 DOI:10.3217/978-3-85125-378-8-9

Cognitive Rehabilitation through BNCI: Serious Games in BackHome

Eloisa Vargiu[1], Jean Daly[2], Stefan Dauwalder[1], Elaine Armstrong[2], Suzanne Martin[3] and Felip Miralles[1]

[1] Barcelona Digital Technology Center, Barcelona, Spain
{evargiu, sdauwalder, fmiralles}@bdigital.org
[2] Cedar Foundation, Belfast Northern Ireland, U.K.
{j.daly, e.Armstrong}@cedar-foundation.org
[3] Faculty of life and Health Sciences, University of Ulster, Northern Ireland, U.K.
s.martin@ulster.ac.uk

Abstract

This paper presents a framework for the development of cognitive skills. In particular, we focus on the definition and provision of cognitive rehabilitation tasks to people with neurological disorders returning at home after a discharge. Those tasks will be executed through a Brain-Neural Computer Interface system and will consist of desktop-based serious games. The framework and the implemented games are part of the BackHome project and are currently under testing at the end-users facilities, in Belfast and Würzburg.

1 Introduction

Cognitive Rehabilitation (CR) is defined as "a systematic, functionally orientated service of therapeutic activities that is based on assessment and understanding of the patient's brain-behavioral deficits" directed toward many areas of cognition, including (but not necessarily limited to) attention, concentration, perception, memory, comprehension, communication, reasoning, problem solving, judgment, initiation, planning, self-monitoring, and awareness [2].

CR is a core intervention in rehabilitation, aimed at restoring function or compensating for a cognitive defect. When cognition has been adversely affected, this is considered a predictor of other important aspects of psycho-social recovery [6]. When a cognitive disability is present, people are limited in their capacity to plan and sequence thoughts and actions, conceptualize ideas, and to interpret the meaning of social and emotional cues, and numbers and symbols [5] [1]. Therapeutic interventions may emerge from established approaches which assist the therapist in the planning and delivery of treatment. A restorative approach focuses on strengthening and improving functional performance that has been impaired by developing cognitive skills and retraining.

In this paper, we focus on the definition and provision of CR tasks to people with neurological disorders (traumatic brain injury) going back to home after a discharge. This research adopted a user centric design philosophy in the development of a rehabilitation tool that would focus on CR to complement and improve upon traditional methods. Tasks will be executed through a Brain-Neural Computer Interface (BNCI) system and will consist of desktop-based serious games [4]. Using desktop-based serious games within therapy is not yet established but emerging. This study provides the novel and unique opportunity to provide CR tasks by relying on a BNCI system.

This work is part of the BackHome project[1] [3]. The CR framework is one of the BNCI

[1] http://www.backhome-fp7.eu/

services provided by the BackHome platform. Moreover, the implemented games are fully integrated in the telemonitoring and home support system developed within the project [7].

2 Method

Working directly with service providers for people with traumatic brain injury, a framework for the development of cognitive skills has been created against which cognitive tasks will be mapped. The adopted framework as well as the implemented games have been defined together with Occupational Therapists and Speech and Language Therapists. Initially, two focus groups were held (N= 8; N=58) to identify the user requirements for the overall system. A research collaboration was then formed with Specialist neurological Occupational Therapists and Speech and Language therapist who have worked with us over the past year to develop and review the various prototype of the CR application. The therapists have meet with the researchers on three occasions to date in the lab (N=10; N=9; N=3). The technical developers integrated the therapist's recommendation into the system for the therapists to review the next iteration of the CR prototype. The system development has been iterative and incremental to enable reflections with the therapists prior to changes in the system becoming permanent.

As shown in Figure 1, the domains emerging with the framework reflect various levels of cognitive complexity: perception, attention and concentration, memory, and executive functions. The sequential approach is important, as problems in lower levels will impact on the ability of the person to advance in their cognitive competencies. The framework provides a backdrop to CR tasks performed using a BNCI system. It also provides a base for the future development of validated CR interventions by therapists with expertise in this area.

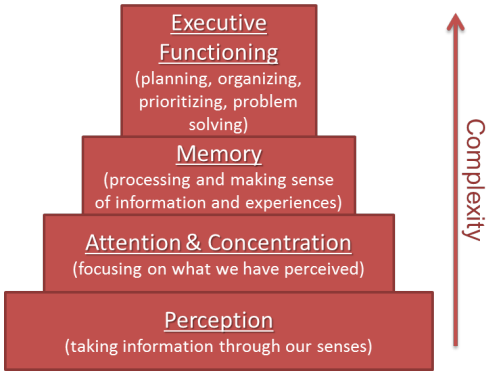

Figure 1: Cognitive skills.

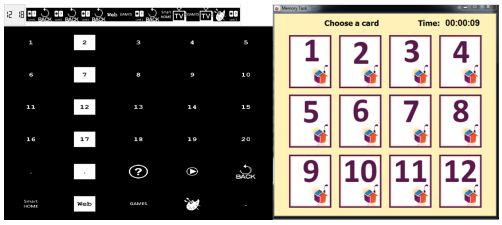

Figure 2: The memory-card game starts with all the cards covered.

3 The Memory-card Game

Currently, two serious games have been defined and implemented: find-a-category and memory-card. In this paper, we presents the memory-card game that is aimed at enhancing memory skills. The game starts showing on the P300 interface all the cards covered (see Figure 2), the user chooses which card turning out and then the second one looking for its pair. If the pair is

not found, the cards are covered again. On the contrary, the game follows with the remaining cards. The game ends when all the pairs have been found.

Different levels of difficulty have been defined, depending on the ability of the user. In particular, difficulty increases by augmenting the number of available cards -i.e., the dimension of the P300 matrix (level 1, 8 cards; level 2, 12 cards; and level 3, 20 cards)- and the complexity of the adopted images (level 1, shapes; level 2, fruits; and level 3, animals). Figure 3-a shows an example for each of the given levels (for the sake of clarity, the P300 matrix has been omitted).

Results are then shown to the user in numerical and graphical view (see Figure 3-b). The numbers of corrected moves with respect to the total moves represents the score. The score for the last 8 played games (a line for each level) is presented. Moreover, the number of moves together with the elapsed time are shown and some statistics given. All the results are also sent to the therapist.

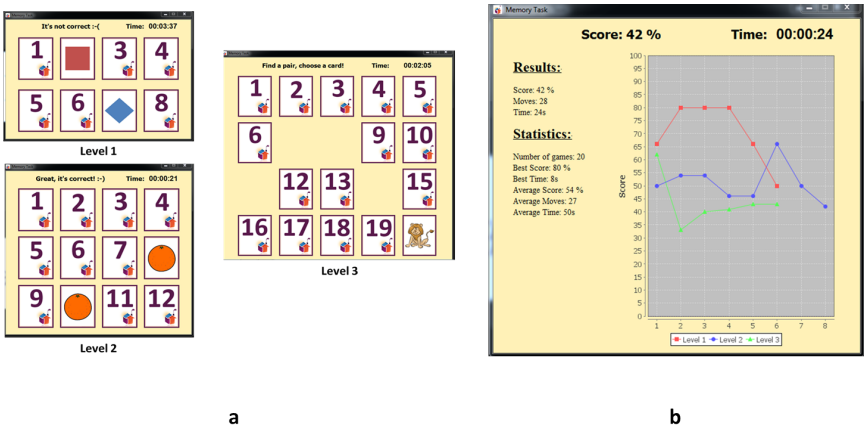

Figure 3: A screenshot of memory-card game for each given level (a) and the results display (b).

4 Discussion

In this qualitative research a user centered approach has been adopted. User centered design is a process of engagement with end users that adopts a range of methods to place the end of user of a technology at the center of the design process in terms of development and evaluation.

It is beyond the scope of our work to develop, validate, and illustrate clinical outcomes. Nonetheless, therapists are able to interact with users in real time, assigning game sessions depending on the level of disability, thanks to a therapist station[2]. Then, they monitor the use and outcomes of the CR tasks to attain therapeutic results. In fact, the ability for the therapist to plan, schedule, telemonitor and personalize the prescription of CR tasks using a therapist station will facilitate that the user performs those tasks inside her therapeutic range (i.e. motivating and supporting her progress), in order to help to attain beneficial therapeutic results.

The second-year-prototype of BackHome integrates all the implemented games as well as the therapist station. That prototype is currently under testing by the end-users of the project,

[2]https://station.backhome-fp7.eu:8443/BackHome

located at Cedar Foundation in Belfast and at the University of Würzburg.

Preliminary experiments have been performed in Belfast at Cedar Foundations premises, a total of N=5 end users with a varying degree of cognitive impairments were involved in the evaluation. We calculated the accuracy (as percentage of correctly chosen symbols) and therefore, asked users during every trial, which cards they wanted to uncover. Results showed an average selection accuracy of 78%. Those users, who had no or low control over the games, had no or low control over the BNCI in general. This was either caused by the severity of their physical impairment or bad EEG signals due to problems with data acquisition.

5 Conclusions and Future Work

In this paper, we presented a framework that provides a backdrop to cognitive rehabilitation tasks performed using a BNCI system. The framework is part of the BackHome project and, according to the cognitive skills that it defines, two serious games have been defined and implemented. The corresponding system is currently under testing by people with traumatic brain injury.

As for the future work, we are currently implementing a daily-life-activity game aimed at improving perception. Moreover, apart serious games, we are also considering defining and implementing cognitive rehabilitation tasks relying on an e-puck robot, which might become especially engaging to users.

Acknowledgments

The research leading to these results has received funding from the European Community's, Seventh Framework Programme FP7/2007-2013, BackHome project grant agreement n. 288566.

References

[1] David Braddock, Mary C Rizzolo, Micah Thompson, and Rodney Bell. Emerging technologies and cognitive disability. *Journal of Special Education Technology*, 19(4), 2004.

[2] Keith D Cicerone, Cynthia Dahlberg, Kathleen Kalmar, Donna M Langenbahn, James F Malec, Thomas F Bergquist, Thomas Felicetti, Joseph T Giacino, J Preston Harley, Douglas E Harrington, et al. Evidence-based cognitive rehabilitation: recommendations for clinical practice. *Archives of physical medicine and rehabilitation*, 81(12):1596–1615, 2000.

[3] J. Daly, E. Armstrong, F. Miralles, E. Vargiu, G.R. Müller-Putz, C. Hintermller, C. Guger, A. Kuebler, and S. Martin. Backhome: Brain-neural-computer interfaces on track to home. In *RAatE 2012 - Recent Advances in Assistive Technology & Engineering*. 2012.

[4] P. Rego, P.M. Moreira, and L.P. Reis. Serious games for rehabilitation: A survey and a classification towards a taxonomy. In *Information Systems and Technologies (CISTI), 2010 5th Iberian Conference on*, pages 1–6, June 2010.

[5] Marcia J Scherer. *Assistive technologies and other supports for people with brain impairment*. Springer Publishing Company, 2011.

[6] David J Schretlen and Anne M Shapiro. A quantitative review of the effects of traumatic brain injury on cognitive functioning. *International Review of Psychiatry*, 15(4):341–349, 2003.

[7] Eloisa Vargiu, Juan Manuel Fernández, Sergi Torrellas, Stefan Dauwalder, Marc Solà, and Felip Miralles. A sensor-based telemonitoring and home support system to improve quality of life through bnci. In *Assistive Technology: From Research to Practice, AAATE 2013. Encarnao, P., Azevedo, L., Gelderblom, G.J., Newell, A., Mathiassen, N.-E. (Eds.)*, 2013.