Eldergames Project: An innovative Mixed Reality Table-top Solution to Preserve Cognitive Functions in Elderly People

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***Abstract* — Advances in new technologies can provide solutions to prevent impairments associated with normal aging, track performance at specific tasks, and provide an entertaining experience to elderly people. Based on these premises we present Eldergames, an EU funded project that aims at creating an interactive tool for preserving cognitive functions impaired by aging and affording sociability. A first prototype has recently been created and its acceptance has been tested on groups of elderly users.**

The prototype proved able to provide a pleasant social cognitive training because of its simplicity, usability of the interface, and multiplayer architecture.

***Keywords* — cognitive aging, ergonomics, mixed-reality, table-top, gerontechnology**

I. INTRODUCTION

IT HAS BEEN estimated that in the next 40 years one out of five people will be over 60 years old [1]. The medical and scientific progress has increased life expectation and assistance demand at the same time.

Aging causes several physical and psychological problems: besides the deterioration of sight [2] and hearing [3], and the emergence of motor complications (arthritis) [4], elderly people suffer from loss of memory, cognitive/attention deficits, and linguistic impairment. Social isolation, loneliness, and associated depression are often natural consequences of these problems. Moreover, elderly people often face decline in self-esteem, which could worsen their quality of life [5] by making it difficult to accomplish even their basic daily tasks and forcing them to seek necessary external help [6]. This generalized decline requires a continuous support and monitoring, but health-care expenses constitute an important load on public institutions and families. In this respect, the advancement in health technologies could provide a helpful resource.

Assisting technologies include independence maintenance [10], personal assistance to aged or invalid users [11], rehabilitation [12], and health care [13]. VAE (Virtual Augmented Exercise) protocol represents, in fact, a collection of cognitive exercises addressed to the mental stimulation of the elderly [19]. Cognitive and mental training supported by electronic and computerized systems have proved able to provide notable benefits [7] [8] [9] since the beginning of the eighties by establishing criteria and principles that have become standard over the years. Video games stimulate the nervous system acting directly on concentration, on reflexes control, and on the attention system. Studies conducted on normal adults have shown benefits to the perceptive and cognitive abilities [14], spatial ability, and reaction times [15]. More specifically, video games have been found effective in reasoning processes [16], memory [17], and visual processing speed [18]. Systems can also address the social sphere by involving people of different ages [20], or by stimulating the interest through physical activity [21].

Tabletop platforms are technological devices that are receiving increasing interest and their main advantage is their simple and natural interaction approach [22]. Tabletop interfaces rely mainly on touch-screens and multi-touch technologies. Touch screen is a hardware device that allows the user to interact with a computer by touching the screen directly instead of using a mouse or a touch pad. Multi-touch is the natural evolution of the touch-screen. Its peculiarity is that the software can detect more than one touched point on the screen at a time.

Tabletop solutions allow a more intuitive approach to the interaction with technology [23] and with the other users [24]. Tabletop platforms were initially utilized in work environments to facilitate the collaboration within small groups of employees. Recently, several tabletop solutions directed to elderly people like Share-pic, a multi-user and multi-touch tabletop to share, manipulate, and modify digital photos [25], and TeleTable, a table-based device to play simple games, converse, exchange digital photos, and organize digital media [26], have appeared.

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They seem to receive a better evaluation compared to traditional game interfaces [31].

This paper describes a gaming platform, using a tabletop solution aimed specifically at preserving cognitive functions in elderly people. The next sections will present the prototype design and development, and will illustrate the results of its tests.

Unlike conventional tabletops, a mixed-reality solution [27] [28] where real objects are used to interact with virtual ones was adopted here. Besides technical reasons, this decision was influenced by the goal of utilizing familiar operations such as using a pen to tap on a surface, increasing the familiarity of the prototype, and then facilitating users' access to it.

II. PROTOTYPE DESCRIPTION

The Eldergames project aims at maintaining elderly cognitive abilities as intact as possible through exercises, preventing the occurrence of cognitive dysfunctions, and at the same time using exercise scores as a diagnostic tool to describe the status of users. The focus is on elderly people whose cognitive abilities are not deteriorated and who are not suffering from serious deficits or diseases.

After a series of stages including identification of requirements, planning and development of initial concepts, and usability and acceptance analysis of early prototype, the project has reached the final phase of producing a pre-commercial prototype.

A.1. Eldergames physical apparatus

The table (Fig. 1) allows a maximum of four players. Players do not need to use the same table; they can be connected remotely from a similar table located in a different site. This possibility can be extended to include players of different nationalities thanks to the heavy reliance on icons and the automatic translation of some basic messages into other languages.

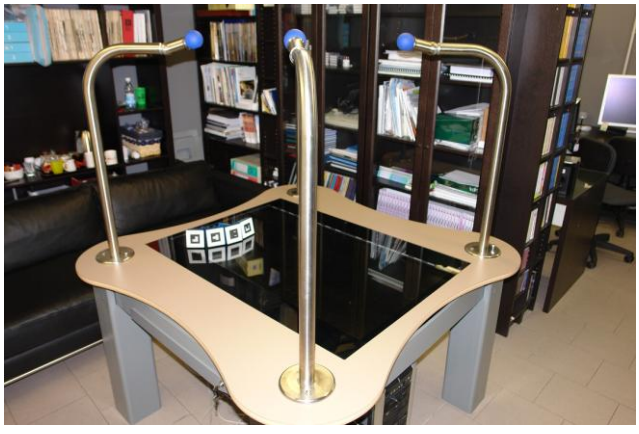


Fig. 1. The Eldergames prototype with the 4 pens on the table top and the cameras lodged in the 4 blue spheres.

The input devices are pens (Fig. 2), through which users select the options visualized on the screen thanks to four cameras positioned on the table at different angles recognizing a marker on the pens. Each pen has a different marker to identify the player using it.

The table edges are rounded and the structure is resistant to sustain the weight of the players leaning on it. Cables and electronic components are completely hidden from the users and installed under the surface in a point that does not prevent players to sit comfortably.

Fig. 2. The objects/pens used to interact with the table.

The table is 75 cm high. The playing area measures 60x60 cm out of a total 120x120cm surface area. Four metallic pipes are positioned in the four angles of the table. Inside pipes, adjustable cameras (Logitech 9000 - 640x480 pixels) are positioned at a maximum distance of 80 cm from the screen. The screen is an LG 47LF65 cooled through four fans of 12 cm in diameter covered by a plate of protective glass. Power sockets for connecting Pc and TV are placed inside the table. The inside of the table is made of metallic material. A keyboard is also included in a small drawer for administrators and experts to work on the computer.

Minimum requirements of the computer in which applications run are: video-card nVidia GeForce 8600 GT, processor Intel Core 2 Quad 2,40GHz - 8MB L2Caches, Ram 2GB, operating system Windows XP Professional. The assemblage of the whole structure does not require particular abilities because the table contains only few basic components that can be easily moved to different locations.

A.2. Eldergames software

The software consists of two main sections. The first one is directed to the end users (Memo Game and Minigame), and the second one to the experts, therapists, or health-care specialists (Management and Monitoring Modules).

Fig. 3. The Memo game.

An entire session involves the Memo game and a number of individual exercises called Minigames, which have the purpose of training specific cognitive abilities. The Memo-game (Fig. 3) appears as a central square panel with covered cards surrounded by four personal panels with six cards, the scoreboard, and a communication system to send emoticons to other players. The scoreboard counts the paired cards, and the time gained, or lost. The players' task is to pair their six cards with covered cards situated in the center of the screen and visible for only 10 seconds at the beginning of each game round. The game includes a system of bonuses and penalties. When a player correctly pairs one of her/his cards, s/he receives extra seconds or an extra turn. On the contrary, if the pairing is wrong, s/he is given the possibility to compensate for the loss by playing a Minigame. Success in the Minigame allows one to continue in the game. Failure deprives the player from gaining additional seconds or a turn. The first player to pair all six cards wins. Collaborative or competitive multiplayer game is introduced at the end of the Memo game where earned or lost seconds during the Memo game can be spent.

Minigames belong to five main categories according to the cognitive functions they intend to train: memory, reasoning, selective attention, divided attention, and categorization. A single user can play Minigames either for personal training, or within the Memo game. The online module is still under development and includes one multiplayer game and a communication system with emoticons, sentences, and icons.

The Management module allows the recording of users' information and personalized content such as pictures. Once the user is registered, an identification number and a graphic password (consisting of three images chosen by the user, which are easier to remember with respect to numerical ones) to access the game are provided.

The Monitoring module visualizes users' performance by game or by cognitive area, and compares different users or different periods.

B.1. Usability evaluation

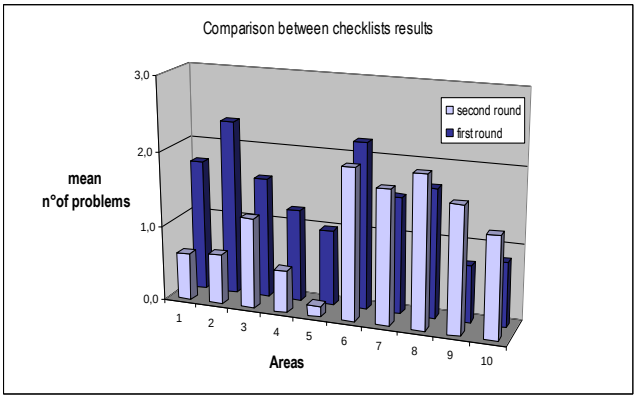
The usability evaluation was conducted with target users and with experts.

The evaluation with target users involved three different groups of four elderly players (Mean Age = 68.083, Range = 64-75, Standard Deviation = 3.34) who were asked to perform different tasks (to retrieve scoreboard information; to communicate with emoticons; and to recall their PIN number) and to play freely during a complete session that was video-recorded (Fig. 4) for a subsequent analysis. All free play sessions included Login, the transitions from one game to the other, Memo Game, Minigame, and Bonus/Penalties. Some groups played Multiplayer Game and exchanged Emoticons. No error was made while performing the tasks. Regarding the spontaneous game sessions, repetitions of pen input and requests for help were under scrutiny. Regarding the former, the repetitions of the command were partly due to a problem with a camera and partly to the lack of use of the feedback light on the top of the pen. The requests for help were observed mainly in the Minigames and were directed to the co-players as well as the expert. They revealed the need for improving the Minigame instructions and feedback.

Fig. 4. The setting of the video recorded game session.

The expert usability evaluation involved the usage of a checklist [29] consisting of 83 questions with yes/no/not applicable answer options, and the exploration of the main usability features of an interface: Visual clarity, Acoustic perception, Attention and memory, Interpretation, Consistency, Feedback and help, Control and performance, Environmental setting, Multiplayer setting, and Table usability. The questions were taken from classic usability checklists, and some items were added or emphasized to reflect special elderly peoples' usability requirements outlined in the first months of the project.

The checklists were applied to an early and a subsequent version of the prototype that were both used in the trials at different times. Trial managers filled in the former, usability experts the latter. The second round of checklists showed improvements in the areas of Visual clarity, Acoustic perception, Attention and memory, Interpretation and Consistency (Graph. 1). The last improvements are planned for the pre-commercial prototype in the areas of Feedback and help, Control and performance, Environmental setting, Table usability.



Graph. 1. The graph shows the improvements in checklists results between two versions of the prototype (First round vs Second round). X-axis represent the different areas: 1 - Visual Clarity, 2 – Acoustic perception, 3 – Attention and memory, 4 – Interpretation, 5 – Consistency, 6 – Feedback and help, 7 – Control and performance, 8 – Environmental setting, 9 – Multiplayer setting, 10 – Table usability.

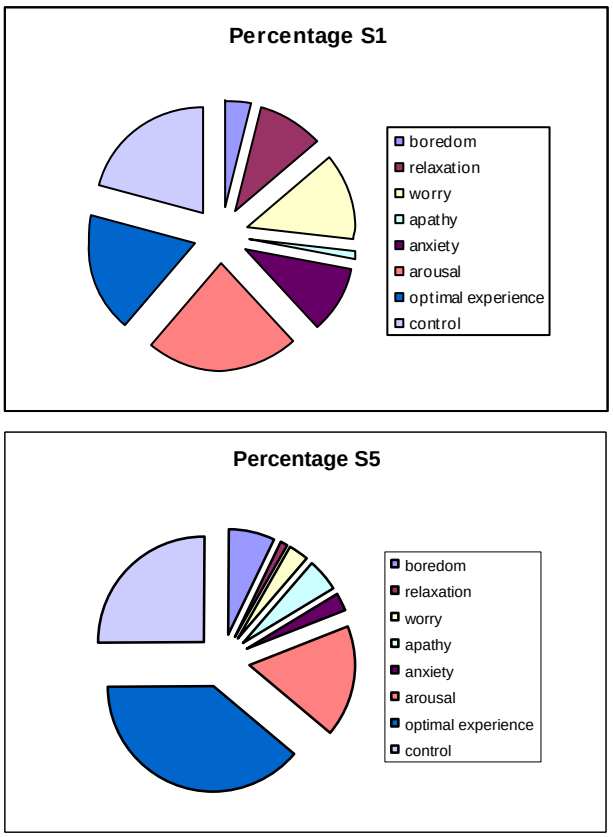
B.2. Level of acceptance of the prototype

The prototype acceptance level has been studied via questionnaires and focus groups repeated over 12 weeks of testing coinciding with the stages of learning, improvement, and autonomous use of the tool. The questionnaires were administered to 107 elderly users in three trial centers (Spain 46%, England 14%, and Norway 40%). Flow,, defined as "the state in which people are so involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it for the sheer sake of doing it," was the general framework for the acceptance analysis [30]. The questionnaires included a four point Likert scale ranging from 'Strongly disagree' to 'Strongly agree.' Over 250 items divided into seven motivational areas were used: Playability/immersion, Challenge/skills, Feedback, Control, Clear Goals, Concentration, and Social Interaction.

'Playability/immersion' is related to the user's capacity to complete game tasks without losing the sensation of playing as well as to experience a deep but effortless involvement and reduced concern for self and time. Results confirm a high degree of 'Playability/Immersion'. For example, 59.2% of the elderly strongly agree with the item 'As the weeks gone by I have enjoyed playing Eldergames more.'

'Challenge/skills' refers to the perceived agreement between skills and challenges. This dimension received less positive results for a few games, which some players considered too difficult, other players considered too simple. In general, 64,9% of the elderly agreed with the item 'The game has the right level of difficulty.' For this reason, calibration of the difficulty level is being reassessed and corrected in the pre-commercial prototype.

The 'Feedback' dimension contained items that asked users to judge whether they received immediate feedback and if it was easily understandable. The users' evaluation was negative. Important aspects to be modified concerned the personal game area: users suggested to improve identification of single elements in order to distinguish



Graph. 2. The graph describes the differences between first (S1) and last session (S5) game in regards of the emotional aspects connected to it.

among scoreboard points, cards, and other information; in fact, 42% disagreed and 40.1% agreed with the item 'I have difficulties in finding my personal score during the game.' Users also suggested improving the indicator of the player's turn, which is important especially when turn is lost because of a penalty.

'Control' dimension is related to the sense of control over actions. On this dimension, problems were linked exclusively to the cameras detection of the pen.

The 'Clear goals' dimension controlled if goals proposed during the game sessions were clearly understood. Overall, 67.8% of the users strongly agreed with the item 'I have managed to understand the game rules without any major problems.' Demonstrative tutorials and additional visual information that would clearly explain the objectives during the game will probably suffice.

'Concentration' corresponds to users' feeling of being able to concentrate on the game. Results showed that this is the most critical area of evaluation for the reasons already quoted with respect to 'Feedback.'

'Social interaction' refers to the opportunity to create and maintain new relationships, and 65.8% users agreed with the item 'The most interesting thing has been to share my time with other people while playing.' The outcomes showed that the social interaction and the creation of a compact group are already at high levels in that prototype.

A group of 21experienced users (7 people in each centers) evaluated the game experience on the dimensions already described so far as well as on additional

dimensions (arousal, boredom, relaxation, worry, apathy, anxiety, control and optimal experience). The outcome pertaining to the dimensions already described was the same as with other users; answers pertaining to additional dimensions are synthesized in Graph 2. Overall, arousal, control, and optimal experience increased from the first session to the last one. Negative feelings decreased.

B.3.Consistency of the monitoring module

In this last section, the results of the analysis of the monitoring module consistency are reported. Specifically, we considered the statistical distribution of the score of 59 elderly participants during five playing session in the Minigames for memory, reasoning, selective attention, divided attention, and categorization. The results obtained with the Minigame were compared to those obtained with the WASI III (Wechsler Abbreviated Scale of Intelligence). The scoring system from the game was built using a "minimum unit of measurement" (udm) obtained from the following calculation:

(Number of correct answers/Number of possible correct answers) * Weighting factors

The weighting factor depends on the assessed ability and on the specificity of each game. Three weighting factors were considered independently or combined according to the game: time factor (ft), error committed factor (fe), and level factor (fn). The Kolmogorov-Smirnov (K-S), Shapiro-Wilks, Lilliefors, and Pearson Chi-square were used to analyze the score distribution. All p-values obtained using one-sample K-S test were greater than the significance level (Tab. 1). We can conclude that analyzed variables corresponding to each of the five cognitive capacities studied in the Eldergames playing session follow a normal distribution.

Cognitive Capacity	Avg. Score	K-S p-value (<.01)
Divided Attention	6.73±1.21	0.338 n.s.
Memory	7.32±1.59	0.267 n.s.
Categorization	7.15±1.68	0.441 n.s.
Reasoning	7.15±1.68	0.093 n.s.
Selective attention	6.82±1.27	0.453 n.s.

Tab. 1. The table shows the average scores and the Kolmogorov-Smirnov p-values for each cognitive capacities considered in the Eldergames exercises.

Cognitive Capacity	t	df	p (<.01)
Divided Attention	2.05	78.07	0.043 n.s.
Memory	1.93	53.18	0.058 n.s.
Categorization	0.81	51.15	0.421 n.s.
Reasoning	0.44	61.57	0.660 n.s.
Selective attention	-1.91	66.47	0.060 n.s.

Tab. 2. The table shows the T-test p-values for the comparison between scores obtained in Eldergames exercises and WASI test.

The scores from Minigames and from WASI were compared using two independent samples T-test.

As shown in Tab. 2, p-values were not significant. We can conclude that the cognitive performance measured through Eldergames does not differ from the one obtained from the WASI. This result is important in order to affirm that it is possible to evaluate the level of progression of each cognitive capacities included in the Eldergames application.

III. CONCLUSION

This paper describes the nature and evaluation of Eldergames, a prototype aimed at offering elderly users several different games to train their cognitive functions, especially those that deteriorate with aging (memory, reasoning, selective attention, divided attention, and categorization). Eldergames can be used either individually or with three other people. The platform is a tabletop where real objects, in this case pens, are used to interact with digital objects on the screen. The system exploits the potentialities provided by recent technological advances by utilizing an intuitive interface. Therefore, it resembles a normal table around which people gather to play cards or other social games, but embeds much more functionalities including monitoring of performance, specific programs suiting the registered users' abilities, and connection with remote players.

The evaluation of the prototype carried out with elderly people shows the extent to which the designers' goals are met. It adds to the showcase of technical solutions currently available in the literature by actually testing the system and describing the results of the test. The methods included (1) video-analysis of spontaneous play to identify requests for help, (2) checklists filled by experts at different stages of the prototype development to test usability, (3) questionnaires based on flow theory and focus groups to evaluate acceptance in three trial centers around Europe, and (4) statistic comparison of the scores provided by Eldergames with those obtained with the WASI to validate the scoring system. The positive results of the evaluation confirm the suitability of the platform to elderly users, and suggest areas of improvement, especially the feedback and instructions system of Minigames, the calibration of the difficulty level between different games, and the visibility of personal scores. The project Consortium will then complete the pre-commercial prototype, and demonstrate its functionalities across Europe. It will also explore the possibility to deploy the technology in the cognitive training of people with other impairments and/or a different age.

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