論文 / 著書情報
Article / Book Information

題目(和文)	
Title(English)	Investigating the Neural Representation of Finger-Movement Directions Based on Decoding Approach Using Electroencephalography
著者(和文)	Mohamed Mounir Tellache
Author(English)	Mohamed Mounir Tellache
出典(和文)	学位:博士(学術), 学位授与機関:東京工業大学, 報告番号:甲第12021号, 授与年月日:2021年3月26日, 学位の種別:課程博士, 審査員:吉村 奈津江,小池 康晴,金子 寛彦,八木 透,小尾 高史
Citation(English)	Degree:Doctor (Academic), Conferring organization: Tokyo Institute of Technology, Report number:甲第12021号, Conferred date:2021/3/26, Degree Type:Course doctor, Examiner:,,,,
学位種別(和文)	博士論文
Category(English)	Doctoral Thesis
種別(和文)	論文要旨
Type(English)	Summary

（博士課程）
Doctoral Program

論 文 要 旨

THESIS SUMMARY

系・コース： Department of, Graduate major in	Information and Communications Engineering, Human centered sciences and biomedical engineering 系 コース	申請学位（専攻分野）： Academic Degree Requested	博士 Doctor of (Philosophy)
学生氏名： Student's Name	Tellache Mohamed Mounir	指導教員（主）： Academic Supervisor(main)	Associate Professor Yoshimura Natsue
		指導教員（副）： Academic Supervisor(sub)	

要旨（和文 2000 字程度）
Thesis Summary (approx.2000 Japanese Characters)

This study aims to first, gain a better understanding of the different neural processes that occur during finger movement in the extrinsic and intrinsic frames using electroencephalographic (EEG) recordings by employing a decoding analysis, and second, to explore the common neural commands across individuals by temporally concatenating EEG sets originating from several participants.
EEG is contaminated with artifacts. Eye movements in particular can be problematic as they have a large magnitude and carry information about the movement of the eyes which can be confounded with the neural commands of motor control when using a visual cue.

Independent component analysis (ICA) was used to unmix the EEG signals to mutually temporally maximally Independent Components (ICs) and the properties of the ICs were studied to select the ones reflecting brain activity. To improve the low spatial resolution of EEG, electrical head models were constructed using individual MRI images of each participant. The ICs were then located in the brain by approximating them to equivalent dipoles that have the same projection to the scalp. A set of criteria was used to select ICs representing brain activity, based on their temporal, spatial, and spectral properties.

The time series of the selected ICs were used to decode eight finger movement directions in both the extrinsic and the intrinsic coordinate frames in a leave-one-out cross-validation scheme. Sparse Logistic Regression (SLR) with Laplace approximation was used for classification because it automatically selects the important features. Each participant moved their index finger in eight directions from the center of a circle to the circumference. Adjacent targets were 45° apart. The elbow was extended for half the trials and bent at 90° for the other half. The separation between the extrinsic and the intrinsic coordinate frames was achieved by varying the elbow angle. Classification accuracy of the extrinsic frame (47.97%) was significantly higher than the chance level (12.51%) and significantly higher than the classification accuracy of the intrinsic coordinate frame. This suggests that the selected ICs are biased towards the finger-motion direction, and may reflect visuospatial information rather than information about finger muscles and joints action. A non-parametric permutation test with 5,000 repeats was applied to check the significance of the classification results. Analysis of confusion tables revealed that most false positives occur in the adjacent directions. Consequently, the classification accuracy within -45°, 45° of the desired direction is 75.8 % in the extrinsic frame.

To find the common active brain regions across participants, the selected ICs of all participants were grouped into clusters based on the similarities in their spatial and temporal properties. Fourteen clusters were identified and their centroids were located in several brain regions. These regions were mainly visuospatial areas (e.g. lingual gyrus, superior occipital lobe, precuneus, inferior temporal gyrus, inferior parietal gyrus), motor areas (e.g. precentral gyrus, supplementary motor area), and the cingulate gyrus (posterior cingulate gyrus and anterior cingulate gyrus).

The temporal aspect of the clusters was elucidated by analyzing the decoders' weight matrices. The importance of each data point in the time series of the clusters was defined as the number of times the said datapoint was chosen by the decoders. The critical time periods to the classification from 125 ms to 187 ms were before the EMG onset at 220 ms for visuospatial regions, which is physiologically reasonable. The centroids of the two most important clusters were located in the lingual gyrus and accounted for 20.87% of the contribution to the classification, which further suggests that the decoders used visuospatial information in the time series of the ICs.

The second part of the study aimed to evaluate whether there are common neural commands between different individuals during finger movement. The comparison was performed between individual-level and group-level. For the individual-level, the EEG set of each participant was divided in half. the first half was used to obtain the ICA unmixing matrix and to train the decoders. The unmixing matrix was then applied to the second half and the performance of the decoders was evaluated using the resulting ICs. concerning the group-level, the EEG sets of each five participants were temporally concatenated. The resulting set was used to obtain the unmixing matrix and to train the decoders. The unmixing matrix was then applied to the remaining participant and the decoders were tested on the resulting ICs. Individual-level classification results (38.62%) were significantly higher than chance level (12.87%). Group level classification results (27.26%) were also higher than the chance level (13.44%). The accuracy within -45°, 45° of the desired direction is 70.03% for the individual-level and 62.63% for the group-level. The common brain regions between the two groups were involved in visuospatial processing: lingual gyrus, precuneus, superior parietal gyrus, reorienting of attention: middle frontal gyrus, and motor execution: supplementary motor area. 22 out of 29 clusters were most contributive before EMG onset at 125 to 187.5 ms further solidifying the results of the first part of the study