

“Positive Bike” – An Immersive Biking Experience for Combined Physical and Cognitive Training of Elderly Patients

Andrea GAGGIOLI ^{a,b,*} Luca GRECI ^c, Sara ARLATI ^{c,d},
Marco STRAMBA-BADIALE ^e, Elisa PEDROLI ^a, Desirée COLOMBO ^a,
Silvia SERINO ^{a,b}, Pietro CIPRESSO ^a, Giuseppe RIVA ^{a,b}

^a*Applied Technology for Neuro-Psychology Lab, I.R.C.C.S. Istituto Auxologico Italiano, Milan, Italy*

^b*Department of Psychology, Università Cattolica del Sacro Cuore, Milan, Italy*

^c*Institute of Industrial Technologies and Automation, Consiglio Nazionale delle Ricerche, Milan, Italy*

^d*Department of Electronics, Information and Bioengineering, Politecnico di Milano, Milan, Italy*

^e*Department of Geriatrics and Cardiovascular Medicine, I.R.C.C.S. Istituto Auxologico Italiano, Milan, Italy*

Abstract. Previous evidence shows that combined cognitive and physical exercises (dual-task intervention, (I-DT)) potentiates cognitive performance more than either type of single training alone (Lauenroth et al., 2015). Here, we describe the rationale, the design and the implementation of the “Positive Bike”, a fully-immersive virtual reality biking experience for implementing I-DT training protocols in older patients. The system consists of a cycle-ergometer positioned within a Cave Automatic Virtual Environment (CAVE). The system also features a cloud-based platform which allows the therapist to configure the exercise parameters (i.e. duration and load). Using the Positive Bike, the patient can take a virtual ride by physically pedalling at variable paces within a simulated scenario (i.e., a park). During the virtual ride, the patient can be presented with different interactive cognitive exercises (attentional, memory etc). In one of such exercises, for example, the patient has to recognize different animals appearing on the route sides and press a button if such animal has a name beginning with a specific letter. Potential applications of Positive Bike in geriatric wellness and rehabilitation are discussed.

Keywords. Positive technology, neuro-rehabilitation, dual-task, virtual reality, CAVE

1. Introduction

Previous evidence shows that combined cognitive and physical exercises (dual-task intervention, I-DT) potentiates cognitive performance more than either type of single

* Corresponding Author: andrea.gaggioli@auxologico.it

training alone (Lauenroth et al., 2015). The "Positive Bike" is a fully-immersive virtual reality biking experience for implementing I-DT training protocols in older patients.

In every-day life, many activities make use of dual-task (cognitive and physical) ability. Frail older individuals, who are characterized by general vulnerability and a decreased resistance to stressors, may show difficulties in dual-task activities (i.e., walking and talking) and this could lead to an increase risk for falls [2].

2. System architecture

The system is constituted by a cycle-ergometer (EuroBike 320, Lumed, Opera, MI, Italy), a pushing button anchored on the cycle-ergometer handlebars, a pulse-oximeter, a blood pressure meter, an Arduino2 board, an Xbox controller. The virtual environment is displayed in a Cave Automatic Virtual Environment (CAVE) via a series of stereoscopic projectors. Interaction with the VE occurs via the Xbox controller and a wand that is recognized by the tracking system integrated in the CAVE and can be used like the 3D equivalent of the PC mouse. The VE has been designed and implemented using Unity3D, and displayed in the CAVE using MiddleVR (<http://www.middlevr.com/middlevr-for-unity/>), a Unity plug-in that allows multi-screens / multi-computers synchronization for higher-resolution VR systems. A graphical user interface allows the therapist either to create a new user or to load the information of a preexisting user and set the parameters of the scenario (i.e., task difficulty level). The patient's profile data as well as session data are stored in a XML file for further analysis.

The VR scenario consists of a large park populated with plants and animals. The dual task includes an attentional task and a motor task. The attentional task consists of selecting those (and only those) animals, appearing on the side of the route, starting with a target letter (i.e., if the letter "b" pops out, the patient will select all animals starting with "b", like bear, bison etc.). Another version of the attentional task requires the patient to determine whether the color of street furniture corresponds to the target one. To perform the selection, the patient presses a physical button mounted on the cycle-ergometer's handlebars. If the choice is correct, the target is highlighted in green; if wrong, the target's color turns red. For each one of these two tasks four difficulty levels have been set, as specified in Table 1.

Table 1. Stimuli used in the dual task within the virtual cycling scenario

Level nr.	Frequency of the stimuli appearance [s]	# target	Target animals' names first letter	Pieces of furniture's target colors	Cycle-ergometer workload [W]
1	20	5	G	Red	20
2	15	5	T	Blue	30
3	15	5	C	Green	40
4	15	5	S	Yellow	50

The motor task consists in pedaling at a target speed (predefined by the therapist). The user's cycling speed is constantly monitored during the task; if the patient's speed is slower or faster than the target velocity, an audio warning feedback is provided.



Figure 1. A screenshot taken from the virtual park route. An animal has appeared on the route side.

The cycling velocity data is used also to synchronize the visual flow in the VE: the virtual bike proceeds in the park along the predefined path according to the real cycle-ergometer rounds-per-minute parameter. During the whole exercise, users' vital parameters are continuously monitored. Patient's heart rate is measured through a pulse-oximeter that can be worn on a fingertip or on the ear lobe; arterial blood pressure is measured by a blood pressure meter every two minutes. Both sensor devices, as well as the push button, communicate with the VR application via Arduino.

3. Conclusion

The Positive Bike is currently being tested in a pilot trial to determine the usability and clinical feasibility of the system, as well as potential adverse effects (i.e. motion sickness). In the next phase of the research, the Positive Bike will be tested with a sample of frail older individuals to improve functional status and wellbeing.

4. Acknowledgment

This work was partially supported by the Italian Ministry of Health-funded project "High-end and Low-End Virtual Reality Systems for the Rehabilitation of Frailty in the Elderly" (PE-2013-02355948).

References

- [1] A. Lauenroth, A. E. Ioannidis, and B. Teichmann, Influence of combined physical and cognitive training on cognition: a systematic review. *BMC Geriatrics*. **16** (2016) p. 141.

[2] S. Vermeiren, R. Vella-Azzopardi, D. Beckwée, A. K. Habbig, A. Scafoglieri, B. Jansen, ... and Gerontopole Brussels Study group, Frailty and the Prediction of Negative Health Outcomes: A Meta-Analysis. *Journal of the American Medical Directors Association*. **17**(12) (2016): p. 1163.e1-1163.e17.