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Towards Detecting of Walking Intention from Readiness Potentials for a Powered Exoskeleton Control

Ji-Hoon Jeong, No-Sang Kwak, and Seong-Whan Lee*

Department of Brain and Cognitive Engineering, Korea University, Seoul, Korea

*Seoul 02841, Republic of Korea. E-mail: sw.lee@korea.ac.kr

Introduction: Readiness potential (RP) is an appearance of cortical contribution to the premotor planning of voluntary movement [1]. Due to its characteristics, RP could be a useful feature for brain-machine interface (BMI)-based gait-rehabilitation using exoskeleton. Our final goal is a development of the RP-based lower limb exoskeleton control system without commands by muscle activation. The system may promote brain plasticity efficiently and can offer shorter response time for generating commands than other BMI paradigms. In this pilot study, we propose a self-paced exoskeleton control system using electromyography (EMG) in order to decode the walking intention-based RP signals. We also investigate the artifact influence in the RP patterns under the exoskeleton operation compared with normal walking (without exoskeleton) because the various artifacts in electroencephalography (EEG) signals can be induced by the powered exoskeleton locomotion [2].

Material, Methods and Results: The proposed system consists of the exoskeleton (REX, Rex Bionics Ltd), wireless EEG, and EMG modules (MOVE, BrainProduct GmbH). The system was controlled by movement onset triggers generated by EMG processing; the onset triggers were transmitted to the exoskeleton and EEG module when amplitude became higher than a threshold that determined by one tenth of the maximum value of EMG. The EMG electrodes were attached on the tibialis anterior and biceps femoris muscles of the right leg [3]. The EMG data were processed in real-time using 2s sliding window size with 100ms shift. The EEG data on 32 Ag/AgCl electrodes were band-pass filtered by 2nd Butterworth filter ([0.5 2]Hz) and were segmented into 10s epoch between 4s before and 6s after the movement onset. Three subjects (age: 26-29, 3 males) were asked to perform half step walking (basic walking function of the exoskeleton) and standing repeatedly with 50 trials in the normal walking and exoskeleton walking sessions.

We acquired the grand averaged RP patterns of normal and exoskeleton walking in Cz. To this end, each trial was baseline corrected in [-4 -2]s, and the amplitude was normalized to [0 1]. The RP patterns were detected approximately from -1000 to 0ms in the both sessions.

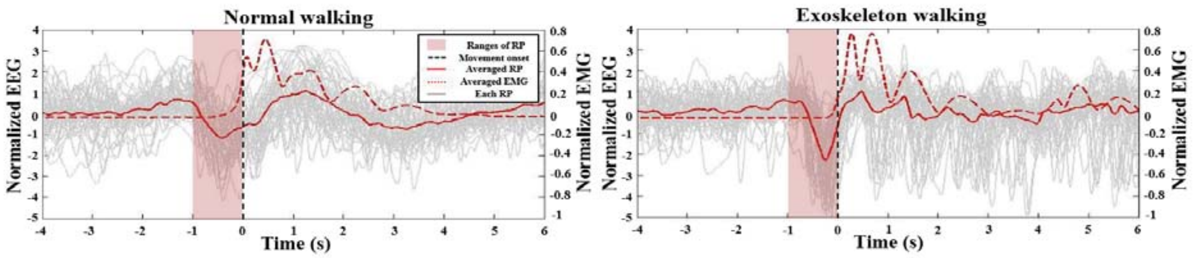

Figure 1. *The grand averaged RP patterns in normal walking (left) and exoskeleton walking (right).*

Discussion: We found the RP patterns in the exoskeleton walking as well as normal walking during [-1 0]s (Fig.1); specifically, negative slope appeared before the movement onset by EMG activation. Also, we confirmed that EMG signals showed similar muscle activation patterns (average and std) in the both sessions. However, the EEG patterns showed large variations in exoskeleton walking ([0 6]s) compared to normal walking in each trial; the exoskeleton operation time requires approximately 6s. For the RP based asynchronous control in the single trial, misclassification of user intention due to artifacts induced by exoskeleton walking should be minimized. Hence, gait-related artifact removal techniques in low frequency will be investigated in our future work.

Significance: We compared the grand averaged RP patterns of both walking sessions through the proposed system. We confirmed artifact influence in the EEG signals during exoskeleton walking. Our results show feasibility of the RP-based powered exoskeleton control system for BMI-based gait rehabilitation.

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