Brain dynamic changes during different grasping tasks: a pilot fNIRS-EEG multimodal study

Xiaohan Wang[1], Huijing Hu[1], Le Li[1, *]
[1] Institute of Medical Research, Northwestern Polytechnical University, Xi'an, China
Email: lile5@nwpu.edu.cn

Summary

This study aims to implement a multimodal fNIRS-EEG synchronous acquisition system, combining functional near-infrared spectroscopy (fNIRS) and electroencephalography (EEG). Based on the multi-modal acquisition system, this study designed experimental paradigms for different grasping tasks to explore the activation degree of different brain regions and the cross-regional information transmission mode in the process of hand fine motor control, and further analyze the neural mechanism of hand fine motor control. Finally, this study provides a theoretical basis for revealing the neural mechanism of impaired hand motor function after stroke through multimodal neural signal analysis.

Introduction

Rehabilitation robotics has increasingly focused on hand motor function recovery [1]. A study emphasized the importance of fine motor skills in finger grasping, particularly two-finger, three-finger, and five-finger grasps, which are essential for daily activities [2]. Stroke survivors often experience upper limb dysfunction, including impaired fine motor skills, which hinder daily living and reduce quality of life [3]. In recent years, EEG-fNIRS multimodal studies have been increasingly used in cognitive neuroscience, neurological disease diagnosis, brain computer interface and other fields, which can avoid the limitations of a single model and improve the accuracy of assessment [4]. Therefore, based on the fNIRS-EEG multimodal synchronous acquisition system, this study designed various hand movements to investigate the neural activation mechanisms across different tasks, providing theoretical basis for further research on hand motor function rehabilitation post-stroke.

Methods

In this study, a custom-designed fNIRS-EEG dual-mode electrode cap was employed, based on the 32-channel EEG cap of the international 10-20 system, and integrated with connectors for the fNIRS photodetectors. EEG signals were recorded using the ZhenTec NT1 system (ZhenTec Intelligence, China), which utilized 32 electrodes at a sampling frequency of 500 Hz. fNIRS data were simultaneously acquired using the multi-channel NirSmart system (Danyang Huichuang Medical Equipment Co. Ltd, China) at a sampling rate of 11 Hz. Four healthy subjects performed four motor tasks: five-finger extension, five-finger, three-finger, and two-finger grip, with each task consisting of both continuous and periodic force conditions. The subjects also performed a 5-minute resting task before and after the experiment.

Results and Discussion

In the activation results of fNIRS brain region, we found that different grasping tasks had a certain activation trend compared with the resting state (Figure 1(A)). Under the same force task condition, the activation of the fast periodic force task is higher than that of the continuous force task. Further, we found that in the continuous force task, although the force task lasted for 20 s, we found that there was a peak value around 6-8 s, and then a downward trend. In the fast periodic force task, we can see that the 20 s force task is in a continuous activation state, and there is no obvious downward trend (Figure 1(B)). The EEG results further indicated that event-related desynchronization (ERD) occurred in the C3 region during the two-finger grip and five-finger extension tasks in the fast periodic force condition (Figure 1(C)).

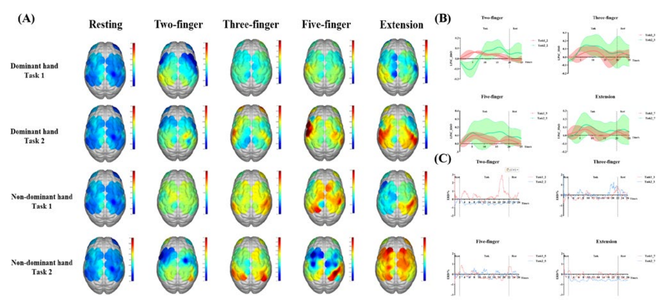

Figure 1: (A) The changes in cerebral blood oxygen activation of fNIRS; (B) The concentration changes in time for HbO averaged over subjects in different grasping tasks; (C) The ERDS changes in time averaged over subjects in different grasping tasks.

Conclusions

This study explored changes of neural activation in the brain under different grasping motor tasks, providing theoretical foundation for the development of personalized hand fine motor rehabilitation for stroke patients.

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