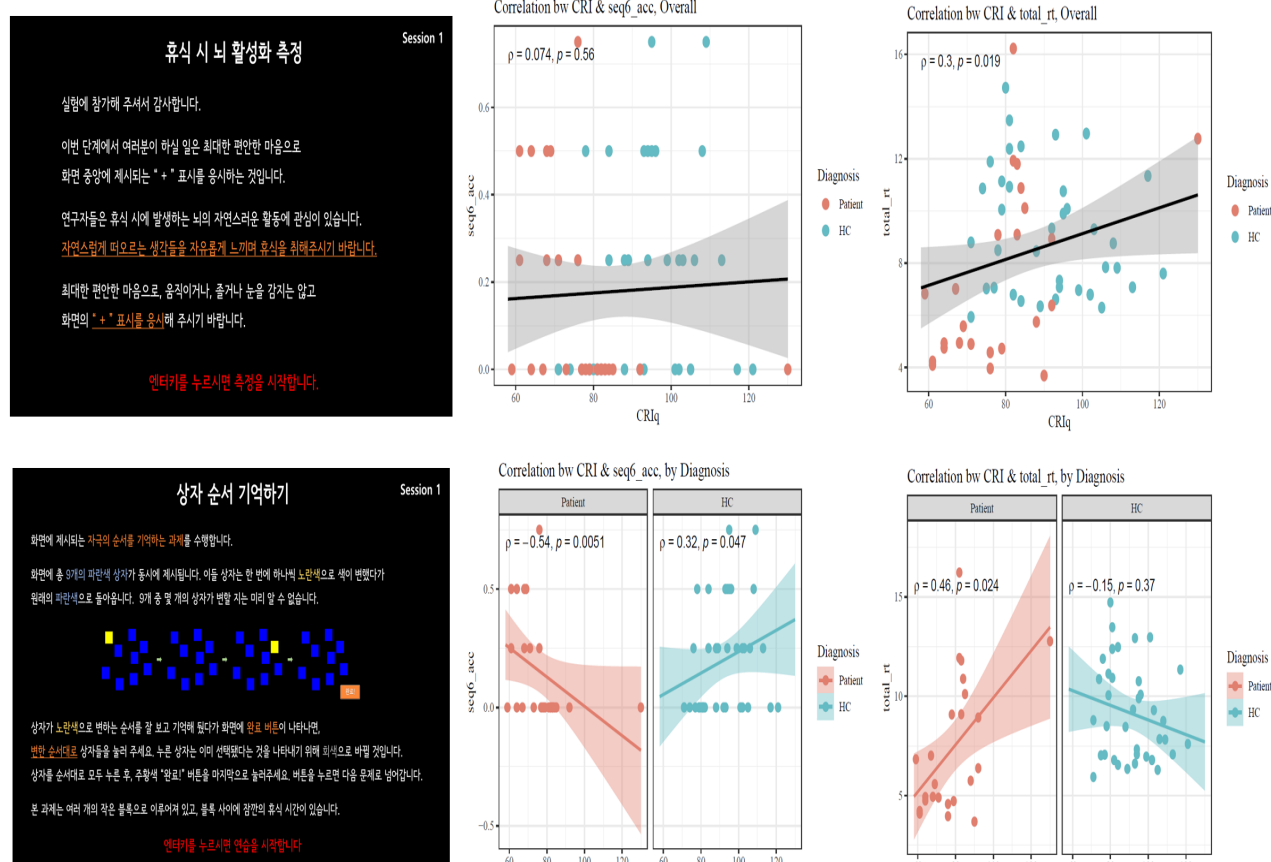


Fig. 2. Corsi block task paradigm and experimental results(accuracy, reaction time)

RESULTS

In the HC group, higher cognitive reserve (CRIq) was associated with greater accuracy in the working memory task. In contrast, the patient group exhibited a reverse pattern, where higher cognitive reserve was linked to decreased task accuracy. A similar divergence was observed for reaction times(RT): in healthy controls, higher cognitive reserve predicted faster RT, whereas in patients, it was associated with slower RT(Fig. 2).

Regarding the neural substrates associated with cognitive reserve, task activation in the right dorsolateral prefrontal cortex (Rt. DLPFC) emerged as one of the key regions showing a significant association with cognitive reserve indices (CR_working activity). In the patient group, higher cognitive reserve was linked to increased activation in this region. Conversely, the HC group exhibited a negative correlation, where higher cognitive reserve was associated with decreased activation.

Among brain network metrics, assortativity showed a significant correlation with cognitive reserve indices, specifically the CRIq and CRI-leisure time (Fig. 3).

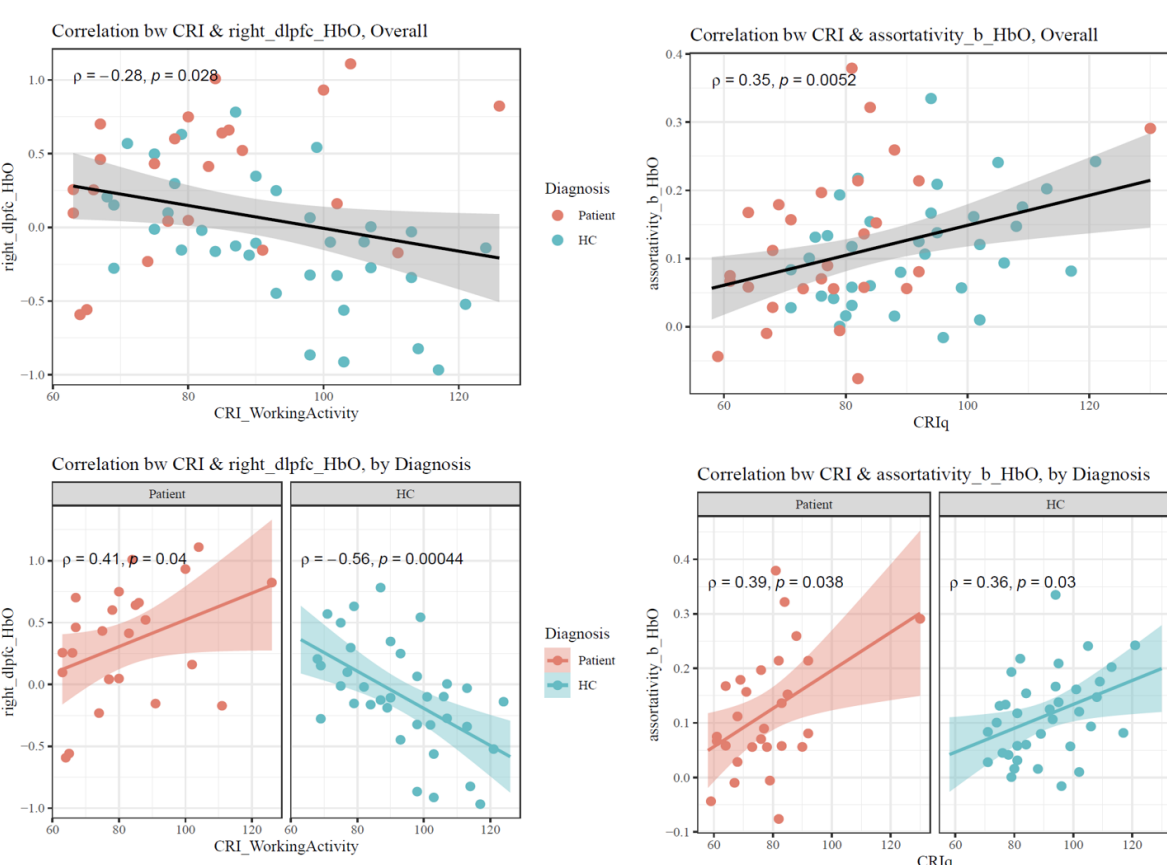


Fig. 3. Brain activation regions and network metrics showing a significant correlation with the CR index

CONCLUSIONS

In this study, we aim to identify the mechanism of acupuncture stimulation on CR in normal aging and cognitive impaired groups and to explore the neural correlates of CR.

Based on the results of working memory task, we confirmed that while the CR boosts cognitive function and exerts a neuroprotective effect in healthy individuals, it acts as a cognitive burden in cognitively impaired individuals.

Furthermore, the right dorsolateral prefrontal cortex (DLPFC) emerged as a region showing significant activation in relation to cognitive reserve; this suggests that while high cognitive reserve in the patient group led to increased compensatory activation in this area, less activation was observed in the healthy control group. Finally, assortativity reflects the tendency of highly connected major nodes (hubs) in the brain to connect with each other, forming a "rich-club" network. Because this structure allows other hubs to compensate for functions if a specific hub is damaged, it serves as an indicator of brain information processing efficiency and resilience. By confirming a significant positive correlation between these indices and cognitive reserve, it was possible to explore the neural substrates of CR in fNIRS-based functional brain imaging research.

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