Designing an Ecological and Adaptable Virtual Task in the Context of Executive Functions

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Abstract. Brain damage is a major cause of disability that often leads to deficits in Executive Functions (EF) with dramatic consequences on activities of daily living. While rehabilitation approaches of the dysexecutive syndrome are still limited, Virtual Reality (VR) has shown its potential to propose innovative intervention strategies based on ecologically valid functional tasks. The purpose of this paper is to present the design process of the Therapeutic Virtual Kitchen (TVK) in which ecological and adaptable virtual tasks may be configured by the therapists for patients’ assessment and rehabilitation. The outcomes of a preliminary test of feasibility among members of our laboratory and Kerpape Rehabilitation Center are reported and discussed.

Keywords. Brain damage, Executive Functions (EF), Virtual Reality (VR), Ecological task, Adaptable task

Introduction

Executive functions (EF) are the high-level cognitive processes that are required to perform complex or non-routine tasks [1]. Deficits in EF, known as the dysexecutive syndrome, may be the consequence of brain damage, such as stroke or traumatic brain injury [2]. They refer to a collection of impairments in the sequencing and organization of behavior, and include other problems in attention, planning, or multi-tasking [3-5]. People with EF evince handicaps in performing complex daily living activities, known as Instrumental Activities of Daily Living (IADL) [6,7]. Many tests have been developed to assess different aspects of EF [8]. The use of functional tasks, like the Multiple Errand Test (MET) [9], is the preferred method, as they have ecological validity. But they are often time consuming, expensive to perform and must be carried out outside the clinic.

Virtual Reality (VR) has now emerged as a promising tool in the therapeutic field and a wide range of studies has shown the feasibility of using VR for cognitive care [10,11]. Brooks et al. [12,13] reported its use in memory assessment and rehabilitation. Rizzo et al. [14] designed a virtual classroom and a virtual office for attention and memory evaluation. Recently researchers have investigated the potential of virtual

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supermarkets [15-17] or virtual kitchens [18-20] to evaluate and train executive functions during IADLs. For example, the SOFTHAVEN™ system was designed by Christiansen et al. [21] to teach and assess basic life skill performance (e.g., meal preparations) to persons with traumatic brain injury (TBI). Zhang et al. [19] found that this VR environment was a good predictor for the actual kitchen performance.

In the context of our collaboration with Kerpape Rehabilitation Center and in order to provide the patients with dysexecutive syndrome more opportunities of training, we developed the Therapeutic Virtual Kitchen (TVK) in which we implemented an ecological and adaptable VR-based task. The purpose of this paper is to present the design process of the TVK project and its preliminary evaluation among our laboratory members and Kerpape Rehabilitation Center members.

1. Method

1.1. Participants

Three women and 3 men – either graduate students or laboratory staff members, and 3 persons from Kerpape Center – 2 female therapists who work with brain injury patients on a daily basis and 1 male computer scientist, participated in the experiments. All of them had computer experience. Since the intention was to gather experiences and show the potential of the TVK, it was considered too early to include patients.

1.2. Instrumentation

The first step of the design process was to collect the clinical habits and the needs of the therapists related to EF exploration, and then to design the Therapeutic Virtual Kitchen (TVK) that is graphically very close to the kitchen of the Center, with its standard objects and appliances (Figure 1). The TVK is also functional since most of the 3D objects needed in meal preparation are endowed with behaviors, and ensure interaction of the participant within the virtual environment. Real sounds are provided according to the activated 3D objects, in order to increase the feeling of immersion within the virtual kitchen. According to our objective of low cost devices use, participants navigate and interact using respectively the keyboard arrows and the mouse.

The general virtual task, initially selected by the therapists, is related to the preparation of a coffee. Both planning of all the steps of this “complex” task and spatio-temporal organization are required so that the participant carries out the task. The TVK offers the therapist various possibilities to individualize the task (e.g., time constraint) and to adapt it to the capacities of the participant (e.g., number of cups to prepare) or to the therapeutic purpose (assessment or rehabilitation). According to the configuration of the task, help can be provided to the participant via visual or auditory cues. One of our challenges is to design the assessment of the participant’s performance according to the practice of Kerpape therapists (e.g., action omission, action addition) in order to provide the therapists a VR-based assessment template. We used the Virtools™ Life Platform (www.virtools.com) to integrate the scenario and the interactivity as well as to ensure participant’s immersion.
1.3. Design issues

While designing the TVK and the “coffee task”, we had to address some basic issues related to the primary tasks, to the graduation of the task and to the modalities of interaction (Figure 2).

Primitive tasks are available in the TVK to insure the familiarization of the participant to the system and tools, but also to provide simple tasks, which can be proposed before engaging the patient in the complex “coffee task”. Visual cues are given to facilitate the understanding of the interaction opportunities, like the modification of the mouse cursor when an item is “pickable.”

In the TVK, graduation of the “coffee task” is ensured by various parameters, like: 1) number of cups to prepare (from 1 to six), for counting requirements; 2) time’s constraint, for time organization and stress induction; and 3) position of the required items (easy: all are ready at the right place; medium: all are on the table; hard: necessity to fetch all the items in the cupboards).

Due to the various items positions, we worked on interaction metaphors to represent the action “take and put”. We proposed various solutions: 1) use of an inventory, like in video games (with one item or two items); 2) use of “Drag and drop”, like on PC desktop; and 3) stick of the item on the mouse cursor after its selection (“Stick on mouse”).

1.4. Procedure

The participants were made aware that the purpose of the experiments was to assess the functioning of the VR-based system and the feasibility of the tasks. During a training session, they were asked to perform some primitive tasks (e.g., search of a utensil), and then during a second step to carry out the “coffee task” for two persons within 20 minutes, all this by using the keyboard arrows to navigate and mouse clicks to interact. All their actions and time were recorded. They were then asked for criticism about the system as well as to give suggestions about further developments.
2. Results

This first study allowed us to assess various conditions of experimentation within the TVK. At first, the participants succeeded in the configuration of the task that allows an adaptation of the task according to various parameters, like time constraint or items position.

If the Lab members appreciated the inventory with two items and so the possibility to anticipate actions, it was considered too difficult by the therapists for TBI patients. They preferred what we called the “Stick on mouse” way of interaction.

The “primary” tasks were considered useful for familiarization with the system, the spatial context and the metaphors of interaction. The therapists made suggestions for new developments in order to propose various possibilities of training, notably with objects, which are not related to the “coffee task”.

All the participants succeeded to perform the “coffee task”, with or without the helping cues. It appears that the manual helping cues provided by the therapist seem better than temporal helping cues delivered by the system because of the difficulty to sometimes understand the intention of the participant. The results show that an average time of $9.2 \pm 3.9$ minutes is required to complete the task, from $5.4$ minutes when the items are on the table to $15.7$ minutes when it is necessary to look for them.

The “coffee task” is a complex task with at least 16 steps. If the chronology of some steps is obvious (you have to put a filter before putting the spoonful of coffee), no chronology is required for other ones (you may put the cups on the table before or after having prepared the coffee). Due to this issue of chronology, the suggestions of the participants (sometimes related to their habits) will be useful to improve the management of the unfolding of the task.

3. Conclusion and Novelty

We reported the design process of an ecological and adaptable VR-based task in the TVK whose final objective is to address EF rehabilitation and to explore the capacities of transfer from virtual world to real world. Results of our preliminary study highlighted some forces and weaknesses of the TVK, the feasibility with control subjects, and showed the way for further developments.

Since, we improved the system and we worked on the addition of new components such as the delivery of a final virtual scale of evaluation based on the traditional scale used in Kerpape Rehabilitation Center. An analysis of the recorded data will be provided as well as an assessment of the unfolding of the task performed by the participant in order to provide a performance indicator and to follow the progress of the participant along the interventions. A clinical trial among patients with TBI is scheduled in April 2009.

The achievement of these developments will provide effective observation of the patient’s activity, and will lead our clinical partners to novel therapeutic practices.

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References


