Virtual City system for cognitive training in elderly

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***Abstract*— The aim of the project is to create a complex training software in virtual city environment with high ecological validity that would enable a comprehensive training of cognitive abilities. The training program could be later applied in healthy aging programs as a prevention of cognitive decline. Individual tasks placed in specific locations (both indoor and outdoor) of the city are focused on various cognitive domains, while the whole city structure is used for training of spatial navigation. We shortly describe the principles of the Virtual City system and characteristics of individual training games. We also suggest possible concepts of application of this system in elderly.**

Keywords—virtual city environment, cognitive training, elderly

I. INTRODUCTION

This paper describes Virtual City (VC) - a complex system created in virtual reality (VR) environment for training of cognitive abilities in the target group of healthy seniors.

The concept of complex training systems in ecologically valid city environment was already implemented in various forms. Most of the previous studies implemented computer systems designed in two-dimensional environments applied e.g. for cognitive rehabilitation in schizophrenia [1] or in traumatic brain injury patients [2,3]. Virtual reality-based city environments were also proposed for cognitive training using simulation of daily living activities in elderly and stroke patients [4,5,6].

The proposed VC project incorporates training games located in a complex region-specific urban environment allowing simulation of real-like situations and scenarios. An immersive form of presentation using virtual glasses incorporating body movements allows us to create more intuitive control of games functionality and possibly motivates active body and hands' movements of the trained subjects.

Current studies demonstrated that the strongest effect of rehabilitation techniques can be achieved in domains of executive functions (working memory and processing speed) and memory abilities [7]. Moreover, memory decline represents the most common subjective complaint in the aging population and is also the first function weakened by the aging process [8]. The training tasks applied in VC project therefore focus on the above-mentioned cognitive skills, emphasizing long-term memory functions (including verbal, spatial and episodic memory).

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II. SOFTWARE AND HARDWARE

The VC application is developed in the game engine Unity that provides, together with the SteamVR, very good support for VR hardware. The system is designed according to the model-view-controller paradigm that allows to dynamically register (load) individual games. Two immersive VR devices, HTC Vive and Oculus, are currently used for visualisation of virtual environments.

III. VIRTUAL CITY TRAINING CONCEPT

The city consists of several districts that include key locations (both indoor and outdoor) where individual training tasks take place. Some additional locations (e.g. Zoo) might be entered only as a reward in exchange for tokens collected in individual training games - intended as a motivational gamming element. Moreover, the designed spatial structure of the city environment enables training of spatial navigation. The city environment includes also animated computer-controlled characters (non-player characters - NPCs) and other active environmental elements, such as vehicles (cars) or animals, that form a realistic social environment of the city and/or create specific social situations.

We have created prototypes of seven serious games (for details see Table I) with gradually increasing level of difficulty according to player's progress in the task. The training system records participant' performance in individual games for each session. Besides standard behavioural data output (Table I), the system enables us to analyse also the spatial behaviour of each participant and facilitate the implementation of cognitive strategies [9].

The VC training program should be applied in elderly in individual setting. This way the senior receives the maximal training effect and therapist can provide individually related advise on strategies to improve performance. However, we suggest that the system could be applied also in group setting (presenting the game in the VR glasses and mirroring it on video projector to the rest of the group). This approach could be more accessible for day-care programs in various facilities. Moreover, such form enables us to operate with the group dynamics not available in single-subject approach. The training model applying group setting is currently tested in a pilot study.

TABLE I. DESIGN OF INDIVIDUAL TRAINING GAMES WITH ADJUSTABLE PARAMETERS AND MEASURED VARIABLES

Training game	Targeted cognitive functions	Description	Adjustable parameters	Measured variables
ACTIVITY PLANNING	decision-making and planning	requires multimodal information processing in order to schedule a daily program	information sources, number of activities to plan	number of errors (dressing & to go items), number of tasks planned/completed, execution time
NAVIGATION	spatial memory & orientation	requires pointing and navigation to city locations [10]	navigation aid availability, the distance to the target, number of crossroads	angle error & pointing time, time to complete, number of stops, success rate, navigation aid usage time ratio, path efficiency (shortest vs. travelled trajectory)
OBJECTS	episodic-like memory (what, when, where)	requires memorizing of the spatial position & order of objects [11]	number of objects, number of categories, delay length btw. acquisition and recall	what-where-when errors, time to complete, number of corrections
FLIES	attention, psychomotor speed & visuo-motor control	requires to find and hit a sitting fly	rounds duration, number of sitting areas; number of flies to be hit & present simultaneously, min/max time of fly sitting, flight speed	reaction time, the number of successful hits, number of missed flies, speed of fly-flap movements
SUPERMARKET	verbal & visual declarative memory	requires to remember & locate items from a shopping list [12]	number of items, number of item categories, time limit	number of errors (missing vs. additional), accuracy rate, time to complete the task, number of corrections
SHOOTING RANGE	selective attention, psychomotor speed & inhibition control	demands differentiation of targets from non-targets (Go/Nogo paradigm)	number of target/non-targets or rounds duration, number of balls, speed of objects' (dis)appearance, "STOP" signal presence	number of targets completed, number of correct hits (targets), number of incorrect hits (non-targets), number of missed hits (stop signal in targets), number of balls used
CAROUSEL	mental flexibility & spatial working memory	requires orientation in separate spatial frames while searching for hidden targets [13]	number of sets of targets to be found, time limit to find the target	time to locate the target, number of targets found for each set, path efficiency

IV. CONCLUSION

During the conference venue the VC system will be presented in means of training concepts, design of individual games and specific cultural context. Preliminary data obtained using prototypes of individual games in the ongoing pilot study with training system used in a group setting will be compared with the results of individually applied sessions.

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