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A Dual-Modal Virtual Reality Kitchen for (Re)Learning of Everyday Cooking Activities in Alzheimer's Disease

Abstract

Everyday action impairment is one of the diagnostic criteria of Alzheimer's disease and is associated with many serious consequences, including loss of functional autonomy and independence. It has been shown that the (re)learning of everyday activities is possible in Alzheimer's disease by using error reduction teaching approaches in naturalistic clinical settings. The purpose of this study is to develop a dual-modal virtual reality platform for training in everyday cooking activities in Alzheimer's disease and to establish its value as a training tool for everyday activities in these patients. Two everyday tasks and two error reduction learning methods were implemented within a virtual kitchen. Two patients with Alzheimer's disease and two healthy elderly controls were tested. All subjects were trained in two learning sessions on two comparable cooking tasks. Within each group (i.e., patients and controls), the order of the training methods was counterbalanced. Repeated measure analysis before and after learning was performed. A questionnaire of presence and a verbal interview were used to obtain information about the subjective responses of the participants to the VR experience. The results in terms of errors, omissions, and perseverations (i.e., repetitive behaviors) indicate that the patients performed worse than the controls before learning, but that they reached a level of performance similar to that of the controls after a short learning session, regardless of the learning method employed. This finding provides preliminary support for the value of the dual-modal virtual reality platform for training in everyday cooking activities in Alzheimer's disease. However, further work is needed before it is ready for clinical application.

I Dual-Modal Virtual Reality Kitchen for (Re)Learning of Everyday Cooking Activities in Alzheimer's Disease

Everyday activities are familiar tasks that require multiple cognitive processes such as serial ordering of task steps and object selection, in order to achieve practical goals such as preparing a cup of coffee. Everyday tasks are familiar and routinely performed with subjective ease. However, in individuals with brain damage or disease, errors are frequent and may preclude the achievement of the task goal (Chevignard et al., 2008; Fortin, Godbout, & Braun, 2003; Giovannetti, Schmidt, Gallo, & Sestito, 2002; Rusted & Sheppard,

2002). Everyday action errors are a serious concern in dementia (Giovannetti, Libon, Buxbaum, & Schwartz, 2002; Giovannetti, Schwartz, & Buxbaum, 2007; Giovannetti et al., 2008). In fact, everyday action impairment is one of the diagnostic criteria of Alzheimer's disease and is associated with many serious consequences, including institutionalization, depression, and death (Adam, Van der Linden, Juillerat, & Salmon, 2000; Hargrave, Reed, & Mungus, 2000; Knopman, Kitto, Deinard, & Heiring, 1988; Noale et al., 2003).

In an effort to prevent these dire consequences, neuropsychologists commonly recommend that dementia patients learn or relearn potentially useful instrumental activities of daily living, as this may increase the patients' functional autonomy (Giovannetti et al., 2007; Dechamps et al., 2011). To date, research on everyday action interventions in dementia has shown that extensive training and repetition of everyday activities improves performance on trained tasks (e.g., procedural memory stimulation; Avila et al., 2004; Farina et al., 2002; Josephsson et al., 1993; Josephsson, Backman, Borell, Nygard, & Bernspang, 1995; Zanetti et al., 1997, 2001). The errorless learning methods, which are construed as teaching techniques that prevent people from making mistakes during learning, have also been successfully used in some single-case (Clare et al., 2000; Lekeu, Wojtasik, Van der Linden, & Salmon, 2002) or group approaches (Dechamps et al., 2011) to (re)learn instrumental activities of daily living in patients with Alzheimer's disease. Dechamps et al. showed that error reduction approaches are more effective than trial and error learning. Today, there is no doubt that (re)learning methods have beneficial effects in patients with Alzheimer's disease, in particular when they have explicit memory deficits. However, they are time-consuming and not always feasible in typical clinical settings.

Virtual reality (VR)-based technology is one of the emerging tools that has great potential for use in rehabilitation (Le Gall, Bersnard, Louisy, Richard, & Allain, 2008; Rizzo & Kim, 2005; Weiss & Katz, 2004; Weiss, Kizony, Feintuch, & Katz, 2006). VR is a technology that allows people to view, navigate, or interact with a computer-generated three-dimensional world in real time. Virtual environments create the opportunity for

people to be engaged in activities as in the real world (Broeren, Claesson, Goude, Rydmark, & Sunnerhagen, 2008; Crosbie, Lennon, Basford, & McDonough, 2007; Henderson, Korner-Bitensky, & Levin, 2007). In the domain of everyday activities, several virtual environments have been created to simulate daily tasks, namely cooking (Allain et al., 2011; Christiansen et al., 1998; Richard et al., 2010; Zhang et al., 2001, 2002) and shopping (Klinger, Chemin, Lebreton, & Marié, 2006; Lee et al., 2003). While virtual environments appear to be a good predictor of real performance, VR technology remains rather underexploited for rehabilitation compared with neuropsychological assessment (Standen & Brown, 2005). Nevertheless, VR offers the opportunity for intensive repetition of meaningful tasks with augmented feedback for rehabilitation in a manner that may be more revealing than conventional therapy (Crosbie et al., 2007). It poses no threat to or physical limitations upon participants in the simulated environment, and can easily be modified to change levels of difficulty, which may not be possible in the real world (Christiansen et al.). Moreover, VR-based rehabilitation involves real-time information processing and dynamic interaction (Henderson et al., 2007). Recent intervention studies are promising, since they have empirically substantiated the usefulness of VR-based training in patients with acquired brain injury, especially in daily functional tasks such as cooking (Christiansen et al.; Davies et al., 2002, Zhang et al., 2002), route-finding (Davies et al.), and cash management (Fong et al., 2011; Grealy, Johnson & Rushton, 1999). Several virtual supermarkets have been used to assess and rehabilitate the activity of shopping, which necessitates executive functions (e.g., the virtual action planning supermarket of Klinger et al.). These VR-based applications have demonstrated their efficiency to assess executive functioning not only in patients with brain injury (Josman et al., 2006; Klinger et al., 2008; Klinger et al., 2009; Lee et al.), but also in those with mild cognitive impairment (Werner, Rabinowitz, Klinger, Korczyn, & Josman, 2009). For example, in the study by Lee et al., patients showed a reduction in time spent, distance walked, collisions, and errors after five sessions (compared to the second session). An original system has combined a 2D virtual supermarket with

GestureTek video capture technology, in which real-time data included the participant's video in the VE (Rand, Katz, & Weiss, 2007). This system trains the cognitive activity of shopping and also requires motor activity of the upper limbs, since interaction with the VE (e.g., navigation by arrows, access buttons to cart, entrance) was performed by maintaining the hand over the item for a minimum of 2s. In a first study, where the patients used the system for one session, they reported that the task was interesting, motivating, encouraged them to move, and facilitated the intervention of executive functions. In a second study, with 10 training sessions, patients showed a substantial learning transfer (7.7% reduction of errors) when they were assessed in a real supermarket (Rand, Weiss, & Katz, 2009). However, patients verbally reported an improvement in their independence to perform activities of daily living such as shopping and cooking. Finally, another VR-based cognitive rehabilitation program proposed a virtual town to train brain injured patients to perform activities of daily living. This nonimmersive VR community skills training program included traveling by bus, shopping, using a telephone booth, and meeting a friend at a predetermined venue (Yip & Man, 2009). After 10 training sessions, the patients showed improvement on real daily tasks. Thus, effective VR rehabilitation can be adapted for individuals with Alzheimer's disease for use in inpatient, outpatient, and home care settings as a supplement or alternative to conventional therapy.

Since no study so far has attempted to create a virtual environment specifically designed for the (re)learning of everyday activities in patients with Alzheimer's disease, the potential benefits of such an environment led to our project to design and evaluate a multimodal VR application in which patients with Alzheimer's disease could practice everyday activities. The application was created on the basis of our own virtual kitchen (VK) assessment tool (Allain et al., 2011; Richard et al., 2010). We developed the VK for use as an intervention tool to treat everyday cooking deficits in patients with Alzheimer's disease. Thus, the first aim of our study was to examine the effectiveness and usability of this newly revised VK for (re)learning activities of daily living (cooking activities) in Alzheimer's disease. The second aim was to

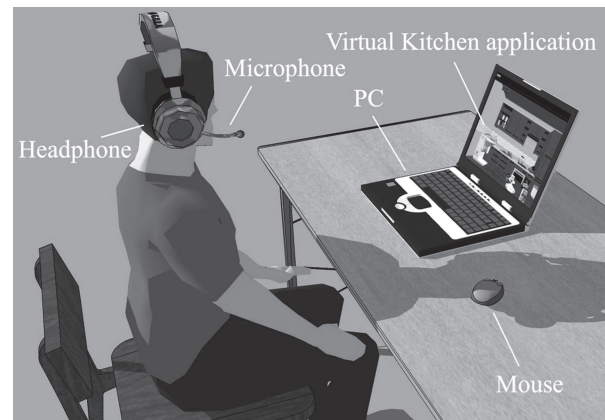


Figure 1. System configuration of the VK system.

implement and assess a new learning method which added the repetition out loud of each subgoal (i.e., repetition of the instruction of each step) to the step-by-step learning method (goal management training type).

2 Proposed System: Virtual Kitchen

Figure 1 shows the VK system configuration. It is composed of one notebook PC, a mouse, a headset, and the VK application, which runs on the PC. The system is designed to be as simple as possible in order to make it portable and to facilitate setup. The application is visually implemented in a 3D environment in order to make it immersive and improve the reality of the system. However, since 2D mouse interaction is the most common and usual interaction model for people, and since the system focuses on cognitive performance but not on motor abilities, we decided to control the vertical and horizontal position of objects in the 3D environment.

2.1 Virtual Kitchen Application

The VK application consists in (re)learning everyday tasks, especially cooking tasks.

2.1.1 Tasks. Two virtual tasks were developed: Preparing two pieces of toast for breakfast using an electric toaster (breakfast task); and Preparing a cup of coffee with a coffee machine (coffee task).

F1

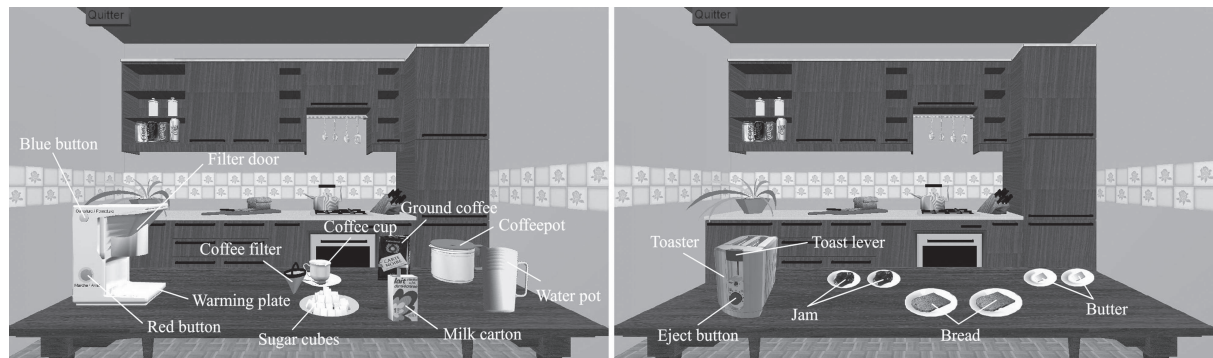


Figure 2. Screen shot of breakfast task (left) and coffee task (right).

F2 2.1.1.1 Toast Task. This task trains subjects how to prepare two pieces of toast in everyday life. Figure 2 shows a screen shot of the coffee task, which contains seven manipulable visual objects: a toaster, two pieces of bread, two spoons of jam, and two pats of butter. These objects can be manipulated with the mouse. To prepare two pieces of toast in this application, a total of 10 manipulations are required as shown below.

1. Take a piece of bread from the table and put it into the toaster. (Drag the piece of bread with the mouse. When it is moved over the bread toaster, the piece of bread is automatically released and drops into the toaster.)
2. Take the other piece of bread from the table into the toaster. (Same procedure as above.)
3. Depress the lever on the toaster to insert the two pieces of bread into the body of the toaster. (Click mouse on the toaster lever.)
4. Press the eject button on the toaster to pop up the two pieces of toast. (Click mouse on the eject button.)
5. Take a piece of toast from the toaster and place it on a plate on the table. (Drag the piece of toast with the mouse. When it is over the bread plate, the toast is automatically released and placed on the plate.)
6. Take the other piece of toast from the toaster and place it on the other bread plate on the table. (Same procedure as above.)

7. Take a pat of butter and place it on a piece of toast. (Drag a pat of butter with the mouse. When it moves over a piece of toast, the butter is automatically released with a melting animation and is spread on the toast.)
8. Take the other pat of butter and place it on the other piece of toast (Same procedure as above.)
9. Take a spoonful of jam and place it on the bread plate. (Drag a spoon of jam with mouse. When it moves over a piece of toast, the jam is automatically released and placed on the bread plate.)
10. Take the other spoonful of jam and place it on the other bread plate. (Same procedure as above.)

2.1.1.2 Coffee Task. This task trains subjects how to prepare a cup of coffee with a coffee machine in everyday life. Figure 2 shows a screen shot of the coffee task. The coffee task contains seven manipulable visual objects: a coffeemaker, a coffee filter, ground coffee, a coffeepot, a water pot, sugar cubes, and a milk carton. These objects can be manipulated with the mouse. To prepare a cup of coffee in this application, a total of 10 steps are required as shown below.

1. Press the blue button on the coffeemaker to open the filter door. (Click the mouse on the blue button.)
2. Take the coffee filter from the table and place it in the filter door. (Drag the coffee filter with the mouse. When it is over the filter door, the coffee filter is automatically released and becomes invisible.)

3. Take the ground coffee from the table and place it in the filter door. (Drag the ground coffee with the mouse. When it is over the filter door, the ground coffee is automatically released and the ground coffee animation is played at the same time. The ground coffee automatically returned to the initial position on the table.)
4. Press the blue button on the coffeemaker to close the filter door. (Click mouse on the blue button.)
5. Pour some water from the water pot on the table into coffeemaker. (Drag the water pot with the mouse. When it is over the coffeemaker, the water pot is automatically released and the water-pouring animation is activated. Then it is automatically returned to the initial position on the table.)
6. Put the coffeepot on the table on the warming plate of the coffeemaker. (Drag the coffeepot with mouse. When it is below the filter door, the coffeepot is automatically released, and is placed on the warming plate.)
7. Press the red button on the coffeemaker to start making coffee and to see coffee dripping into the coffeepot. (Click mouse on the red button.)
8. Pour some coffee from the coffeepot into the coffee cup on the table. (Drag the coffeepot with the mouse. When it is over the coffee cup, the coffeepot is automatically released and the coffee-pouring animation is activated. After that it is automatically returned to the initial position on the table.)
9. Take a sugar cube from the table and place it in the coffee cup. (Drag the sugar cubes with the mouse. When it is over the coffee cup, the sugar cube is automatically released and becomes invisible.)
10. Pour some milk from the milk carton into the coffee cup. (Drag the milk carton with the mouse. When it is over the coffee cup, the milk is automatically released and the milk-pouring animation is activated. After that, it is automatically returned to its initial position on the table.)

2.1.1.3 Type of Action for Cooking Activities. Each manipulation described in the toast task/coffee task can be categorized into press type manipulation and drag type manipulation. The toast task contains two

press type manipulations and eight drag type manipulations; while the coffee task contains three press type manipulations and seven drag type manipulations.

For drag type manipulation where target manipulable objects are dragged with the mouse, the system detects the performed action as a trigger event. For press type manipulation, a detection area is set up around the target manipulable object in order to detect the mouse pointer's position. When the mouse rolls over the detection area, the system detects it as a trigger event.

In both cooking activity tasks, each motor step was transformed into a verbal instruction in order to develop two error reduction learning methods. The first one was strictly based on a written instruction strategy, while the second one was based on a verbalization strategy.

2.1.2 (Re)Learning Methods. Prior real attempts to remediate everyday actions using written and/or verbal instructions approaches (e.g., Bickerton, Humphreys, & Riddoch, 2006; Dechamps et al., 2011) have proven to be successful in patients with action disorganization problems, showing that such approaches could be very helpful to guide their actions. These clinical data allowed us to develop and compare two different instruction learning methods (ILM). Both methods provide step-by-step written instructions for each motor action to be performed in order to achieve the task. These instructions were proposed to reduce errors during (re)learning. The first ILM was based only on written instructions, while the second one combined written ILM with verbal repetition of instructions.

2.1.2.1 Written Instruction Learning Method (Written ILM). When training begins in written ILM, the instruction sentence appears at the top of the screen in order to explain the current target manipulation (e.g., for the first step of the coffee task, the patient is told what he or she has to do, i.e., Press the blue button on the coffeemaker to open the filter door, before performing the step. The same is true for each step up to the last one). The sentence automatically fades out after 5 s. Then, when the subject achieves the target manipulation, the written instruction for the next target manipulation shows up until the cooking task is completely

performed. If the subject does not succeed after the instruction disappears, the instruction sentence for next target manipulation shows up.

2.1.2.2 Self-Recorded Instruction Learning Method (Self-Recorded ILM). In the self-recorded ILM, written instructions appear step-by-step in the same manner as in the previous method. However, before executing each target action, that is when a target object is dragged, the system asks the question: What are you going to do?¹ Then, the subject has to say aloud in a microphone what he or she is going to do. The recording controller is automatically activated. For example, the subject records aloud what he or she is going to do by saying “I am going to put toast in the electric toaster” in the microphone. Then, the self-recorded message is played once per second until the subject achieves the target action. The recorded message is automatically repeated until the subject executes the step. If the subject cannot say the instruction, the therapist offers encouragement by asking him what he is doing with the selected virtual object. If the subject does not know, the therapist pronounces the sentence that the subject should be saying and the latter has to repeat it. Finally, when the subject achieves the target manipulation, a written instruction for the next target manipulation appears until the cooking task is completely performed. This verbalization strategy relies on verbal maintenance of the steps during the task within the phonological loop of working memory (Baddeley, 1998). Consistent with Bickerton et al. (2006), we suggest that the phonological loop of working memory can be used as a substitute for more complex functions (executive control) during the performance of everyday tasks in patients with Alzheimer’s disease.

2.1.2.3 Recording Controller for Self-Recorded ILM. The recording controller makes it possible to control the audio parameter/recording status. In the show

1. If the target object is a draggable object (coffee filter, ground coffee, toast, butter, etc.), the question: What are you doing to do? is displayed at the same time as the dragging action. If the target object is undraggable, (the blue button on the coffeemaker, the black button on the toaster, etc.), the question is displayed when the mouse pointer is close to the undraggable object.

question part of the self-recorded ILM panel, the system shows a message: What are you going to do? at the position of the mouse pointer and recording controller at the bottom right of the screen at the same time. The time interval between the playing of the recorded sequences can also be changed. The system also includes assessment (Allain et al., 2011; Richard et al., 2010) and pretraining modes (see Section 3.3).

3. Method

3.1 Design

The present research aimed to test the efficiency of two (re)learning methods designed to train cooking activities with Alzheimer’s patients. Since all subjects tested the two (re)learning methods, we used two different everyday tasks with comparable levels of difficulty. In particular, familiarity was controlled since both tasks were cooking activities (i.e., breakfast cooking and coffeemaking), so we used routine activities with a similar number of objects (seven for breakfast cooking and eight for coffeemaking), a machine (a coffeemachine and a toaster) with two buttons and 10 manipulations to be performed. In this way, the test-retest effect was avoided. Moreover, we were able to test the feasibility of the proposed tasks in a virtual kitchen using mouse interactions with healthy elderly volunteers and Alzheimer’s patients.

We conducted an exploratory study using a multicase study design including two healthy elderly participants and two Alzheimer’s patients. All subjects first performed the breakfast task and then the coffee task. The ILMs were counterbalanced between subjects in each group.

Quantitative outcome measures of task performance were obtained in terms of time spent and numbers of correct actions, and errors and useless actions, before and after each learning session. Task performance was scored according to the same criteria. Three types of independent variable were taken into consideration: total time to complete the task, total number of actions including omissions (step omissions), and commission errors (either perseverations or additions). We also calculated an accomplishment score corresponding to the percentage of task steps completed with or without error.

Table 1. *Participants' Characteristics*

Subject	Gender	Age	Main former activity	MMS	Major deficits
1	Male	85	Manager in agronomy	28	—
2	Female	80	Secretary in a post office	28	—
4	Female	81	Orderly	22	Short-term memory, orientation in space and time
3	Female	76	Secretary in an insurance company	23	Short-term memory, orientation in space and time

Questionnaires were used to obtain information about the participants' subjective impressions regarding the VR experience. Finally, qualitative outcome measures were collected from the experimenter's observations and from verbal interviews.

3.2 Subjects

Four elderly subjects participated, including two female patients and two healthy control subjects, one man and one woman. Table 1 shows a summary of the subjects. All had normal or corrected-to-normal vision and were right handed. All lived in their own home. Healthy subjects and the patients were comparable in terms of age and years of education since all had attended school through about 14 years of age. None had any previous history of neurological illness, substance abuse, or psychiatric illness. The ability of the two patients to perform daily activities, such as preparing meals, declined over the previous two years. The patients were neither unaware of their condition nor in total denial of their condition, inasmuch that they refused any help. They met the clinical criteria established by the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA; McKhann et al., 1984) for Alzheimer's dementia type. All subjects received a letter of information and informed consent was obtained in accordance with the Declaration of Helsinki.

Case 1 worked in the domain of agronomy. He raised pigs, and helped to optimize pig food production lines

and marketing strategies. He lived with his wife in his own one-floor home with a garden, was used to seeing people, and often went to his country house.

Case 2 worked in a factory and then at the post office as secretary. She lived in her own home. She was very dynamic and participated in numerous activities run by an association for elderly people.

Case 3 was a secretary in an insurance company. She lived in her own home. She was very dynamic and participated twice a week in group activities run by a retirement home.

Case 4 lived with her husband in her own one-floor home with a garden. They saw their son and daughter-in-law very frequently. She had trained as an orderly but has stayed at home to raise her three children. The therapist reported a loss of short-term memory (i.e., iterative questions) and both spatial and temporal confusion.

No subjects had ever interacted with a computer and a mouse before the experiment and none had ever played a game requiring the manipulation of objects.

3.3 Experimental Protocol

Both learning methods were proposed in two successive half-day sessions, with a time lapse of one day between them. The subjects were seated in front of a screen monitor and first received general verbal information about the assessment, the learning method, and the use of the virtual kitchen. Then they received a phase of familiarization with the interaction, during which they had to select and move virtual objects placed on the virtual table via the mouse. Since we were investigating

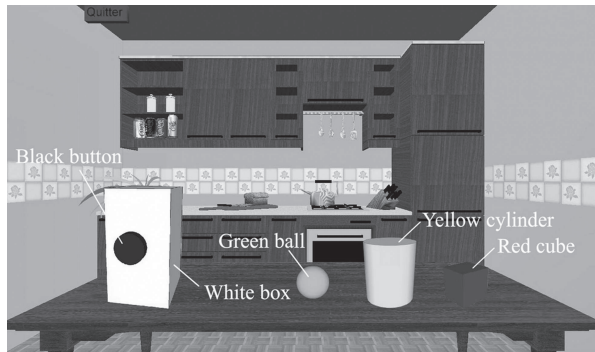


Figure 3. Screen shot of pre-training mode.

cognitive performance, all objects were automatically rotated or moved in depth in order to help the subjects. Then, the subjects received two pretraining sessions to familiarize them with the method (i.e., written IML or self-recorded IML). They were in the same condition as the learning condition but with different objects on the kitchen table and other instructions (see Figure 3). The pretraining sessions were designed to familiarize them with the use of the mouse and the visual instructions, and for the self recorded modality, with the voice-recording system. We could thus assess their ability to interact with virtual objects using the mouse, and to estimate their potential for learning to interact. After these two pretraining sessions, the subjects were asked to show how they would do the task (sweetened coffee with milk or toast buttered with jam) with such material, using the free mode version of the virtual kitchen application. Then, they were given a 20-min learning session during which a task was performed six times using written IML or self-recorded IML. At the end of the training session, they were asked to redo all the steps of the trained task (using the free mode). Thereafter, we asked the subjects about their possible sickness and asked them to complete the sickness simulator questionnaire (Kennedy, Lane, Berbaum, & Lilienthal, 1993). For each phase using different methods, a questionnaire of presence was administered (Witmer, 1996). In addition, we noted any comments made by the subjects in order to have qualitative feedback about the task as well as the usability of the system. The experiment lasted about 90 min.

4. Results

4.1 Individual Case Reports

Here, we present subjective outcomes of individual case reports, in terms of observations by the therapist and data from questionnaires, as well as objective outcomes of the system in terms of time spent, score, number of perseverative errors of repetition and number of additional useless actions.

4.1.1 Subjective Outcomes. All subjects

reported no simulator sickness.

Case 1 first learned the breakfast task and then the coffee task. His presence score was first 102 points (60.71%) and then 105 points (62.05%). He was very motivated to participate, and said that the kitchen was beautiful and that he wanted to interact with it. Moreover, he added that the cooking tasks were easy to do and intuitive. He reported minor fatigue after the coffee task and no fatigue after the breakfast task. However, he said that the coffee task offered a framework forcing him to structure his actions and wonder about the organization of the task.

Case 2 first learned the breakfast task and then the coffee task. Her presence score was first 108 points (64.29%) and then 107 points (63.69%). She reported minor fatigue after learning with both methods. She showed great enthusiasm for the coffee task and reported that it was very funny to hear her voice. She said aloud what she was doing even when it was not required in this method. She reported that she preferred the breakfast task because it did not interrupt her current action by the voice recording and did not stop her from speaking.

Case 3 first learned the breakfast task and then the coffee task. Her presence score was first 81 points (48.21%) and then 87 points (51.79%). She reported no fatigue after learning with both tests. She reported liking the system for its interactivity. The therapist noted that she was disturbed by the coffee task.

Case 4 first learned the self-recorded ILM (the breakfast task) and then the written ILM (the coffee task). Her presence score was first 75 points (44.64%) and then 80 points (44.64%). Case 4 reported fatigue after learning with the breakfast task but not with the coffee task.

Table 2. Summary of Objective Outcomes from Individual Case Reports

Subject	Written ILM		Self-recorded ILM	
	Baseline	Assessment	Baseline	Assessment
Case 1 (healthy control)				
Time spent (s)	85	103	124	85
Accomplishment score (%)	100	100	100	100
Perseverations	0	0	4	4
Additions	7	6	3	0
Case 2 (healthy control)				
Time spent (s)	324	128	406	170
Accomplishment score (%)	50	100	100	100
Perseverations	0	0	3	0
Additions	8	5	42	14
Case 3 (AD patient)				
Time spent (s)	139	72	404	183
Accomplishment score (%)	100	100	90	100
Perseverations	0	0	0	3
Additions	5	1	9	2
Case 4 (AD patient)				
Time spent (s)	230	823	783	454
Accomplishment score (%)	10	90	50	100
Perseverations	3	1	0	0
Additions	4	0	69	7

Concerning the breakfast task, she reported that she liked the butter and strawberry jam but the therapist noted that she was disturbed by the background of the kitchen. For example, she said would prefer to use other objects such as those in her own kitchen.

Before training, they had a mean accomplishment score of 87.5%. However, they performed a mean number of 14.5 additions before training. According to the results of the questionnaire, they found that the cooking experiment was like cooking in the real environment (92.9%).

T2 **4.1.2 Objective Outcomes.** Table 2 shows that after using both tasks, subjects could completely perform cooking tasks, thereby reducing their perseverative actions (i.e., stopping at a step and showing repetitive behavior) and additions.

4.2 Cross-Case Results

4.2.1 Healthy Elderly Subjects. The control group was composed of two healthy elderly subjects (one woman, one man) whose mean age was 82.5.

4.2.1.1 Written ILM (Breakfast Task). The control group took less time to perform the virtual breakfast after training (116 s) compared to before training (204 s), that is, a reduction of 43.14%. Their accomplishment score increased from 75% to 100% while additions decreased from $n = 7.5$ (before) to $n = 5.5$ (after learning).

4.2.1.2 Self-Recorded ILM (Coffee Task). The control group took less time to perform the breakfast task after training (128 s) compared to before training (292 s),

that is, a reduction of 56.16%. Their accomplishment score was 100% before and after learning. However, their perseverative errors decreased from $n = 3$ to $n = 0$ after learning and additions decreased from $n = 23$ to $n = 9$ after learning.

4.2.1.3 Interaction. According to the results of the questionnaire, healthy subjects felt able to anticipate the consequences of their movements (89.3%). The interaction task interfered with the execution of virtual cooking tasks (57.14%). They said they could not totally concentrate on the virtual cooking tasks (78.57%) but rather on the mechanisms of interaction. The control group verbally reported difficulties in dragging objects using the mouse. They explained that dragging required more attention on the interaction task because it consisted of two simultaneous actions: pressing the mouse button and sliding the mouse at the same time.

4.2.2 Patients with Alzheimer's Disease. The experimental group was composed of two female Alzheimer's disease patients whose mean age was 78.5. They had a mean accomplishment score of 62.5% before the training, that is 25% less than the healthy elderly. Before training, they had a mean number of 21.75 additions and a few perseverations ($n = 0.75$). According to the results of the questionnaire, they found that the cooking experiment was like the real environment (71.43%).

4.2.1.1 Written ILM (Breakfast Task). Patients took more time to perform the task after training (447 s) than before training (185 s), that is, an increase of 141.38%. However, their accomplishment score increased from 55% to 95% while perseverative errors and additions decreased respectively from $n = 4.5$ (before) to $n = 0.5$ (after learning) and from $n = 1.5$ (before) to $n = 0.5$ (after learning) respectively.

4.2.1.2 Self-recorded ILM (Coffee Task). Patients took approximately the same time to perform the virtual breakfast task before (593 s) and after training (519 s). Their accomplishment score increased from 70% to 90%. The number of perseverative errors was approximately the same before and after learning ($n = 0$ before and

$n = 0.5$ after). However, additions dropped from $n = 39$ (before) to $n = 4.5$ (after learning).

4.2.1.3 Computer Interaction. According to the results of the questionnaire, patients felt able to anticipate the consequences of their movements (46.43%), that is, 42.86% less than the healthy elderly. The task of interaction interfered with the execution of the virtual cooking tasks to a greater extent in patients (67.86%) than in the healthy elderly. However, they felt that they could not totally concentrate on the virtual cooking tasks (75.00%) but rather on the mechanisms of interaction, similar to the healthy elderly. Patients reported difficulties in using the mouse and needed a longer phase of familiarization. Case 4 showed critical difficulties and also needed to be reminded of how to interact during the learning. She experienced difficulty in sliding the mouse, pressing the mouse button, and dragging objects, while case 3 only reported difficulty in dragging.

5. Discussion

It is increasingly recognized that pharmacological treatments for dementia should be used as a second-line approach and that nonpharmacological options should ideally be used first (Douglas, James, & Ballard, 2004). Consequently, an increasing number of studies in recent years have examined the effect of nonpharmacological therapy (e.g., behavioral therapy, reality orientation, validation therapy, cognitive therapy), with promising results on quality of life, in particular in Alzheimer's disease. One type of cognitive intervention that may contribute to increasing patients' autonomy and independence is learning or relearning potentially useful everyday activities such as food preparation. Despite their profound memory impairment, people with Alzheimer's disease are able to (re)learn everyday skills, in particular when error reduction learning methods are used (Dechamps et al., 2011).

In this paper, we used the potential offered by virtual environments for rehabilitation (Crosbie et al., 2007) to design a VK devoted to the (re)learning of everyday activities in patients with Alzheimer's disease.

5.1 Virtual Cooking Tasks Before Training

In our experiment, virtual cooking tasks were easily understood and virtually performed by the healthy elderly controls, given their high accomplishment score before training and their impression of the realism of the cooking experiment. Our virtual cooking tasks were obviously more difficult for patients to understand than for the control group, given their high accomplishment score before training and their impression of the realism of the cooking experiment.

The fact that our patients committed high rates of commission errors in both virtual tasks before training is consistent with past research showing that this kind of error is frequent in neurologically impaired patients (Humphreys & Forde, 1998) testing in real life settings, including patients with Alzheimer's disease (Giovannetti et al., 2008). This supports the validity of our VK as a measure of real-life functioning in patients with Alzheimer's disease. Indeed, we have already shown that our VK kitchen makes it possible to detect disturbances in Alzheimer's disease patients' activities of daily living, and that confirms that the test has a predictive value for Alzheimer's disease patients' functioning in daily life situations (Allain et al., 2011). Moreover, patients took more time to perform virtual tasks than the healthy elderly, in agreement with another study in which healthy and MCI subjects showed a comparable accuracy of performance but where the latter took significantly longer than healthy subjects on several everyday functional activities (Giovannetti et al., 2007; Wadley, Okonkwo, Crowe, & Ross, 2008). Our result reinforces the feasibility of assessing time limitations using a VR environment.

5.2 Computer Interactions

Both patients and healthy subjects showed difficulties in interacting, consistent with the fact that people over 65 typically lack information technology skills. The patients clearly had more difficulty with the mouse than the control group. This finding can be linked with a study showing that elderly subjects with the worst results on a computerized assessment presented a risk of devel-

oping dementia in the subsequent two years (Aharonson, Halperin, & Korczyn, 2007).

5.3 Methods to (Re)Learn Activities of Daily Living

In the healthy elderly, the addition of verbal repetition (self-recorded ILM), did not lead to a better or worse performance compared to the written ILM. After a learning phase of six sessions and regardless of the method employed, it was possible to improve virtual task performance, especially with a higher improvement score on the written ILM and a decrease in the number of useless actions (commission errors) on the self-recorded ILM. The time spent performing the task was also reduced by about half after the written ILM (43.14%) and after the self-recorded ILM (56.16%). Consequently, our results suggest that the healthy elderly derived benefit from training with our VK system, in which they used two types of implemented error reduction learning methods.

Patients were almost able to accomplish both tasks. The written ILM also induced an improvement in their performance through an increase in their accomplishment score and a decrease in the number of additions and perseverations. As for the self-recorded ILM, it led to a clear drop in the number of perseverations, even though they remained notable. The time spent performing the task was increased after learning with the written ILM, while it was approximately the same before and after learning with the self-recorded ILM. No detailed conclusion can be drawn from the patients' data because scores before learning varied widely between the two methods. While neither methods proved superior to the other, our preliminary results demonstrate the efficiency of both versions of error reduction learning methods for the (re)learning of everyday action in VE. This method is therefore not only effective in the real context but also in the virtual context, in agreement with other studies using this method (Clare et al., 2000; Giovannetti et al., 2007). Like Giovannetti et al. (2007), we found that ILM induced an improvement in the performance score and a reduction in the number of perseverative errors in our AD patients. Despite the low presence score due

especially to interaction problems and to difficulty in accepting the psychological metaphor of the virtual cooking experience, the patients showed improvements. Other studies suggested that a high level of presence could explain the efficiency of training in VE (e.g., Rand et al., 2007). The ecological validity of the system might contribute to improving daily life activities even if the subject is psychologically immersed in the VE to a lesser extent.

The self-recorded ILM offered an assisted rehearsal learning strategy that demonstrated its benefit in elderly subjects with cognitive functioning decline in everyday activities (Moffat, 1989), and more recently in the recall of names (social, familiar, and famous names) and personal information (Clare et al., 2000). On the other hand, it seems to disturb subjects, because it interrupts the current action and adds a verbal task to the main task of object manipulation for performing a cooking activity. These points could explain the fact that in spite of the additional aloud rehearsal, we failed to find any critical advantage with self-recorded ILM compared to the simple written ILM, both in AD patients and the healthy elderly.

5.4 Limitations of Case Studies

Although promising, our findings should be interpreted with caution and considered as preliminary for several reasons. First, we tested the system in only four subjects, so it is not possible to extrapolate to the whole population of patients with dementia. In addition, our patients were affected by a moderate form of AD. Indeed, there are different stages of Alzheimer's disease, in particular with patients with more severe impairments in everyday activities. Whether more demented patients would benefit to the same extent or more from one and/or the other error reduction method implemented in our VK remains to be established. Our findings cannot account for AD patients referred for nonpharmacological treatment, so it remains to be established whether our (re)learning VK is usable with more affected patients. Further, since we could not observe our patients in similar naturalistic settings before and after the short training sessions, we do not know whether the

difficulties observed correspond strictly to problems in real-life settings and/or whether the benefits observed here might have been spontaneously transferred. However, some studies showed that the benefits in daily life activities obtained in virtual reality sessions transfer to the real world (e.g., Rand et al., 2009; Yip & Man, 2009; Werner et al., 2009). Another issue is the value of the two learning methods used in the VK. We did not find any difference between them but using more participants might demonstrate a difference. Finally, since we could not obtain any follow-up data for the patients, we do not know whether the benefits persisted over time.

6. Conclusion and Future Work

The present study tested two learning methods in a VR environment: one based on step-by-step verbal written instructions and the other using rehearsal aloud of instructions. The tasks focused on two activities of daily living: cooking breakfast and making coffee. The main finding is that both of the error reduction learning methods are of value and hold promise for improving the performance of everyday actions in both healthy elderly and Alzheimer's disease patients. Error reduction learning methods implemented in virtual environments could be successfully used in such populations. Future studies with groups and subanalyses using disease severity levels are needed to confirm our pilot results and to evaluate each virtual learning method. Furthermore, a more intensive treatment design of several sessions per week should be explored, in particular in more impaired AD patients, in order to confirm the effectiveness and usability of virtual reality for (re)learning in these subjects. Future studies should also explore whether patients successfully transfer these acquisitions in their own home. Another interesting topic for future research is the comparison with other real context training methods that have been found to improve autonomy and independence reliably in everyday activities in these patients (e.g., see Adam et al., 2000). Our aim at the outset of this study was to identify ways to incorporate VR technology to improve everyday function in patients with Alzheimer's disease.

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