EEG Measurement Using A Headset with Candle-like Microneedle Electrodes While Walking/Running

Ryo Ichikawa, Takumi Kawana, Yuki Zenba, Takefumi Hiraki, Hiroki Ishizuka, and Norihisa Miki

***Abstract*— An EEG headset with candle-like microneedle electrodes was developed, which takes less than one minute to be set and start measuring EEG without any skin treatment. In this paper, in order to further explore the characteristics of the headset, EEG measurement during walking and running was experimentally investigated. It was found that EEG measurement was successful with a sufficiently small noise while walking, or less than 4 km/h, whereas the measurement in running was not due to the large acceleration of the head.**

***Clinical Relevance*— This shows the performance of our EEG headsets for daily applications and has a positive impact on EEG applications.**

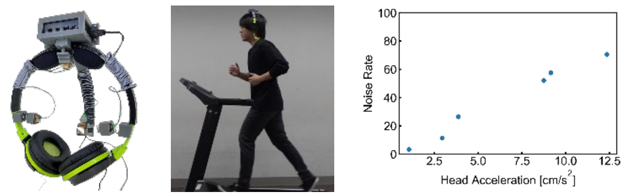
I. Introduction

EEG measurement of untethered users outside laboratories is demanded for promising applications of EEG, such as BMI and neuromarketing. Such measurement mandates EEG measurement systems that can be setup in a short period of time and used for a long period of time without harming the users. Our group successfully developed a candle-like micro-needle electrodes (CME)[1] with pillar structures that automatically avoid hairs and micro-needles that penetrate the stratum corneum to reduce the skin-to-electrode impedance. In addition, we developed an EEG headset with CMEs, which can be setup in less than 1 min and be continuously used for longer than 60 min without providing discomfort to the users (Fig. 1(a)) [2]. However, in these experiments, the users were sitting still in chairs in the lab, which did not represent the scenes of the applications.

In this study, we attempted to measure EEG while the user was walking and running. The acceptable measurement conditions and the dominant factors to prevent the successful measurement were experimentally deduced.

II. Experiments

The experiments were conducted with three subjects using the EEG headset with CMEs and the commercially available OpenBCI headset as a reference. The user wore the headset and walked/ran on a treadmill while EEGs were measured from Cz, T4, T3, and Oz in the international 10-20 system (Fig. 1(b)). First, EEG was measured for 1 min while the user was standing still and then, the treadmill speed increased from 3 to 8 km/h with a 1km/h gap per a minute. Then, EEG was again measured for 1 min while the user was again at rest. The noise rate was defined as the proportion of the signals with the



(a) (b) (c)

Fig. 1 (a) EEG headset with CMEs, (b) A scene of experiments and (c) Head acceleration vs. noise rate.

absolute amplitudes greater than 100 μV. If the noise rate was less than 50%, the EEG measurement was considered to be successful. When the headset with CMEs were used, EMG was also measured from the neck to specify noise factors.

III. Results & Discussion

EEG measurement was successful at the speed smaller than 4 km/h, when the users were walking. However, when the treadmill speed reached 5~6 km/h, the noise ratio suddenly increased to more than 50%. We investigated the correlation of various factors to the noise, among which the walking/running frequency (or speed) and the acceleration of the head showed particularly high correlations with noise ratio(Fig. 1(c)). In our experiments, the thresholds for the frequency, the speed and the head acceleration were found to be 2.34 Hz, 5.3 km/h, and 6.1 cm/s2. The headset with CMEs involved one-fifth at the noise level at rest and one-tenth while walking.

IV. Conclusion

In this study, we experimentally verified that EEG can be successfully measured with the EEG headset with CMEs while the users are walking. This can readily expand the applicability of the EEGs.

References

[1] M. Arai, "Polymer-based candle-shaped microneedle electrodes for electroencephalography on hairy skin", Jpn. J. Appl. Phys., vol. 55, 2016, pp. 4–10.

[2] T. Kawana, Y. Zemba, R. Ichikawa, N. Miki, “Easily attach/detach/reattachable EEG headset with candle-like-microneedle electrodes”, Micromachines vol. 14, 2023, 400.

*Research supported by JSPS KAKENHI Grant Number 20H02121 and JST CREST Grant Number JPMJCR19A2, Japan.

R. Ichikawa, T. Kawana, Y. Zenba, and N. Miki are with the Mechanical Engineering Department, Keio University, Yokohama, Japan.

T. Hiraki is with the Metaverse Lab, Cluster, Inc., Tokyo, Japan.

H. Ishizuka is with the Graduate School of Engineering Science, Osaka University, Osaka, Japan.