A VIRTUAL KITCHEN TO ASSESS THE ACTIVITIES OF DAILY LIFE IN ALZHEIMER'S DISEASE

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Abstract: This paper presents the EVACOG project that aims to investigate the usefulness of Virtual Environments (VEs) in cognitive assessment. Our objective is to evaluate the cognitive and/or behavioral abilities of patients with brain lesions in scenarios implying the planning and the execution of everyday tasks such as driving a car or preparing a cup of coffee. In this paper we describe a simple and effective VE (a kitchen) designed to assess patient's ability to prepare a cup of coffee. We focus on the assessment results obtained with eight patients with Alzheimer's disease which were compared to healthy elderly subjects. Participants were instructed to prepare a cup of coffee in the virtual kitchen. Results revealed significant impairments in patients with Alzheimer's disease. Results of this study support the use the virtual kitchen to assess everyday life activities among persons with Alzheimer's disease.

1 INTRODUCTION

Lesions of the brain with cognitive and/or behavioral neuropsychological deficits are one major problem for patients, their family and the whole society. The EVACOG project has the ambition to think of the improvement of the strategies of cognitive diagnosis and the comprehension of the deficits, among patients carrying memory disorders and neuropsychological deficiencies thanks to the use of Virtual Reality (VR) technologies (Richard et al., 2006). VR gathers techniques and technologies for ultimate objective to immerse a human subject in a Virtual Environment (VE) with which he/she will be able to communicate via interaction techniques based on its natural faculties of action, perception and expression (Fuch et al., 2001; Burdea and Coiffet, 2003). VEs can play an important role in reducing the cognitive demands on health care practitioners by helping them to manage, filter and analyze multiple sources of information (Riva, 1998). Indeed, with VEs, all the experimental data is fully controlled, which considerably limits error making. Moreover, metrics can also be improved and it becomes possible to analyze parameters difficult to apprehend in "Paper-pencil" tasks. These parameters such as latencies, hesitations, strategies, etc. can be more easily recorded and even "replayed". This lead to think that it is possible to discriminate more subtle disorders by using VR techniques compared to regular techniques. VR offers many advantages which rest on the immersive, dynamic, interactive and highly expressive character of VEs (Riva, Mantovani and Gaggioli, 2004). VR also authorizes the construction of very concrete scenarios that allows to "virtually" confront the brain injured patients with everyday life situations like crossing a street, driving a car, preparing a meal, using public transports, shopping, etc. (Rizzo, 1994). Another advantage of VR lies in the possibility of adjusting the difficulty level of the sensorimotor or cognitive tasks simulated, according to the severity and of the evolution (positive or negative) of the difficulties of the brain injured patients. The therapist can also confront the patients to situations/environments adapted to their sensory handicaps (hemianopsy), motor (hemiplegia) or cognitive (syndrome of negligence).

The objective of our work is to evaluate the cognitive and/or behavioral abilities of patients with brain lesions in scenarios implying the planning and the execution of everyday tasks such as driving a car or preparing a cup of coffee. Experimental VEs

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designed within the framework of the EVACOG project have been integrated in both a human-scale immersive VR platform and a desk-top VR set-up. These VEs are the following: a virtual “Tower of London”, a virtual city, a virtual supermarket, and some virtual kitchens. In this paper we present the last virtual kitchen that allows the user to make a cup of coffee and focus on the assessment results obtained in patients with Alzheimer’s disease.

The remainder of the paper is organized as follows: In section 2, we look at the related work. Then, in section 3, the VIREPSE platform is described together with some experimental VEs. Section 4 is dedicated to the description of the virtual kitchen and the interaction techniques. In section 5, the experimental study is presented along with the results analysis. The paper ends by a conclusion and gives some tracks for future work.

2 RELATED WORK

VR techniques have been used in cognitive neuropsychology for more than ten years. A relatively exhaustive state of the art was carried out by Rizzo et al. and Pugnetti et al. worked out a test of VR taking again the problems of the evaluation of the executive processes of generation of concept and mental flexibility (Rizzo et al., 2004; Pugnetti et al., 2004). Indeed, the Virtual Wisconsin test simulated a building environment in which the subjects had to make use of environmental cues to choose the doors to be opened in order to evolve/move through the structure. The choice of the doors to be opened varied according to several criteria. As in the "Paper-pencil" version, the criterion selection making it possible to cross the doors was modified after a predetermined number of successes. The user was forced to adopt another strategy to go further while seeking the relevant cues in the environment. The virtual Wisconsin test was more often overdrawn than the "Paper-pencil" version.

In a study by Brooks et al., a patient with amnesia was trained in route finding around a hospital rehabilitation unit using a detailed computer-generated VE based on the real unit. Prior to the training, she was unable to perform 10 simple routes around the real unit, all involving locations which she visited regularly. She was tested at weekly intervals on these same 10 routes around the real unit during the course of the study. Her first course of training involved practising two of the 10 routes in the VE for 15 minutes each weekday. After three weeks' training, she successfully performed these two routes in the real unit and she retained her knowledge of these routes for the remainder of the study, despite not receiving any further training on these routes. For her second course of training, two more of the original 10 routes were chosen, one of which she practised in the VE and one in the real unit. Within two weeks, she had learned the route practised in the VE, but not the route practised in the real unit, and she also retained her knowledge of this route (Brooks et al., 1999). More recently, applications more particularly dedicated to the study and the treatment of social phobia or behavioral impairments were also successfully developed (Riva et al., 2003; Klinger et al., 2006).

3 THE VIRTUAL KITCHEN

Our objective is to evaluate the cognitive and/or behavioral abilities of patients with acquired brain injuries in scenarios involving action planning and/or problem solving and the execution of everyday tasks. The virtual kitchen described in this section allows the patients to prepare a cup of coffee using a virtual coffee machine. Different interaction techniques and kitchen configuration have been implemented. All actions of the patient in the virtual kitchen are recorded in real-time and are proposed to the therapist in excel files for further analysis. These actions include both the objects involved in the task and the distractor objects that could not be moved but can be selected.

3.1 Experimental Configurations

Four different configurations of the kitchen are proposed: (1) a basic configuration (Fig. 1), (2) a basic configuration with distractor objects (Fig. 2), (3) a complex configuration (Fig. 3), and a complex configuration with distractor objects (Fig. 4). In the basic configuration, objects of interest are arranged on the table from left to right in the order of use in the task. In the basic configuration with distractors, objects are also arranged in the order, but distractor objects that are visually and/or semantically similar to target objects (e.g., water pot, a box of chocolate, etc.) are also placed on the table.

In the complex configuration, objects are put away from each other (for example, the milk is placed away from the cup). In the complex configuration with distractor objects, interacting objects are put away from each other and distractor objects are displayed.

Figure 1: Snapshot of the basic virtual kitchen configuration: the virtual objects are arranged in the order that they should be used.

Figure 2: Snapshot of the basic kitchen configuration with distractor objects (chocolate boxe, fork, and bottle of wine).

Figure 3: Snapshot of the complex configuration of the kitchen: interacting virtual objects are put away from each other.

Figure 4: Snapshot of the complex configuration of the kitchen with additional distractor objects.

3.2 Interaction Techniques

In order to accomplish the task (to prepare a cup of coffee), the users have to select and move some virtual objects. To this aim two interaction techniques have been developed. The first one is based on the computer mouse, while the second uses a data glove (http://www.5DT.com) along with a Patriot^{TM} 3D tracking device (http://www.polhemus-corp.com). In the first interaction technique, the user move the computer mouse in the horizontal plane (real table) while in the second one, the user moves his/her hand in the vertical plane. In both cases, the user controls only the vertical and horizontal position of the manipulated objects. The objects are automatically rotated or moved in depth in order to help the patient, to avoid sensory-motor coordination difficulties, and to get rid of the depth perception problem. Selection is done by putting the 2D cursor on an object and by clicking of the left button (first technique) or by closing the hand (second technique).

4 EXPERIMENTAL STUDY

Everyday activities are familiar tasks that require multiple cognitive processes, such as serial ordering of tasks steps, object selection, and so on, to achieve practical goals such as preparing a cup of coffee. However, among individuals with brain damage or disease, errors are frequent and may preclude achievement of the task's goal (Buxbaum, Schwartz and Montgomery, 1998; Humphreys and Forde, 1998; Schwartz et al., 1998, 1999). Everyday action errors are also a serious concern in dementia (Giovannetti, Libon, Buxbaum and Schwartz, 2002). In fact, everyday action impairment is one of the diagnostic criteria of Alzheimer's disease and is associated with numerous serious consequences. The aim of this study was to examine the value of the previously described virtual kitchen to detect disturbances in activities of daily life in Alzheilmer's disease through the task of preparing a cup of coffee with a coffee machine.

Figure 5: Subject performing the task in the more complex configuration.

4.1 Task

Due to the reduced number of participants and to the fact that patients with Alzheimer's disease were early in the course of the disease, we decided to use the more complex condition (Fig. 4). Participants were instructed to perform the following steps using the virtual kitchen:

- Open the coffee machine drawer (1)
- Put the filter inside the machine (2)
- Put the coffee powder on the filter (3)
- Close the coffee machine drawer (4)
- Open the machine water recipient (5)
- Put some water in the coffee machine (6)
- Put the coffee recipient on the machine (7)
- Turn on the coffee machine (8)
- Wait until the coffee is done (9)
- Put the coffee in the cup (10)
- Put back the coffee recipient (11)
- Put a piece of sugar in the coffee cup (12)
- Put some milk in the coffee's cup (13)

Sounds events were integrated in order to foster the sense of presence in the VE when participants were performing the task. A subject performing the task is shown in Fig. 5.

4.2 Method

Sixteen subjects participated in the experiment. Eight patients (5 females and 3 males) diagnosed with probable or possible Alzheimer's disease (McKhann et al., 1984). Participants met the following inclusion criteria: (a) Mini Mental Status Exam (MMSE, Folstein, Folstein and McHugh, 1975) comprised between 20 and 26/30, (b) no evidence of psychiatric or medical history (focal lesions or cerebrovascular accidents, medication damaging cognition and memory), (c) no vision problems. The average age of the patients was 84.8 (+/- 4.4) years. Their average education level was 8.4 (+/ 1.8) years of study since the first grade. Their mean MMSE score was 22.7 (+/-1.5). Eight healthy elderly subjects (5 females and 3 males) without previous medical or psychiatric disorders and without visual problems were used as controls. Their mean age was 78.5 (+/- 4.6) years. They have been educated on average 10.1 (+/- 2.9) years since the first grade. Their average MMSE score was 28.1 (+/- 1.3).

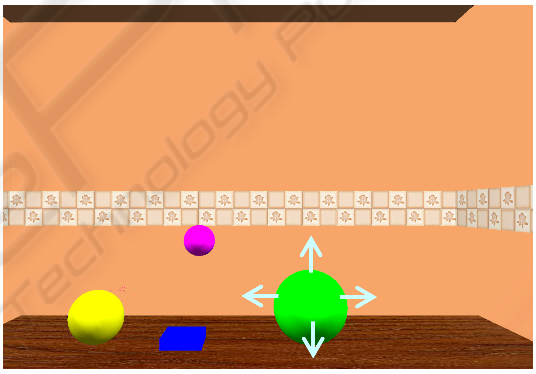
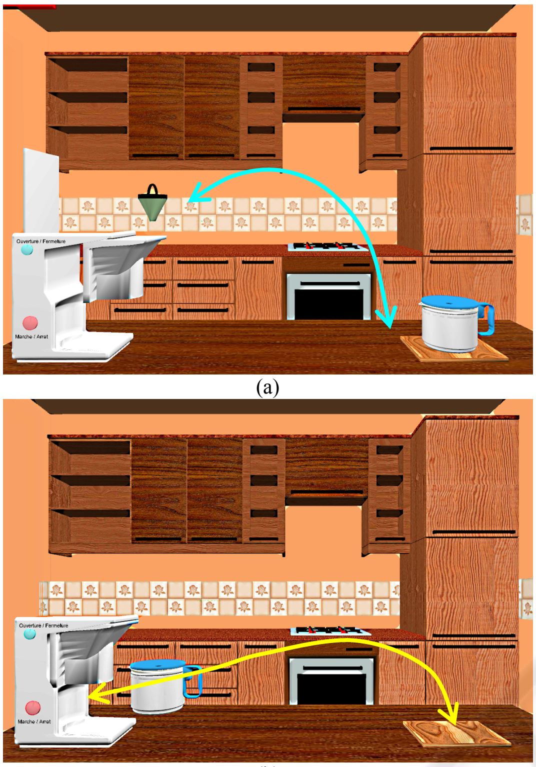


Figure 6: Snapshot of the virtual environment used to familiarize the subjects with the computer mouse (translation and stacking of three spheres on the blue cube).

Before starting the task, participants were given two training session. The first concerned the use of the mouse. Participants were asked to manipulate objects with the movement of the mouse. The interactive training simulation is illustrated in Fig.6. The second training session was designed to familiarize the participants with the use of the virtual coffee machine (Fig. 7a and 7b).

4.3 Data Collection

Task completion time was recorded for each patient with Alzheimer's disease and each control subject. The number of errors made (that correspond to the number of task steps uncompleted or competed with sequencing problems) was also measured. These data were automatically recorded throughout the experiment with all user action involving the virtual object including the distractor ones).



(a)

(b)

Figure 7: Snapshot of the virtual environment used to familiarize the subject with the use of the virtual coffee machine: placing the filter in the machine (a), and placing the pot (b).

4.4 Results

The analysis of completion time revealed a significant difference between control subjects and patients with Alzheimer's disease ($U=0.0$, $z = -3.36$, $p = 0.0008$). Indeed, patients take longer than control subjects to perform the task (Tab. 1). Similarly, the statistical study of errors committed revealed a significant difference between the two groups ($U=6.0$, $z = -2.73$, $p = 0.006$). The average number of errors was higher in patients with Alzheimer's disease (Tab. 1). A qualitative analysis of the type of errors made by control subjects and patients with Alzheimer's disease allowed highlighting that the most common errors committed were the following: not put the filter inside the machine, not close the coffee machine drawer, not put the coffee recipient on the machine before turning the coffee machine and not put the coffee recipient on the machine. This pattern of performance indicates that subjects mainly committed omission errors. After the virtual assessment, each subject was asked to answer a questionnaire of presence to assess their sense of immersion in the VE and to identify any shortcomings in the use of the platform.

All participants have found congruence between the objects, the sounds, the colours and the actions in the virtual environment and real situations. All subjects told us that using the mouse and the coffee machine was difficult and that the training session was important. Finally, no subjects experienced problems of cybersickness.

Table 1: Mean (standard deviation) virtual test scores for controls and patients with Alzheimer's disease on the virtual task.

	Controls	**Patients**
Completion time (Sec.)	277.6 (std 41.4)	780.8 (std 104,8)
Number of errors	0.2 (std 0.4)	2.0 (std 1.2)

5 CONCLUSIONS AND PERSPECTIVE

In this paper, we have presented the EVACOG project that aims to contribute to the development of evaluation tools for the assessment of cognitive and/or behavioral dysfunctions resulting from lesions of the central nervous system. We focused on the virtual kitchen developed to investigate the abilities of patients with Alzheimer's disease to prepare a cup of coffee with a coffee machine. This preliminary work confirms that such a simple VE allows detecting disturbances in activities of daily living in Alzheimer's disease. In future work, we will add these few preliminary data with greater groups of control subjects and patients with Alzheimer's disease. We will confront our data with those obtained from evaluating the same activities in real context and from autonomy scales completed by relatives of the patients in order to ensure the good ecological value of the virtual coffee task. We will also develop other spots in our virtual kitchen to expand our studies of autonomy in everyday life activities in patients with dementia or other neuropsychological problems. Beyond these prospects, we will study the way in which VEs are perceived by the patients. Indeed, as "realistic" as can be these environments, they are only representations of the reality. Which relations the patients can build between these representations and their daily environment? The development of the use of VEs at ends of diagnosis or rehabilitation also depends on the answers which one will be able to bring to such questions (Le Gall and Allain, 2001; Le Gall et al., 2008).

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