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Designing a Computer-based Rehabilitation Solution for Older Adults: The Importance of Testing Usability

Fátima González-Palau[*1,2], Manuel Franco[1-3], José M. Toribio[1], Raquel Losada[1], Esther Parra[1] and Panagiotis Bamidis[4]

[1]Intras Foundation (Spain) [2]University of Salamanca (Spain) [3]Mental Health Unit of Zamora Hospital (Spain) [4]Aristotle University of Thessaloniki (Greece)

ABSTRACT

Over the past years, the development of technology applications for elderly people has increased, creating new possibilities for treatment. These applications are usually identified as successful solutions for mental health but usability limitations may influence their effective deployment in clinical use. The objective of this study was to examine the usability aspects of a cognitive and physical training platform, comparing these aspects in healthy elderly, subjects with mild cognitive impairment (MCI) and others with dementia. Method: 80 elderly were recruited from different clinical contexts. They received three months of training with the Long Lasting Memories (LLM) platform and were assessed through a special questionnaire that asked for the usability aspects of the program. Results: High scores were found in all the sections of the questionnaire, indicating good usability and satisfaction with the LLM system. Participants with dementia expressed more difficulties than the rest of subjects ($F(2,160) = 4{,}488$; $p = .009$) in learning how to use LLM. Also most of the professionals found LLM difficult (60%) or very difficult (20%) for elderly subjects with cognitive impairment to use without help and revealed that this group needed more explanations in the use of the platform. Conclusion: The strengths and problems found related to usability enabled a better understanding of the LLM system that contributed improving the software. The results also highlighted the importance of examining not only the cognitive effectiveness of new rehabilitation programs, but also the immediate issues of design and acceptance by end users.

Keywords: *Usability, Cognitive Training, Physical Training, Dementia, Mild Cognitive Impairment, Aging.*

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1. Introduction

Ageing causes impairment in various aspects of cognitive function. One of the extremes of this decline is represented by dementia. The medical concept of dementia refers to a pattern of cognitive and behavioral symptoms which typically arises from

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*Corresponding Author:
Fátima González Palau
Intras Foundation. Ctra. De la Hiniesta esquina con c/ La Cierva, s/n, bajo. CP. 49024, Zamora, Spain
E-mail: fatimagonzalezpalau@yahoo.com.ar

chronic and often progressive brain diseases (Kurz and Lautenschlager, 2010). In Alzheimer Dementia (AD), memory loss is the initially dominating problem due to deterioration of the hippocampus (Borlikova et al., 2013). In addition to the diagnosis of dementia, during recent years, the concept of mild cognitive impairment (MCI) has been developed and appears to apply to a group of individuals in a transitional state between normal aging and AD. The different definitions of MCI comprise: (1) a cognitive complaint; (2) preserved basic activities of daily living; (3) cognitive impairment (not normal for age and education) or decline in cognition evidenced by performance on objective cognitive tasks; (4) preserved general cognitive functioning and (5) absence of dementia (Petersen et al., 2001; Portet et al., 2006; Winblad et al., 2004).

Physical exercise and cognitive training are two of the main psychosocial solutions that have shown a potential impact on the improvement of cognition in the elderly with and without cognitive impairment. Many studies have evidenced the effectiveness of traditional methods for the training of cognitive functions in healthy aging people (Ball et al., 2002; Buiza et al., 2008; Craik et al., 2007; Tsai, Yang, Lan, and Chen, 2008) and subjects with MCI (Belleville et al., 2006; Greenaway, Hanna, Lepore, and Smith, 2008; Hampstead, Sathian, Moore, Nalisnick, and Stringer, 2008; Wenisch et al., 2007). Also, randomized control trials have shown significant evidence of the influence of exercise in the improvement of cognitive faculties in elderly people with and without cognitive impairment (Brown, Liu-Ambrose, Tate, and Lord, 2009; Geda et al., 2010; Lautenschlager et al., 2008; Liu-Ambrose et al., 2010; Scherder et al., 2005; Williamson et al., 2009).

Despite all the evidence related to the effectiveness of physical and cognitive training, due to the increasing demand of psychosocial interventions among the aging, these solutions are not always accessible to all patients in health care settings (Faucounau, Wu, Boulay, De Rotrou, and Rigaud, 2010). Technology applications are thus one possible answer to provide effective strategies for populations in rapid growth, such as older adults (Barnes et al., 2009; Cipriani, Bianchetti, and Trabucchi, 2006; Gunther, Schafer, Holzner, and Kemmler, 2003; Talassi et al., 2007).

These new technological applications have introduced numerous ways to expand health care to multiple fields (Demiris, Doorenbos, and Towle, 2009). For example, previous studies have analyzed the benefits of new technologies in the fields of dementia (de Oliveira Assis, Tirado, de Melo Pertence, Pereira, and Mancini, 2010; Westphal, Dingjan, and Attoe, 2010), age related impairment (Ackerman, Kanfer, and

Calderwood, 2010), as well as healthy older and younger older adults (Harada, et al., 2010). However, usability limitations may influence their effective deployment in clinical use (Fillit, Simon, Doniger, and Cummings, 2008).

Usability is standardized by the International Organization for Standardization (1998) as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a context of use. Usability evaluation is nowadays recognized as critical to the success of interactive health care applications (Becker and Webbe, 2006; Jaspers, 2009).

In this context, the need is to create usable alternatives for cognitive intervention (Caprani, Greaney, and Porter, 2006) that could also reduce the requirements for professional support (González Palau et al., 2012; Soto-Pérez, Franco Martín, and Jiménez Gómez, 2010; Soto-Pérez, Franco Martín, Monardes, and Jiménez, 2010) and enhance the acceptance of the intervention techniques by their users (Jaspers, 2009). In this way, computer-based platforms offer the possibility of widespread dissemination of cognitive training programmes. Other advantages of these new technologies are that the they enable the creation of individualized rehabilitation programs (Cipriani, Bianchetti, and Trabucchi, 2006) and that they provide instant feedback that helps therapists in setting up a systematic training plan (Faucounau, Wu, Boulay, De Rotrou, and Rigaud, 2010).

Long Lasting Memories (LLM) international project involves the validation of an integrated technology platform that combines cognitive exercises with physical activity. This unprecedented approach of simultaneous cognitive and physical stimulation aims to deliver an effective solution for cognitive decline in healthy aging, mild cognitive impairment (MCI) or mild dementia. The objective of this study was to examine the usability aspects of the new LLM training program in a sample of Spanish older adults, comparing the acceptance and usability of the platform by healthy elderly, subjects with mild cognitive impairment (MCI) and others with dementia.

We hypothesized before the beginning of the training that the lack of motivation and of learning possibilities that characterized older adults with AD could affect the intervention process in terms of satisfaction and adherence to treatment. Also, one main advantage of technologies in rehabilitation is, as mentioned, the possibility to reduce personnel support during the session, allowing widespread dissemination of the interventions. We conjectured that this main advantage might be affected when involving elderly with cognitive impairment, since the therapist's presence would be required in the session. Our hypothesis was that the decline of learning possibilities of

impaired elderly in addition to an absence of prior computer use of the participants, would hinder the effective use of the platform.

2. Methods

2.1 Participants

180 older adults recruited from 8 residential facilities, 2 community centres and 1 memory clinic participated in the study. The centers were situated in 5 different cities in Spain. Subjects who were ≥ 60 years old, fluent in Spanish and not currently enrolled in another research study were invited to take part. Older adults with advanced dementia, severe depression or other relevant psychiatric or neurological diagnosis, unstable medication or severe un-correctable vision/hearing problems that made it impossible to keep up with all components of LLM service were excluded from the study.

Of the total sample, 33 participants had a diagnosis of mild dementia, 52 had a diagnosis of mild cognitive impairment (MCI) and 95 participants did not present any cognitive impairment. All diagnoses were made by a psychiatrist according to DSM - IV criteria for dementia and Petersen criteria for MCI (Petersen et al., 2001; Petersen et al., 1999). Information for these diagnoses was obtained in structured interviews with participants and with family members, on demographic variables, on personal and family medical history as well as social, behavioral and occupational history. Participants also received a battery of cognitive tests that supported the diagnoses. For the assessment of the fulfillment of the inclusion / exclusion criteria, the diagnostic information described above was considered as well as the scores in the MEC 35, a Spanish version of the Mini Mental State Examination (MMSE) (Lobo, Esquerra, Gomez Burgada, Sala, and Seva, 1979) and the Geriatric Depression Scale (GDS) (Yesavage et al., 1982).

2.2 Intervention Platform

LLM's Spanish prototype was based on the integration of the LLM Cognitive Training Component (CTC) and the Physical Training Component (PTC) which perform complementary and interactive tasks to provide the system's services.

Cognitive Training Component (CTC)

The CTC is designed to support the cognitive training procedure provided by the Gradior software (Franco, et al., 2000). Gradior is a neuropsychological assessment system and a multi-domain cognitive training program including attention, perception, episodic memory and working memory tasks. Principles of feedback and difficulty adaptation are used to enhance plasticity and motivation. Verbal-auditory feedback is given in response to correct and incorrect responses. Adaptation of task difficulty is provided by initially setting the difficulty level according to pre-test performance. Afterwards, the task difficulty can be adjusted by the professional according to each patient's individual performance. User-friendliness results from using a touch screen display. All participants received 40 minutes of cognitive training, 3 times a week, during the 12-week program. The training included exercises of perception (6 trials), attention (7 trials), episodic memory (4 trials) and working memory (2 trials). Figure 1 shows the main menu of Gradior Software.

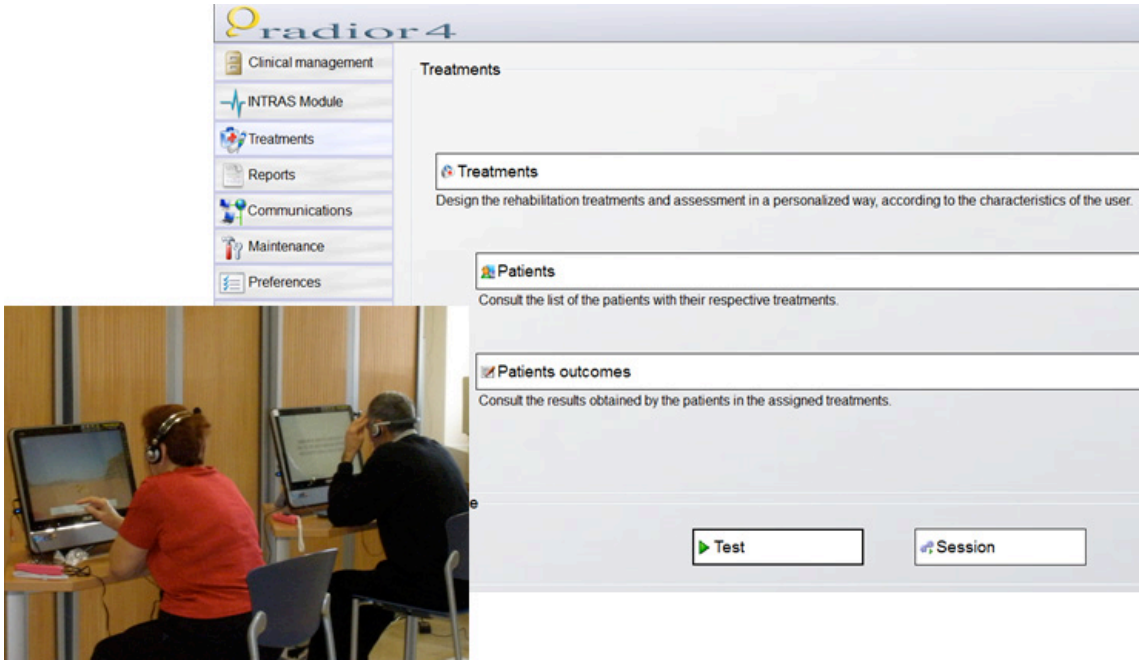

Figure 1. Seniors during the Gradior session in a pilot centre (left). In the main menu, therapist can adjust the user's treatments, select several cognitive modalities and obtain reports of the session´s results (right).

Physical Training Component (PTC)

All physical exercises were implemented on the FitForAll (FFA) platform (Long Lasting Memories, 2009). FFA is a game platform that can help elderly people to keep fit and maintain their wellbeing through an innovative, low-cost ICT platform, such as Wii Balance Board. Participants start on the light intensity level with a target heart rate

(HR) of 50-60% of maximum heart rate (HRmax) and can proceed to the very hard level with a target HR of 80-90% of HRmax within the training period. The program has 4 levels of difficulty which are assigned to the subject according to their physical possibilities. In consultation with a therapist, participants decide every two weeks either to proceed to the next level of intensity or to remain at the present level of intensity. The design of one training session involves the following modules: 1) a warm-up period (5-10 minutes), through aerobic exercises like hiking or cycling, as showed in Figure 2; 2) the main part (30-35 minutes) through exercises of endurance, strength and balance; 3) a cool down period (5 minutes) that includes stretching and warm-up training exercises to recover normal cardiac levels. All participants performed a 1-hour session of FFA, 3 times a week, during the 12-weeks program.

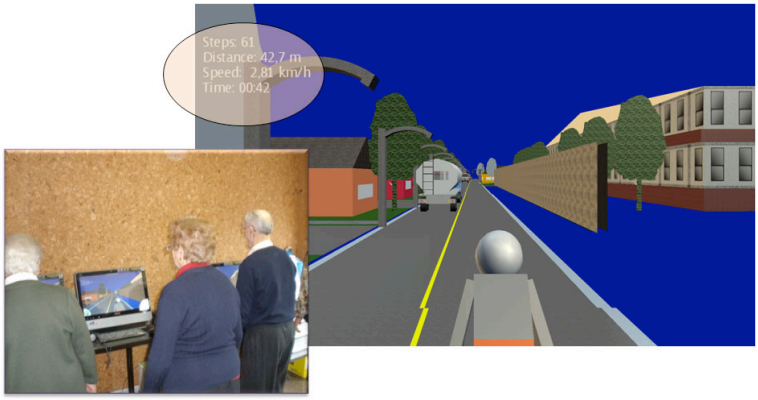

Figure 2. Users during the hiking exercises of the warm up period (left). Seniors wear a Wii Remote attached to their legs that recognizes the steps made and moves the on-screen character through a city landscape. The velocity of the user, the total distance and the total number of steps are measured and displayed on the screen (right).

2.3 Usability measures

At the end of the intervention participants and professionals supervising the treatment were assessed by means of a specifically designed questionnaire that included aspects of their perception of the platform. The questionnaire was created for this study and aims to provide a useful context for identifying factual limitations of the system and the reasons why these deficiencies pose difficulties to its users.

The participant's questionnaire consists of a sociodemographic data and personal information section, 4 open questions (suggestions and LLM benefits and drawbacks) and 43 items rated by the respondent on dichotomic Yes/No answers or five to seven-points Likert scale. Subscales include: a) Affective evaluation of LLM; b) Usability evaluation; c) Satisfaction evaluation; c) Sustainability; e) Independent living; f) Social

integration. A total score for each subscale is calculated. Higher scores indicated positive perception of the respondent towards the platform.

The professional questionnaire includes 4 open questions (suggestions and LLM benefits and drawbacks) and 20 items rated by the respondent on dichotomic Yes/No answers or five to seven-point Likert scale. Subscales include: a) Usability evaluation; b) Satisfaction evaluation; c) Sustainability.

Additionally, a history of computer use was obtained before the intervention, with the treatment supervisor asking the patient, “Do you use a computer? Users had 4 possible answers indicating that they *have never used*, or *rarely*, *sometimes* or *frequently* use the PC.

2.4 Procedure

Intervention

All treatments were conducted at the memory clinic or communitarian centers where participants usually go or at the institutions where individuals lived. To ensure the highest ecological validity and create a comfortable atmosphere, all individuals were located in a comfortable room with proper lighting and space conditions to carry out the treatment.

The treatments were carried out in groups of up to 6 older adults. However, the sessions were individualized and there was no interaction between participants during the interventions. Headphones were used since auditory instructions were provided.

In addition, the same exercises were provided to each participant but at three levels of difficulty. These levels were created to enable homogenous treatments but adapted to the cognitive possibilities of the users. The levels were divided to match the cognitive possibilities of healthy older adults, MCI or dementia population.

Participants were informed about the goals and procedure of this study. An informed consent form was handed out, with general information, which was it mandatory to sign to proceed with the study.

Statistical analysis

Healthy subjects, elderly subjects with dementia and subjects with MCI were compared with respect to demographic variables using analysis of variance (ANOVA) for continuous variables and Chi-square (X^2) for dichotomous ones. After the usability assessment, the scoring process included normalising the responses to reflect a higher number for positive responses than negative ones (i.e., value of 1 for most negative to

value of 7 for most positive). For all users and professionals questioned, frequency was calculated for each response option. One way ANOVA were conducted to compare totals of each section between Healthy, MCI and Dementia group. Post- hoc Tuckey test was used to locate differences in the event of significant main comparisons.

3. Results

3.1 Socio demographic characteristics of the users sample

Demographic characteristics of the complete sample and split by type of group are given in Table 1. The overall sample had more females (74.8%) and had a mean age of 82.23 (± 7.8) years. The sample was Spanish (100%) with a mean education of 8.3 (± 3.35) years. There were no significant differences between the three groups of subjects in gender ($X^2 2 = 2.94$, *df* = 2; *p* = .230); years of education (*F*(2, 243) = 1.326, *p* = .267), age (*F*(2, 284) = 0.810; *p* = .446) and GDS depression scores (*F*(2, 293) = 1.778, *p* =.171).

	All (*n* = 180)	Healthy (*n* = 95)	MCI (*n* = 52)	Dementia (*n* = 33)
Age (*M*, *SD*)	82.23 ± 7.8	81.87 ± 6.84	81.97± 9.16	83.44 ± 5.67
Education (*M*, *SD*)	8.30 ± 3.35	8.15 ± 3.16	8.87 ± 3.25	7.75 ± 3.87
Gender % female	74.8	73.2	81.4	66.1
Gender % male	25.2	25.8	18.6	33.9
Marital Status				
Single %	18.1	13.4	21.6	24.7
Married %	29.7	36.9	23.5	22.0
Divorced %	2.3	2.0	2.9	1.7
Widow %	50.0	47.7	52.0	51.6
Country residence / nationality % Spain/Spanish	100	100	100	100
GDS (*M*,*SD*)	3.69 ± 3.09	3.34 ± 3.07	3.98 ± 3.33	3.61 ± 2.67
MEC 35 (*M*, *SD*)	24.38 ± 4.15	26.74 ± 2.88	23.8 ± 3.76	20.67 ± 4.33

Table 1. Demographic characteristics of the complete sample of users and split by clinical diagnosis

14 users dropped out the study (Healthy *n* = 6; MCI *n* = 4; Dementia *n* = 4) and were not able to perform the usability questionnaire. The reasons for dropping out were

health problems (*n* = 7), family problems (*n* = 4) or reluctance to continue with the study (*n* = 3).

In the questions relating to computer use, 82.4% of the participants indicated that they had never used computers, 8.2% indicated that they rarely (4.1%) or sometimes (4.1%) used a PC. Only 9.5% expressed that they frequently used a PC.

3.2 Usability results

Affective evaluation of LLM

This section of the survey asked the individuals to indicate emotional responses reflecting how they felt about the LLM training. Elderly subjects responded positively to most of the questions. 79.0% expressed that LLM was fun (39.8%), a lot of fun (24.1%) or very much fun (15.1%); 78.9% denied getting bored during the sessions and 87.3 % denied LLM was unpleasant. Similarity, 100% of supervisors agreed (40%) or strongly agreed (60%) that participants seemed to enjoy the LLM sessions. Between elderly participants with MCI, dementia and healthy subjects, there were no differences in this section of the questionnaire ($F(2, 163) = 0.788$; $p = .457$), indicating that the three groups had positive feelings (e.g. they liked it, they felt cheerful after training with it) regarding the LLM training.

Table 2 shows the scores of the three groups in all the sections of the users' questionnaire

Usability evaluation

This section of the survey asked the individuals to respond to questions that reflected on the users' interactions with the LLM technical system. 60.1% of the participants expressed that LLM was easy (47.2%) or very easy (12.9 %) to learn how to use. Similarly, 60% of the supervisors found LLM easy (40%) or very easy (20%) for professional use. Nevertheless, there were significant differences in this section according to the diagnosis of the participants ($F(2, 160) = 4.488$; $p = .009$). Participants with dementia expressed more difficulty than the rest of the subjects ($p < .001$) in learning how to use the LLM system and 40.1% of them found it difficult to use LLM without help. Also most of the professionals found LLM difficult (60%) or very difficult (20%) for elderly subjects with cognitive impairment to use without help and revealed that this group needed more explanations in the use of the platform. These results may represent the difficulties this population has in learning and using LLM alone, especially

the physical components that need particular devices (WII board and remote control) connections to complete the sessions.

Total Section	Minimum - maximum values	All (*M*, *SD*)	Healthy (*M*,*SD*)	MCI (*M*,*SD*)	Dementia (*M*,*SD*)	*F*	*p*
Affective	10 - 70	54.33 ± 9.25	55.03 ± 8.93	54.03 ± 8.92	52.58 ± 10.73	0.788 (2,163)	.457
Usability	5 - 35	26.09 ± 4.43	27.04 ± 4.33	25.09 ± 4.62	24.67 ± 3.76	4.488 (2,160)	.009
Satisfaction	7 - 35	27.04 ± 4.21	27.47 ± 4.33	26.70 ± 4.90	26.19 ± 4.08	1.174 (2,160)	.312
Sustainability	0 - 5	3.49 ± 1.16	3.62 ± 1.10	3.33 ± 1.30	3.33 ± 1.07	1.126 (2,157)	.286
Independent Living	3 - 11	7.49 ± 1.88	7.76 ± 1.75	7.28 ± 2.06	6.78 ± 1.78	3.183 (2,155)	.044
Social integration	3 - 15	10.24 ± 2.60	10.84 ± 2.23	9.68 ± 3.09	9.19 ± 2.40	5.906 (2,156)	.003

Table 2. Mean, SD and differences between groups in total scores of users' questionnaire.

Satisfaction evaluation

This section of the survey asked the individuals to respond to questions that reflected on overall levels of satisfaction and desire to use the LLM system. There were no differences between participants with and without cognitive impairment in this section ($F(2,157) = 1.126$; $p = .312$) indicating the satisfaction of the three groups with the platform. 83.7% of the overall sample believed that LLM was beneficial (58.4%) or very beneficial (25.3%) to their health. All professionals also rated LLM as beneficial (60%) or very beneficial (40%) to the elderly. 73.0% of the participants agreed (55.2%) or strongly agreed (17.8%) that LLM met their expectations and 66.9% indicated that the platform made them feel confident (52.8%) or very confident (14.1%) about using new technologies. All professionals agreed (80%) or strongly agreed (20%) LLM is helpful in training the elderly mentally and physically.

Sustainability

This section of the survey asked the individuals to answer questions that reflected on market-oriented issues, including the possibility of charging users for the LLM service,

whether the LLM service was something the users would like to continue to use after the end of the trials and whether they had recommended the LLM to friends. 78.1% of the elderly and 100% of the professionals expressed that it was worth paying for the LLM service. 84% of the users expressed interest in continuing using LLM after the three-month study and 96.1% indicated that they would recommend the service to other people. No significant differences (F (2,157) = 1.126; p = .286) were found in this section of the questionnaire between the three groups of study.

Independent living and social integration

The Independent Living section asked the participants to answer questions that reflected the impact of LLM on the users' ability to live independently. The social integration section of the survey asked the individuals to answer questions that reflected on the impact of LLM on the individual's social connections. The overall sample presented positive responses in these sections. 58.9% of elderly agreed (38.6%) or totally agreed (20.3%) that LLM made them feel that they could control their health better and 57.2 % agreed (42.1%) or strongly agreed (15.1%) that LLM enabled them to enrich their means of communication. However, differences were found in the independent living section (F (2,155) = 3.183; p = .044) and social section (F (2,156) = 5.906; p = .003) of the questionnaire between dementia and healthy participants. Lower scores were found in the dementia group in both sections, and in comparison to healthy participants who had more positive answers. The MCI group presented higher scores in the independent living sections than healthy participants, and similar scores in the social section.

4. Discussion

The Long Lasting Memories service was designed to provide a simple, user-friendly cognitive and physical training system for elderly people. The large sample analyzed during this study was suitable for the assessment of the clinical feasibility and acceptability of the platform, including participants with and without cognitive impairment, as well as a large number of individuals with no prior computer use.

This usability assessment was performed asking users and professionals that were supervising the treatments to score the platform. The questions asked about positive

as well as negative aspects of the program that would help to identify factual system deficiencies and improve the LLM solution.

Identifying these aspects is vitally important in computer applications for rehabilitation. Although several programs have previously studied the impact of computer based applications on cognitive functions (Barnes, et al., 2009; Cipriani, et al., 2006; Gunther, et al., 2003; Talassi, et al., 2007), only few of them have analysed the solutions in terms of accessibility and possibilities of actual use by their end users (Gonzalez-Abraldes, et al., 2010).

This study provides a real example of a usability analysis, in a sample where most of the participants have never used the PC or have never heard of the Wii or similar devices. This situation is very common among older adults. Frequently the elderly population have to cope not only with a lack of knowledge in using equipment but also with an ignorance of general concepts underlying new technologies (Harada, et al., 2010).

In keeping with our hypothesis, we found during this study that older adults with higher levels of cognitive impairment had limited chances to learn how to use the technology. Professionals supervising treatments also confirmed these difficulties and added that patients with dementia needed far more explanation on how to use LLM components. We understand that the system's functionality involves devices that the elderly subjects have to connect and hold to the legs or arms to ensure correct connection with the PC and this may be hard for participants with cognitive decline to do on their own.

These findings are very important and show that, because of cognitive changes in aging subjects and the prevalence of elderly people with cognitive decline, a consistent design is more important for older than for younger users (Caprani, et al., 2006; Wirtz, Jakobs, and Ziefle, 2009). For instance, several studies have shown that the impairment of episodic memory is one of the most common cognitive deficits in MCI (Brooks and Loewenstein, 2010; Price et al., 2010) and dementias (Cottingham and Hawkins, 2010; Filoteo et al., 2009). Episodic memory is indispensable for learning new concepts and applications (Harada, et al., 2010). Usability evaluation is required to detect issues such as how intuitive a program is or how difficult it could be for a person to learn to use the program without help. This analysis would make it possible to create strategies that can be used effectively for the purpose for which they were created and to avoid exposing users to unnecessary frustration.

Moreover, although differences were found in the users' ability to manipulate the platform independently and learn how to use the devices, the results of this study were surprisingly positive in the affective section and satisfaction section. One of the primary difficulties of rehabilitation is based on the lack of motivation of patients with higher levels of impairment. For instance, previous studies showed that higher levels of cognitive decline are associated with a lower likelihood to use technological devices (Calvert, Kaye, Leahy, Hexem, and Carlson, 2009). However, our results indicate that there were no differences in satisfaction or affective evaluation between healthy, MCI and dementia population. This may suggest that despite the difficulties found in the learning abilities of elderly subjects with dementia, their interest in the system was preserved. These participants also perceived the platform as beneficial for them and were motivated to use it, even when they needed more explanations from the supervisors.

To conclude, this study highlighted the importance of examining not only the cognitive effectiveness and long-term consequences on cognitive faculties of new rehabilitation programs, but also the immediate issues of design and acceptance by end users. An in-depth study is needed in order to understand the potential usability barriers that seniors may come up against during their use of a particular technology. This could help us to find solutions that will really fit individual preferences and capacities, taking full advantage of the multiple features of new software technologies.

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