Disruption of alpha and low-beta functional brain networks in chronic stroke during affected body movements

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INTRODUCTION

- Motor impairment including upper extremity is most prominent symptom after stroke, and the motor impairment is associated with patients' abnormal brain activities.
- To address altered functional brain characteristics in stroke patients, electroencephalography (EEG)-based neurophysiological biomarkers have been investigated, such as event-related desynchronization (ERD) in alpha and low-beta frequency bands.
- However, it is not clearly discovered that mechanisms of brain networks involved in movements of stroke patients' affected bodies.
- The aim of this study is that we investigated abnormal functional brain characteristics of stroke patients when moving both their affected- and unaffected bodies in terms of not only ERD, but also brain network indices (strength, clustering coefficient, and path length).

METHOD

Materials

- **Subjects**: 34 patients with chronic stroke (15 males; mean age, 60.9; age range, 29-80)
- **Fugle-Meyer Assessment (FMA) score** was obtained to evaluate a comprehensive motor impairments in stroke patients (range, 0-66).
- **Experimental paradigm**
  - The hand-extension movement was performed.
  - A single trial consisted of a hand-extension movement of 3 s, followed by a relaxation of 5 s, which was iterated 10 times in a single session.
  - A total of 8 sessions were performed (4 sessions – affected hand movement; the other 4 sessions – unaffected hand movement).

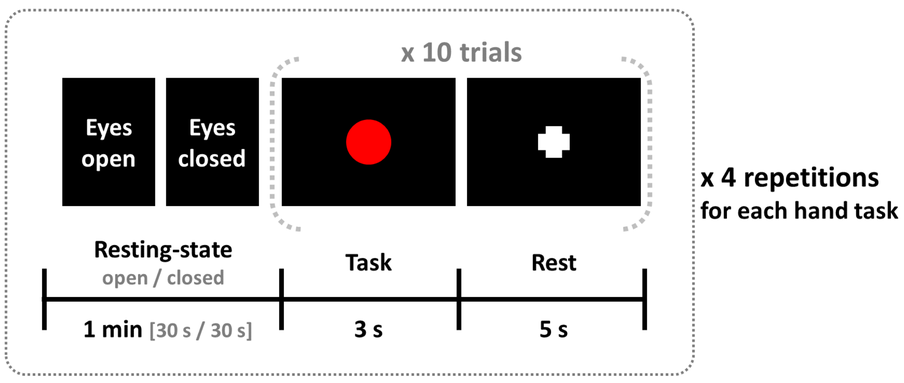

Figure 1. Schematic diagram of the hand-movement task.

- **EEG recording and preprocessing**
  - EEG recoded during performing task using 32 channels Brain Products (sampling rate: 1,000 Hz, reference: FCz)
  - Eyes-related artifacts were removed by Curry 7 software.
  - Rejected artifacts (±100μV) and bandpass filtered rom 0.1 Hz to 55 Hz
  - EEG data were segmented from -1 s to 3.5 s based on task onset
- **Event-related spectral perturbation (ERSP) analysis**
  - Individual alpha frequency (IAF) was computed using eyes-closed resting-state EEG data by detecting a maximum power peak between 7 Hz and 12 Hz at Oz channel.
  - Based on IAF, alpha [8-12 Hz] and low-beta [12-20 Hz] ERDs were quantified using ERSP methods based on short-time Fourier transform.
- **Brain network analysis**
  - Phase-locking value (PLVs) was computed to use as adjacency matrix.
  - Based on graph theory, four different network indices were evaluated – strength, clustering coefficient, path length, and small-worldness.
- **Statistical analysis**
  - A two-way repeated measures analysis of variances (rmANOVA) was performed (with within-subject factors of the task and the hemisphere).
  - A post-hoc paired *t*-test analysis was performed with adjusted two-side *p*-value using the false discovery rate (FDR) method.

RESULT

ERSP results

- A significantly stronger low-beta ERD was observed in the contralesional hemisphere, in comparison with that of the ipsilesional hemisphere for both the affected and unaffected hand-movement task.

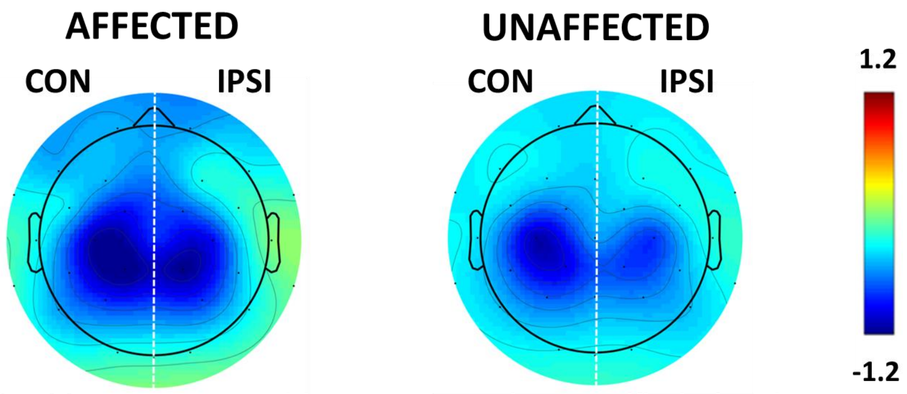

Figure 2. Mean topographic maps and quantified low-beta event-related desynchronization (ERD) over all patients when performing the affected and the unaffected hand-movement tasks, respectively. **CON** means the intact contralesional hemisphere and **IPSI** indicates the damaged ipsilesional hemisphere.

Global-level network characteristics

- Strength and clustering coefficient were significantly reduced, whereas a significantly enhanced path length was found during the affected hand-movement task as compared to the unaffected hand-movement task.

Hemispheric-level network characteristics

- During both affected and unaffected hand-movement tasks, the contralesional brain network was more effective than the ipsilesional brain network for the three network indices (strength, clustering coefficient, and path length) in both alpha and low-beta frequency bands.

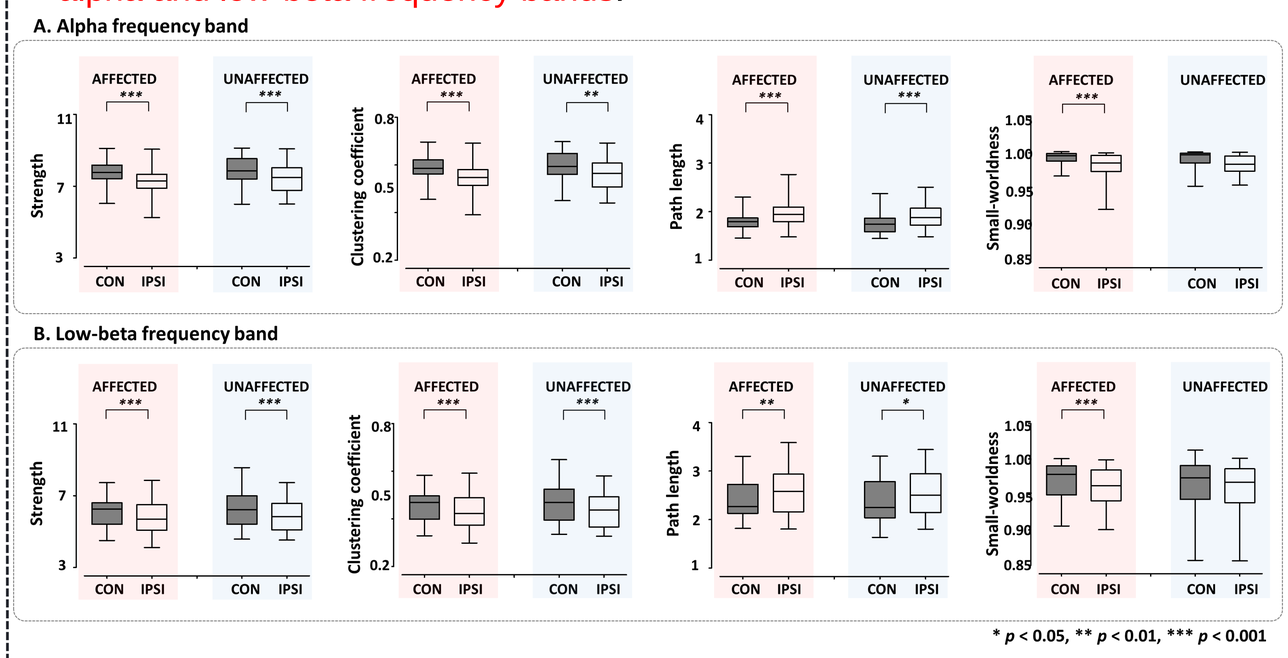

Figure 3. Comparison of the four network indices (strength, clustering coefficient, path length, and small-worldness) between the contralesional hemisphere (CON) and the ipsilesional hemisphere (IPSI) during the affected and unaffected hand-movement tasks, respectively.

Relationships with FMA score

- Alpha ipsilesional brain network indices estimated during the affected hand-movement task were significantly correlated with the FMA scores.

CONCLUSION

- Differences in functional brain characteristics between both hemispheres could be explained from a compensatory mechanism to overcome impairments of stroke patients, verifying the possibility of use as a biological predictor for recovery after stroke.

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