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R-6 Asynchronous Brain Computer Interface Control of a Walking Simulator

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Background and Objective

Individuals with paraplegia due to spinal cord injury (SCI) are unable to ambulate. Current systems using functional electrical stimulation (FES) provide an alternative method for standing support and ambulation, but their operation requires a manual control box, which is unintuitive. Electroencephalogram (EEG) driven brain-computer interfaces (BCIs) can potentially integrate with FES technology to restore brain-driven, intuitive ambulation to these patients. Here, we describe the design and successful implementation of an “intuitively?operated BCI-controlled walking simulator.

Methods

Subjects and Training Data Acquisition: EEG signals from three healthy subjects were acquired using a 32-channel EEG cap and amplifier (Nexus 32, Mind Media, The Netherlands) using 10-20 International Standard and common average referencing. Training data was collected while subjects performed motor imagery (MI) as they watched a video of a 3D avatar alternating between five minutes of standing and walking. Signal Processing and Classification: EEG signals were divided into 4-sec segments, resulting in 75 samples for each mental state. Spectral energies in 6 ?26 Hz band were calculated using Fourier transform. Classwise principal component analysis and linear discriminant analysis reduced the input dimensions to 1D feature space. Linear Bayesian classifier was used to classify the mental state. Evaluation of BCI Control: Subjects were seated in front of a computer screen, while EEG data were acquired and classified. A 3D avatar in an open field virtual environment (VE), using Garry's Mod for Half Life 2 (Havok Engine, Valve Corporation, Bellevue, Washington), was displayed from a third-person, "over-the-shoulder?perspective. Subjects were instructed to use walking MI to move his/her avatar to greet a series of 10 "non-player character (NPC)?positioned along a linear path in front of the subject's avatar, similar to Leeb et al [1]. Subjects must stop within a proximity of the NPC and stand still long enough to receive a verbal greeting. After this greeting, subjects were to initiate walking towards the next NPC until all 10 were greeted.

Results

All subjects obtained meaningful control immediately. Subject 1 averaged 6.8?.8 NPC greetings per trial. Subjects 2 averaged 8.0?.0 NPC greetings per trial. Subject 3 averaged 7.0?.16 NPC greetings per trial. When compared to simulated random walk (2.7?.3 NPCs), these subjects demonstrated purposeful control ($p < 0.0001$).

Discussion and Conclusions

An asynchronous BCI was successfully implemented to control ambulation in a VE. Linear ambulation in a VE is the closest scenario to actual use of a potential BCI-controlled FES device, demonstrating that such a concept may be imminently feasible. In addition, employing automated signal analysis techniques described in [2], allowed for setup without manual selection of EEG channels or signal features, and subjects could utilize a "natural?MI, i.e. walking MI to walk in the VE. Together, these allowed users to gain immediate control, which may have implications in practical clinical BCI applications. Further studies are necessary to implement other degrees of freedom of control, such as turning left and right, and to determine if this technique can be extended to individuals with paraplegia due to SCI.

References

1. Leeb R, Friedman D, Müller-Putz GR, Scherer R, Slater M, Pfurtscheller G. Self-Paced (Asynchronous) BCI Control of a Wheelchair in Virtual Environments: A Case Study with a Tetraplegic. Comput Intell Neurosci. 2007:79642. 2. Das K, Rizzuto DS, Nenadic Z. Mental State Estimation for Brain-Computer Interface, IEEE T. Bio-med. Eng., vol. 56 (8), pp. 2114-2122, 2009. Support: This project was supported by funding from the Roman Reed Spinal Cord Injury Fund of California (RR 08-258, and RR 10-281).

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