BCI-Controlled Videogame for Cerebral Palsy Children

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Abstract. We describe a brain-computer interface (BCI) controlled videogame by integrating a custom made wearable 8-channel wireless EEG system, which samples and wirelessly transmits the EEG and EOG signals to a laptop. The laptop runs a shooting videogame using the features derived from the EEG and EOG. Sixteen cerebral palsy (CP) children were trained to play this game for one month (one hour per week). Their sustained attentional level after training was able to be maintained long enough for exploding the bomb in the videogame for more than 80% of the 30 cues in a 5-min game form the the originally 50% or less before training. These CP children then participated in the Second Mid-Taiwan Assistive Device Videogame Contest in Taichung on Dec. 29, 2012.

*Keywords:*Wireless EEG; Brain-computer interface (BCI); Cerebral palsy; EEG; EOG; Computer game

1. Introduction

Cerebral palsy (CP) children are mostly limited by the activity in their extremities and lack of capability in communication, they are thus in need of assistive devices for conveying their thoughts, training for their skill of communication, and even providing them with entertainments for enriching their life. However, such assistive device can be very specific in terms of how and what purpose the CP patients may use the device. For example, they might not be able to control a device using their hands or feet. As a result, the assistive device may need to utilize the still functioning muscles, such as eyes, cheeks, etc.

Recently, brain-computer interface (BCI) creates the possibilities to utilize the EEG features related to the brain processes of, for example, the P300 activity, motor execution, motor imagery, attentional level, and steady-state responses, etc. [Avanzini et al., 2012; Krusienski et al., 2007; Lim et al., 2012; Pfurtscheller and Neuper, 1997], and use them to control an assistive device, such as moving a cursor. Such a form factor should well fit the requirement of a CP patient due to their lack of muscle activity in their extremities. Here we devised a BCI-based videogame for the CP children to play using their EEG/EOG and, ultimately, to train their sustained attentional level.

2. Material and Methods

2.1. Subjects

A group of 16 CP children were trained to play this videogame and they then participated in an Assistive Device Videogame Contest hosted the Biomedical Engineering Research Center of China Medical University (CMU) in the Love Home of Taichung City, Taiwan on Dec. 29, 2012 (Fig. 1a). The parents and the teachers of these CP children gave the signed informed consent and the agreement for participation for them. The institutional review board of CMU Hospital approved the training process was conducted at Hermei Experimental School, Changhua, Taiwan.

2.2. 8-channel Wireless EEG System

A custom made 8-channel wireless EEG system provided high quality EEG and EOG sampled at 2 kHz per channel with 24-bit resolution. The device weighed 82 g (80 x 50 x 30 mm^3, including battery) and ran on a rechargeable battery for more than 20 hours. The acquired signals were transferred to a PC through a Bluetooth 2.0 channel. Given the ultra lightweight and easy to apply characteristics, the wireless EEG system was very suitable for on-line real-time EEG application, such as BCI. On the other hand, the electrodes used for this training were simply the self-adhesive ECG electrodes used regularly in the clinical environment to ease the application such that the training could be performed at the Experimental School site, where laboratory preparation was not available.

2.3. EEG and EOG Features for Controlling the Videogame

Two-channel EEG from the left and right forehead and one-channel EOG at right canthus were used to control the two actions of the videogame: one for shooting the alien spaceship and the other exploding the bomb. First, the eye blinks were detected from the EOG channel and used to fire the machine gun for 4 . Then, the player needed to blink again to resume the shooting (Fig. 1b). Alternatively, for every 10 s (varied from 8-12 s), a green bear's paw (the bomb) would appear and cease all actions on the screen for 4 s. During this time period, player was required to maintain his/her attentional level such that the green bear's paw would turn yellow and red and, finally, explode to clean all the alien spaceships to gain bonus (Fig. 1c). The EEG features used to derive the sustained attentional level were based on the real-time theta to alpha power ratio extracted from the two EEG channels on the participant's forehead. The performance of the players was evaluated with the percentage (thus, how many times out of the 30) of cases that they could successfully maintain their attentional level to explode the bomb in a 5-min game.

2.4. Training Cerebral Palsy Children to Use the BCI-controlled Assistive Device

Each of the participating CP children was trained once a week for 4 weeks. Each training session lasted for around an hour depending on the condition of the CP child. During the training session, the two channels of EEG and the one channel EOG were recorded for further analysis. The percentage of accurately exploding the bomb using their attention level was also recorded for comparison.

(a) (b) (c)

Figure 1. *(a) The Assistive Device Videogame Contest. (b,c) Operation of the shooting videogame.*

3. Results

After training, all the CP children significantly improved the performance in maintaining their attentional level. More than 80% of the case, the participants could maintain their attentional level for up to 4 s and explod the bomb in the game. Such success rate was initially 50% or less before training. The videogame was then made to end in 5 minutes so as to be used in the Mid-Taiwan Assistive Device Videogame Contest.

4. Discussion

BCI-based assistive device is one of the most effective forms for the CP children due to their limited muscle control for their extremities. Although the CP children participated in the training and the videogame contest were only trained for a month, the effectiveness of the training was reflected in their high accuracy in controlling the videogame as well as the performance in their class, especially in multi-task performing, according to their teachers.

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