Available online at www.sciencedirect.com

ScienceDirect

Procedia Computer Science 121 (2017) 238–243

Procedia Computer Science

www.elsevier.com/locate/procedia

CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies, CENTERIS / ProjMAN / HCist 2017, 8-10 November 2017, Barcelona, Spain

Multimodal approach for polysensory stimulation and diagnosis of subjects with severe communication disorders

Czyzewski A[a*], Kostek B[b], Kurowski A[ab], Szczuko P[a], Lech M[a], Odya P[a], Kwiatkowska A[a]

[a]*Faculty of Electronics, Telecommunications and Informatics, Gdańsk University of Technology, Narutowicza 11/12, 80233, Poland*
[b]*Audio Acoustics Laboratory, Gdańsk University of Technology, Narutowicza 11/12, 80233, Poland*

Abstract

An experimental multimodal system, designed for polysensory diagnosis and stimulation of non-communicative subjects, with severe brain injuries is presented. The user interface uses an eye-tracking device and EEG monitoring of the subject. The system is evaluated on 9 patients, data analysis methods are described, and experiments of correlating Glasgow Coma Scale with extracted features describing subjects performance in therapeutic exercises exploiting EEG and eyetracker are presented. Performance metrics are proposed, and k-means clusters used to define concepts for mental states related to EEG and eyetracking activity. Finally, it is shown that the strongest correlations are between the number of detected mental states and GCSe score, and between maximal length of mental state and GCSm. Weaker correlations are reported as well. Moreover an approach to classification of real and imaginary motion of limbs is presented and discussed. Classifiers based on SVM, Artificial Neural Networks, and Rough Sets were trained and accuracy reaching 91% for the real, and up to 100% for the imaginary type of motion was observed. Assessments of communication skills and therapy is possible with the system, already employed in long-term care facility.

Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies.

* Corresponding author. Tel.: +0-000-000-0000 ; fax: +0-000-000-0000 .
E-mail address: ac@pg.edu.pl

1877-0509 © 2017 The Authors. Published by Elsevier B.V.
Peer-review under responsibility of the scientific committee of the CENTERIS - International Conference on ENTERprise Information Systems / ProjMAN - International Conference on Project MANagement / HCist - International Conference on Health and Social Care Information Systems and Technologies.
10.1016/j.procs.2017.11.033

Keywords: communication disorders; brain injuries; polysensory stimulation; EEG; electroencephalography; multimodal interfaces; imaginary motion

1. Introduction

Each year in Europe approx. 300 people for every 100,000 people suffer from traumatic brain injury (TBI), usually due to traffic accidents[1]. It is estimated that 1 in 8 subjects with severe brain injury fall into a long-term coma or a vegetative state. From diagnostic and rehabilitation points of view, the key problem is the lack of communication with such patients, in up to 40% cases leading to erroneous diagnosis[2]. The multimodal stimulation and diagnosis system developed at the Gdańsk University of Technology, is an innovative solution for diagnosis and rehabilitation of subjects considered to be in a vegetative state. This system integrates different technologies: eye-gaze tracking, EEG analysis, and scent emission for stimulating purposes. The paper presents this multimodal approach and preliminary experiments in human-machine communication. It is organized as follows. Sec. 2. describes developed and implemented multimodal system for patient stimulation and monitoring, Sec. 3 presents results of patients performance assessment and correlation with their Glasgow Coma Scale scores, Sec. 4 documents a methods and results of EEG analysis and classification aimed at recognizing intent of motion, dedicated to HCI user interface. Sec. 5 concludes the paper.

2. Multimodal stimulation and monitoring setup

The developed system assumes various phases of operation: first an objective testing of hearing, then monitoring of brain activity and user gaze, and finally visual and aromatic stimulation. Auditory evoked potentials (ABR - Auditory Brainstem Response) were chosen for their advantages: it is objective and non-invasive, and requires the subject only to stay relaxed, e.g. during sleep. The examination could last hours, so it is the main disadvantage. Test duration depends on the number and types of test signals, longer for precise measurement of hearing threshold, enabling personalized adjustment of signal levels. ABR uses EEG with defined number and arrangement of electrodes and signal acquisition parameters in a dedicated setup (Fig. 1a, 1b).

EEG typically uses 5 to 20 electrodes arranged symmetrically on the head. In the current research, following EEG devices were used: ENOBIO8 by Neuroelectronics with 8 electrodes, and EPOC and INSIGHT models by Emotiv (Fig. 1c) with 14 and 5 electrodes, respectively. Non-professional EEG might be inaccurate because of large area covered by a single electrode, however, for diagnostic and multimedia applications simple devices can be used, determining concentration of the subject, and overall activity in different brain areas.

EyeX Controller is an eye-tracker for monitoring user attention and reaction to visual stimuli presented on a screen. It records the gaze fixation point x, y coordinates in the monitor screen plane, 60 samples per second[3].

Dedicated software applications developed by our team, incl. therapist's application for managing training; database of anonymized subjects results; player application, used as a polisensory interface for the subject, providing an interaction between user's action (gaze fixation point, EEG reaction) and the elements visible on the screen, the reproduced sound, and the emitted scent. In typical session subject activity is monitored with the use of EEG, eyetracker, and video cameras for a reference. The therapist controlling the session could report events by clicking buttons in his application (the exercise beginning and ending, entrance of random person to the room during the session, pain felt by the subject, movement of the subject, and others). Events are automatically logged in the data file of the eyetracker and are linked with current position of the fixation point. Such events may be tracked later on in the post-processing and then visualized along with the gaze position and EEG signals features.

2.1. System evaluation

The system is validated with the participation of 10 persons with Traumatic Brain Injury from Neurorehabilitation Center, Department of Rehabilitation Medical Center "EPIMIGREN" in Osielsko, Poland. Subjects 01-09 are males, subject 10 is a female, the average age of the subjects was 44.2 years, their Glasgow Coma Scale points 11, 10, 6, 7, 10, 7, 8, 9, 9, 8. The GCS is one of the most popular methods of assessing consciousness of subjects with brain injuries,