Virtual Reality as a New Approach to Assess Cognitive Decline in the Elderly

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Abstract

Brain aging is a natural process that leads to a change in cognitive functions. Mild Cognitive Impairment (MCI) is a condition in which a person has cognitive functions that are below normal for his age. However, these deficits are not pronounced enough to confirm for the diagnosis of dementia. It is therefore important to develop new ways to assess cognitive functions in the elderly. This would indeed lead to a better identification of the cognitive losses that are related to normal or pathological aging. The objective of this study was to investigate the relevance of virtual reality as a new evaluation approach in psychology. To do this, 10 elderly people with Mild Cognitive Impairment, and 20 elderly people without cognitive problems, were compared using tests of prospective memory that were presented in a traditional way and in virtual reality. The diagnosis of MCI was made using the Montreal Cognitive Assessment (MoCA). Significant differences between the two groups were noted in virtual reality. Nevertheless, no difference was observed between the two groups with the traditional task. A significant positive correlation between the virtual reality task and the MoCA, but not between the traditional task and the MoCA, was observed. An evaluative approach based on virtual reality seems more sensitive to cognitive impairment associated with aging than an approach based on traditional neuropsychological tests.

1. Introdution

1.1 Cognitive aging

Like the rest of the body, the brain is affected by the effects of aging. This phenomenon is a natural process that causes changes in cognitive functions. However, several intra-individual and inter-individual differences make difficult the description of a typical profile of the natural decline (Christensen, 2001). Throughout the aging, several cognitive domains are affected, some before others. We know, for example, that knowledge "crystallized" (eg vocabulary or general knowledge), is resistant to aging into old age and begins to show a decline very late. In contrast, memory and psychomotor speed showed a continuous decline since the end of adulthood (Christensen, 2001).

Cognitive aging is a field of research increasingly studied and gives rise to new concepts. Among them, the concept of "Mild Cognitive Impairment" (MCI) is an important step in the diagnostic level. The MCI is a zone between normal aging and dementia. It refers to people who get results below the norms on neuropsychological tests, but without matching the diagnostic criteria for dementia (Petersen, 1999). They also remain independent in activities of daily living. The rate of conversion of MCI to dementia is between 10 to 15% for MCI compared to 1-2% for non-MCI (Geda et al., 2008; Geda et al., 2004; Muangpaisan et al., 2008; Peters et al., 2008).

1.2 Aging of the prospective memory

In recent years, researchers have begun to pay more attention to the decline of prospective memory in aging. By definition, prospective memory is memory that allows us to remember to do what we have to do (Ellis, 1996). It is the memory of daily activities, which for example allows us to remember to go buy bread when we go home after work.

Prospective memory is particularly vulnerable to age-related decline due to the greater contribution of internal control mechanisms to succeed in this kind of tasks (Luo & Craik, 2008). Self-initiation needed to accomplish a task of prospective memory would be greater than in a retrospective memory task. Indeed, a significant effect of age on self-initiation processes has been observed in the literature (Einstein et al., 2012).

Prospective memory difficulties are also present in MCI, and may be a good indicator of early cognitive decline. Indeed, Huppert and Beardsall (1993) showed that prospective memory is particularly affected in very early stages of Alzheimer's disease and prospective memory tasks are more sensitive to detect people at the beginning of this disease. Recent studies have found that people with MCI had more prospective difficulties in comparing control groups (Kazui et al., 2005; Troyer et al., 2007). Costa et al. (2010) also indicated that prospective memory was affected in MCI.

1.3 Evaluation Approaches

Traditional neuropsychological assessment is based on "paper and pencil"type tests. For the evaluation of MCI, the main tools are the Mini-Mental Test (MMSE-Folstein et al., 1975), or the Montreal Cognitive Assessment (MoCA-Nasreddine et al., 2005). These screening tools determine the presence or absence of cognitive impairment. Within these tests, which are administered quickly within 10 to 20 minutes, we find memory, naming, abstraction, attention, visuo-construction and mental flexibility subtests.

On prospective memory, few standardized tools remain available for neuropsychological assessment. Those that exist are often self-assessment questionnaires, or questionnaires completed by patients' relatives.

Despite the fact that these traditional tests are used by the majority of neuropsychologists and are very useful when making diagnoses, they have some limitations.

Ecological validity, which is defined as the degree of similarity between the lives of the participant and evaluation requirements, remains relatively limited. With the advancement of knowledge in neuropsychology, ecological validity is increasingly a factor to consider. Greater ecological validity of a test, the easier it is to predict the function of the person in his daily life. Some memory tests with greater ecological validity are available. The Rivermead Behavioral Memory Test (RBMT) (Wilson et al., 1989, 2000) is an interesting alternative to traditional tests in assessing memory. The RBMT is an ecological tool, since it evaluates various aspects of everyday memory (making appointments, leave a message, face recognition, etc.). Despite the fact that this tool allows a comprehensive assessment of memory and, more specifically, prospective memory, this test does not, however, present all aspects of real life. There is still much work to be done to improve the ecological validity of neuropsychological assessment tools and it is important to consider this factor in the development of new assessment techniques.

1.4 Virtual reality

Virtual reality is a technology that allows a user to navigate and interact in real time with three-dimensional objects and computer-simulated environments (Pratt et al., 1995). This technique has an ecological character. It is therefore possible to develop assessment tools that greatly resemble everyday functionning, which could correct in part the limitations of traditional tests. In addition to its ecological character, virtual reality has several advantages. It allows immersion in environments without risk of injury. It is a dynamic environment that fosters motivation participant. Finally, it offers a high level of control for the assessors, both in terms of the presentation of stimuli and for recording scores.

2. Objective and Hypothesis

In summary: elderly population is steadily growing, which results in a proportional increase in some cognitive problems. MCI is an intermediate zone between normal aging and dementia processess. The development of a new assessment tool would allow early detection of MCI and faster care for patients. The evaluation using virtual reality could provide a complement to traditional neuropsychological tests providing a more ecological and more sensitive tool to detect cognitive decline related to age.

The purpose of this study was to demonstrate the relevance of virtual reality as a new evaluation approach in neuropsychology.

It is expected that the task in virtual reality show greater sensitivity to deficits associated with MCI than the traditional task of prospective memory, because of the ecological nature takes virtual reality.

3. Method

3.1 Participants

Group 1 consisted of 10 people diagnosed with MCI. They were 8 men and 2 women whose average age was 64.80 years (SD = 2.50 years). Group 2 consisted of 20 participants with no cognitive problems. These 11 men and 9 women formed the control group. The average age of this group was 63.25 years (SD = 2.98 years). There was no significant difference between the two groups in terms of age (t (28) = 1.41, p> .05) and gender (X2 = 1. 90, p> .05).

3.2 Instrument for the diagnosis of MCI

The diagnosis of MCI was made using the Montreal Cognitive Assessment Test (MoCA), which was developed by Nasreddine et al., (2005). The MoCA was designed to assess mild cognitive dysfunction. It evaluates the following functions: attention, concentration, executive functions, memory, language, visuoconstructives capabilities, capacity for abstraction, calculation and orientation. This test takes about 10 minutes. The maximum number of points is 30, a score of 26 or above is considered normal. MoCA has good values in terms of its validity and fidelity. All participants in Group 1 had a score of 25 or less. All participants in Group 2 had a score of 26 and over.

3.3 Instruments to assess prospective memory in traditional condition

Prospective memory in traditional condition was based on the most commonly cited ecological neuropsychological tool in the literature: the Rivermead Behavioural Memory Test (RBMT-Wilson et al., 1989, 2000). The participant's first task was to ask the experimenter for a business card, halfway through the assessment; the external cue was given by the experimenter. In the second task, having lent the experimenter a personal item, the participant had to ask for it back at the end of the assessment; the external cue was given by the context, i.e. the end of the experimentation. Before proceeding with the experiment, each participant had to correctly state what the two prospective-memory tasks were. The variable used for analysis was the total score on these two subtests. The maximum score was 13 points. A high score indicates good performance in traditional prospective-memory tasks.

3.4 Instrument for assessing prospective memory in virtual reality

The prospective-memory assessment in virtual reality began with a scenario designed to render the task more realistic to everyday life. During the briefing, the participant was informed that he/she would soon have to move to a new apartment in a new city. The task was to visit two apartments (one small and one large) and choose the one he/she would rather live in. The participant was informed that his/her voice would be recorded during the visit and that he/she must give opinions on the apartments based on his/her personal tastes and needs and on practical housing considerations. Over the course of carrying out this task (which we designate here as the 'ongoing task'), the participant was also responsible for performing three prospective-memory tasks: picking up a lease in the smaller apartment and not in the larger apartment; feeding a fish (while saying "I am feeding the fish") upon seeing that the clock showed 11:41; and turning off a fan (while saying "click") in the master bedroom of the large apartment. The maximum score was 14 points. A high score indicates good performance in virtual prospective-memory tasks.

3.5 Materials and procedure

The virtual-reality experiment was conducted using a personal computer (Dell XPS M1530, operating system: Windows Vista) equipped with an nVidia 8600M graphics card GTO supporting video-game environments as well as an eMagin Z800 immersion lens (resolution: 600 x 800) with an integrated head tracker (360 ° horizontal and 60 ° vertical). Movement in the virtual environment was controlled with a standard Logitech mouse. The virtual environments used in this study were created by Bouchard et al (Cyberpsychology Laboratory, University of Quebec in Outaouais http://w3.uqo.ca/cyberpsy), and inserted into the video game Max Payne ™. Participants had to visit a virtual city (learning phase) and then visit the two virtual apartments. The results were directly compiled into a database using FileMaker Pro 8™ software.

The study procedure was approved by the Human Research Ethics Committee of the University of Quebec at Trois-Rivières.

4. Results

The presentation of results is done in two parts. The first part presents the results of comparisons of means tests for traditional and virtual prospective memory. These analysis were designed to verify that Group 1 participants were distinguished from Group 2 participants in each of these tests, using t-tests. The reader can find the results of the two groups in Table 1. The second part of this section focuses on the links between traditional and virtual tests of prospective memory, using Pearson correlations.

4.1 Group comparisons to traditional and virtual tests of prospective memory

The t-test applied to the results of the two groups on the total score of prospective memory in the traditional task showed that there was no difference between the two groups (t (28) = -0.63, p = .53).

Table 1. Means and Standard Deviations for Both Groups on Traditional and Virtual Prospective Memory Tasks

Test	Group	Mean	SD
Traditionnel Prospective Memory Task (Total Score /13)	MCI	9.65	2.60
	Control	10.30	2.79
Virtual Prospective Memory Task (Total score /14)	MCI	5.40	3.17
	Control	8.90	3.37

However, the t-test applied to the results of the two groups on the total score of prospective memory in the virtual task showed a significant difference between the two groups (t (28) = 2.73, p = .01).

4.2 Correlations between traditional and virtual tasks of prospective memory and diagnosis of MCI

The following analyzes were designed to investigate the relationship between the two types of prospective memory tasks (traditional and virtual) and diagnostic test of MCI. The results showed a significant correlation between the prospective memory task in virtual reality and the MoCA (r = .45, p = .01). However, there was no correlation between the traditional task of prospective memory and the MoCA score (r = - .06, p = .76).

5. Discussion

First, the results of the present study support the findings of previous studies that had demonstrated impaired prospective memory in MCI participants (Costa et al., 2010; Beardsall & Huppert, 1993; Kazui et al., 2005; Troyer et al., 2007).

Secondly, the results of this study support the hypothesis that an evaluative approach based on virtual reality is more sensitive to the effects of MCI than traditional neuropsychological tasks. These results can be explained by the ecological nature of virtual environments. These would require more cognitive resources to perform the tasks. Situations of everyday life are more complex than the tasks typically used in neuropsychological assessment. Virtual reality seems to reach a level of complexity that better reflects the functioning of the person in real life. Moreover, the team of Werner et al., (2009) also demonstrated, using a complex task presented in virtual reality (the virtual action planning supermarket),

that MCI participants had performed significantly worse.

However, it is important to be cautious in interpreting the results. Indeed, other aspects of the ecological nature of virtual reality can explain the results. For example it is possible that other traditional tasks of prospective memory, more complex than that used, may allow to observe similar results to those obtained in virtual reality. It is also possible that the results in virtual reality depends not only on the ability of the prospective memory of the participants but also their ability to operate the equipment. Virtual reality still seems promising in the neuropsychological evaluation of several neurological pathologies (Klinger et al., 2006; Nolin et al., 2012;. Rizzo et al., 2000), and represents a complementary tool to traditional neuropsychological assessment. It therefore seems important and appropriate to continue research in this area.

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