TELMYOS – a telemetric wheelchair control interface based on the bilateral recording of myoelectric signals from ear muscles

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Introduction

In individuals with tetraplegia wheelchair mobility is an important prerequisite for social and professional participation. However, 50% of individuals with tetraplegia find it hard or impossible to perform simple wheelchair tasks with traditional control interfaces, such as chin or head control, or sip-and-puff controllers, which severely interfere with communication or head orientation. An established way of controlling assistive devices is the use of electromyographic (EMG) signals. In contrast to evolving technologies based on non-invasive brain computer interfaces, EMG-based control is robust and has a high information transfer rate. The auricular muscles represent an ideal source for myoelectric wheelchair control because of their availability even in individuals with high-level tetraplegia, minimal interference with other activities, and easy accessibility.
The aim of this study was to develop a wireless myoelectric auricular control system (ACS) based on bilateral recording of the EMG activity of the posterior auricular muscles (PAMs), and to investigate its feasibility and performance for powered wheelchair driving.

Methods

EMG was recorded from the PAM of each side with two subcutaneous fine-wire electrodes per PAM for simple, intuitive wheelchair steering (e.g. left contraction = driving left). A clip earlobe electrode was used on each side as a reference. The differential EMG signals were amplified (gain = 1.000), band-pass filtered (4th order Butterworth filter, 20-1.000 Hz), digitized (sampling frequency 2.000 Hz), digitally down-sampled to 125 Hz, and sent via a proprietary ZigBee interface to a specifically developed software. Here, EMG raw signals were rectified, integrated, normalized to the activity level during maximum contraction and converted into wheelchair steering commands. If the normalized signal was higher on the left/right side, the wheelchair turned left/right. If both PAMs were equally activated, the wheelchair was propelled straight ahead. Speed was set dependent on the duration and strength of the co-activation.
Subjects with tetraplegia due to a cervical spinal cord injury (SCI) should perform four days (S1 – S4) of computer training (40 min each) and real wheelchair driving (30 min) on the fifth day (S5). In the training sessions, the participants were allowed to choose from a car race, Tetris, collecting coins and a virtual obstacle course. These games were especially designed to train the lateralized PAM activation and to precisely grade the control signal. The training effects were measured with eight performance tests (20 min) in each session and before (S5a) and after (S5b) wheelchair driving through a complex real-world obstacle course.
The subjects' satisfaction with the ACS was assessed by standardized questionnaires (NASA Task Load Index (TLX), Assistive Technology Device Predisposition Assessment (ATD-PA) = expected benefits of assistive devices from 0=0% of the time to 5=100% of the time).

Results

Two subjects with SCI (T1: Neurological level of injury (NLI) = C5, ASIA Impairment Scale (AIS) A; T2: NLI = C3, AIS C) participated in the study. T1 classified himself as an "ear-wiggler"; T2 as a "non-wiggler". All performance parameters such as contraction rate, lateralized activation, wheelchair speed and path length in a virtual obstacle course improved steadily over the training period in both subjects. T2 needed 35 s less at the end compared to onset of training to complete the virtual navigation course (S1: 139.5 s, S5a: 104.9 s). T1 improved by 20 s, although his initial performance was already high (S1: 91.0 s, S5a: 71.6 s). By day 5, the subjects successfully completed (T1: 86 s; T2: 201.6 s) the real obstacle course (S5b). Both had one collision, but still managed to complete the navigation task afterwards (Figure 1).

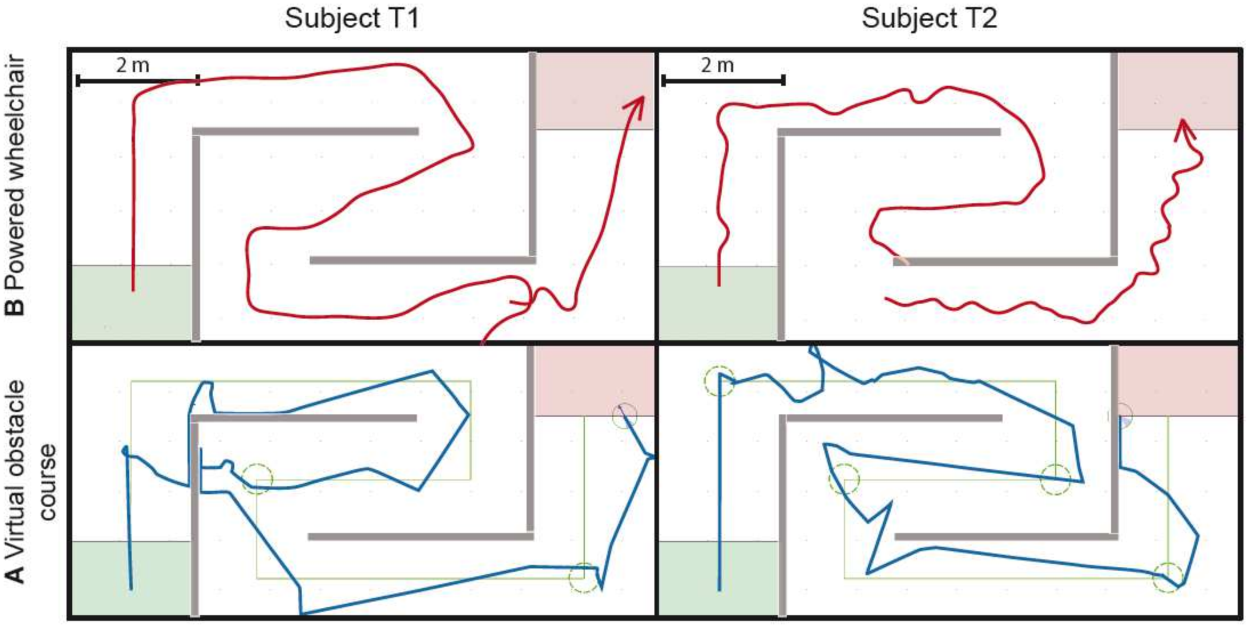

Figure 1: Navigation of T1 and T2 in a virtual (A, blue lines) at S1 and real obstacle course (B, red lines) at S5b.

The TLX shows a low general workload for subject T1 (M=27) and medium general workload for T2 (M=57). Temporal demands and frustration did not matter for both subjects. In the ATD–PA T2 gave a more positive rating (M=4.4) than T1 (M=3.8).

Conclusion

This study indicates that the ability to activate PAMs can be learned by persons with high SCI and used to steer a wheelchair intuitively. The inherent advantages of the ACS such as not interfering with oral communication, robustness and stability over time and precise signal generation meet the specific needs of wheelchair users and render it a realistic alternative to currently available control interfaces.

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