Efficacy of Cognitive Training Experiences in the Elderly: Can Technology Help?

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Abstract. Cognitive training has been a growing field in recent years. It is established that training improves cognitive abilities in healthy elderly people. Specialized software and commercial devices including the possibility of cognitive gaming has been placed into the market; most of them are based on neuropsychological models of cognitive aging, but few have been scientifically tested. Computerized cognitive games are being developed in "HERMES – Cognitive Care and Guidance for Active Aging", a research project co-funded by the European Union under the Seventh Framework Program (FP7). Cognitive training designed for HERMES includes daily live events introduced by the user into the system, allowing the stimulation of prospective memory with their own information. Gaming model, concepts and assessment aims (including usability, subjective value and efficacy) are described.

Keywords: Cognitive training, cognitive stimulation, cognitive games, elderly, aging.

1 Introduction

Cognitive training for older adults has been a growing field in recent years, with increasing scientific knowledge about efficacy of cognitive stimulation programs [1]. This is not surprising attending to cognitive changes in an increasing older population, specially observing implications of cognitive aging for basic and instrumental daily-life activities. For example, cognitive abilities are critical in technological tasks common in daily live, such as operating a mobile phone or buying a train-ticket in a vending machine [2].

Research in the efficacy of cognitive training is pointing to some extent to the achievement of the goals comprised by the concept of successful aging, as described by Rowe & Kahn [3]: a) the preservation of physical and cognitive functions, b) an active engagement with life; and, to some extent, c) the absence of pathology, disability and risk factors. The contribution of cognitive functioning to this ideal of successful aging comes from the consideration that elderly people with a preserved cognitive functioning have healthier lifestyles. In a 20 years follow up study, Gale et al. [4]

C. Stephanidis (Ed.): Universal Access in HCI, Part I, HCII 2009, LNCS 5614, pp. 324–333, 2009.

found that cognitive impairment was associated with an increase of mortality, specially, in association to isquemic cerebral vascular disease. On the other hand, McGuire et al. [5] examined the relative contribution of cognitive function to mortality for a 2 year period in a sample of 559 adults elder than 70 years old with diabetes without cognitive impairment by the time of the initial assessment. They found that elders with diabetes and low cognitive function (even within the normality range) had an increased probability of 20% for dying than those diabetics with a better cognitive function.

The first two sections of this paper describe empirical studies on the efficacy of cognitive training and its computerized applications respectively. Hereinafter, "HERMES: Cognitive Care and Guidance for Active Aging" is described, including sections about HERMES Cognitive games concept, its evaluation plan and the differential values HERMES add in the growing field of computerized cognitive training.

1.1 Efficacy of Cognitive Training

It has been established that cognitive training improves cognitive abilities in healthy elderly people. It includes specific stimulation regarding to concrete processes such as memory or language, as well as more general tasks based on broad constructs such as attention or speed of processing [6]. As a principle, cognitive stimulation must be adapted to the cognitive abilities of each person, which means that the level of difficulty must be in accordance with capabilities [7]: difficult enough to mean a challenge for the elder, but not so difficult that becomes frustrating.

Regarding the question about how cognitive stimulation can work in the maintenance of cognitive function in older adults, Tranter et al. [8] have determined that fluid intelligence, the portion of intelligence which implies an active resolution of problems in tasks for which cannot be derived simple solutions based on formal training or in previous knowledge, shows frequently an almost linear deterioration associated to the ageing process. -Nevertheless, it is not clear that fluid intelligence decline is, indeed, inevitable. Many evidences suggest that elderly people, under appropriate conditions, show a much more flexible thinking and adaptation than what it could have been expected.

Little attention has been placed in this field on older adults' prospective memory stimulation, despite its importance on their daily living. Prospective memory refers to the ability to become aware of previous plans, executing them at the right time and place [9]. Recent research and reviews point out the variability of age-related declines on prospective memory regarding to test setting and sub-domains. On natural settings, age declines are weaker than in laboratory, probably because of contextual information available on daily routines. Using meta-analysis [9], age-significant declines were observed in 1) proper prospective memory, which implies the awareness of previous plans mentioned above, and also in 2) vigilance, in which plans remain on consciousness; significant differences were not found in 3) habitual prospective memory, in which the plan has to be brought back to consciousness repeatedly as long as the cue is presented.

In elderly persons suffering from a neurodegenerative dementia such as Alzheimer's disease, cognitive stimulation maximizes their performance in specific domains such as verbal and visual learning, and also has a significant impact on

related behavioral disturbances and caregiver's quality of life. In these patients, restorative cognitive training strategies, which attempt to directly improve functioning in specific domains – i.e. errorless learning, vanishing cues or spaced retrieval- have achieved larger effects than compensatory approaches [10]. Ideal memory training should target information useful for the everyday functioning of the patients and their caregivers, such as activities of daily living, and use similar training procedures or techniques for every subject involved in a given program. A posterior meta-analysis [11] reviewed the literature and summarized the effect of cognitive training for Alzheimer's disease patients on multiple functional domains. They concluded that cognitive training evidenced promise in the treatment of Alzheimer's disease, having the restorative strategies larger effect sizes than compensatory strategies, with primarily medium effect sizes for learning, memory, executive functioning, activities of daily living, general cognitive problems, depression, and self-rated general functioning.

About the use of cognitive training in the field of dementia, two major limitations have been pointed [12]: the transfer of improvement to other cognitive areas and the durability of the effects. Emerging clinical results indicate that cognitive training do not only slow the cognitive decline for a specific area, but also slows the deterioration of more general indexes of global dementia function. By means of animal models, it has been observed that mental stimulation is a strong signal for the induction of Brain Derived Neurotrophic Factor (BDNF) [13].

1.2 Efficacy of Computerized-Cognitive Training

In parallel to the increasing knowledge about cognitive training, a great amount of specialized software and commercial devices including the possibility of cognitive training have been placed into the market. Most of these programs are based on neuropsychological models of cognitive functioning and cognitive aging, but few of them have been scientifically tested through empirical studies with healthy older people, highlighting the need of more research efforts and publications in order to empirically establish the efficacy of computerized stimulation.

Scientific research in computerized cognitive training with healthy adults has focused on executive functions [14]. Executive functioning implies, for example, the knowingly processing of internal and external problems. It includes processes such as problem solving – to determine concrete aims, to plan actions concerned with these aims and to use feedback from this actions-, mental flexibility –to evaluate behaviors in terms of successful or failure and to change actions planned in the light of these evaluations- and verbal fluency. VitalMind project [15] designs tasks to train these three cognitive functions supported by frontal regions and particularly compromised with age. It also includes four training components: a brain fitness component, a life-skill component, an integrated component and a personal memory and enrichment component. Each component contains activities which train each specific mental function separately and uniquely.

Cogmed Working Memory Training is a home-based program to improve executive function by training working memory capacity, first developed by a team of researchers at the Karolinska Institute in Sweden [16]. In brain injured patients after stroke, Cogmed Working Memory Training was found to have an effect on short-term memory tests, on a paced auditory serial-addition task and also on a selective

attention task –to select numbers 2 and 7 with letters or numbers as distracters- chosen as non-trained test because it is very close but not exactly identical to tasks in the program. In young healthy adults, after this working memory training, authors found an increase in brain activity in the middle frontal gyrus and superior and inferior parietal cortices [17].

In mild and moderate stages of dementia, computerized cognitive training in combination with other cognitive stimulation programs has shown improved outcome scores in cognitive performance. Smartbrain is a system developed for the treatment of cognitive impairment –Alzheimer's disease and other dementias, brain damage and so on. Its efficacy with the cognitive stimulation in Alzheimer's disease has been demonstrated in a single-blind randomized study [18] comparing 12 patients receiving only pharmacological treatment –cholinesterase inhibitors-, 16 patients receiving both pharmacological and non-pharmacological treatment – integrated psycho stimulation program and, finally, 15 patients in an experimental group receiving both treatment and also training in Smartbrain as a interactive multimedia internet-based system. Patients receiving Smartbrain training began at the lowest level of difficulty from 15 levels, increasing the level of difficulty automatically after three consecutive performances and decreasing it when his or her performance fell below 15% correct for three consecutive sessions. No differences were found at baseline; after 12 weeks and also after 24 weeks, significant differences were found in standardized measures of cognitive function, but not in functional assessment nor in specific neuropsychological tests.

In addition to its efficacy on cognitive functioning, computerized games may offer elderly users new ways of social interaction. ElderGames project [19] develops games using digital object interaction with the aim of stimulating the social interaction and participation of elderly people. The social interaction underlying computerized games could be a central motivator to engage elderly people in daily cognitive stimulation routines, as well as an important key to get older adults without experience closer to digital technologies [14].

2 HERMES – Cognitive Care and Guidance for Active Aging

"HERMES: Cognitive Care and Guidance for Active Aging" is a project co-funded by the European Commission within the 7th Framework Program [20]. HERMES has been developed with the aim of reducing age-related cognitive decline. It provides assistance but also promotes the autonomy and independence of users in their daily lives, employing pervasive non obtrusive technology.

The main aims of the HERMES project are facilitation of episodic memory, advanced activities reminding and cognitive training. Regarding age related cognitive decline, the episodic memory may present gaps or some details of the past can be lost. In fact, the autobiographical information memory is weaker than published information memory [21]. HERMES captures user's daily life information through audio and video means as well as information on the context. HERMES also provides reminders through visual and audio patterns in order to strengthen prospective memory, facilitating the information previously captured when it is essential. In this sense, HERMES cognitive games are designed to stimulate not only processing resources and episodic memory, but also prospective memory related to users' daily life. Additionally, conversation

support through everyday conversation recording and mobility support are included into the project.

The first step in the HERMES project was to clearly identify the user's needs as well as their preferences about the new technologies, including computerized cognitive games, with the goal of checking the feasibility of the application [22]. Technical complexity of the product has to be adapted to a very specific population from a user-centred design point of view, providing maximum functionality while being easy to use. In order to achieve this aim, information about users was collected through questionnaires, interviews, cultural probes, diaries of memory failures and memory assessments.

Questionnaires employed in the user's requirements collection were completed by 99 people over 60 years old. The results showed that most of the healthy older adults studied stated they would appreciate a device to play some cognitive games. Older adults want a device to remind them the following issues: shopping list (48.3%), conversations with a doctor (31.0%) or their families (24.1%), things they have to do (48.1%). The situations in which they feel most uncomfortable due to forgetfulness are buying something or doing any task (42.85%); how to get somewhere (22.22%), forget names (61.9%); an important appointment (39.68%) and conversations (28.5%).

On the characteristics of these technological devices, utility is perceived as the most important feature, followed by simplicity. Aesthetics were the least rated feature. Qualitative techniques showed that elderly people of this generation are reluctant to use any technology that may reduce their autonomy or minimize their cognitive or functional efforts. Technology plays a minor role in their life and they did not explicitly see how technology could help them with this but were open to give it a try should they be in need of it. In this sense, technological external aids should be easier and simpler than the aids currently used.

Other important conclusion from user-requirements study was that older adults perceived to maintain the cognitive function as the most needful requirement for an independent living [22]. On cognitive functioning, diary studies on daily memory failures showed that most of the participants forgot from 5 to 7 events per week, while objective cognitive assessment showed low scores in working memory and attention measures [23]. Memory and attentional changes may cause problems in developing conceptual representation and strategies to cope with computerized tasks [24].

2.1 HERMES Cognitive Games Concept

Cognitive games included in HERMES have been designed taking into account age-related changes in memory, executive processing, visual attention and visual-manual coordination, avoiding burden on these functions but stimulating them. HERMES cognitive training games are offered through novel ergonomic interfaces, which provide to aged users comfort, flexibility and natural interaction. In particular the HERMES end-user interface for cognitive training is implemented on multi-touch surface interface based on leading edge finger tracking technology [26], which enhances interaction, motivation and allows complex game features.

Two phases of games implementation have been designed. The first phase takes into account cognitive changes related to aging as well as the multi-touch system potentials. The second phase, following user-requirement study [24] in a narrower sense, will include both attentional and language games.

The two first games to be developed are the "HERMES Maze" and the "HERMES Puzzle". Both take information introduced into the system by the HERMES user and employ it as stimulus for cognitive stimulation, and both stimulate visual-hand and bimanual coordination.

In the "HERMES Maze", the HERMES system asks the user to match an appointment clue (e.g. Doctor visit) and a time clue (e.g. 10:00 h.) from two different start points to an Appointment Sheet, which is inside a maze and serve as a reaching point (see Figure 1).

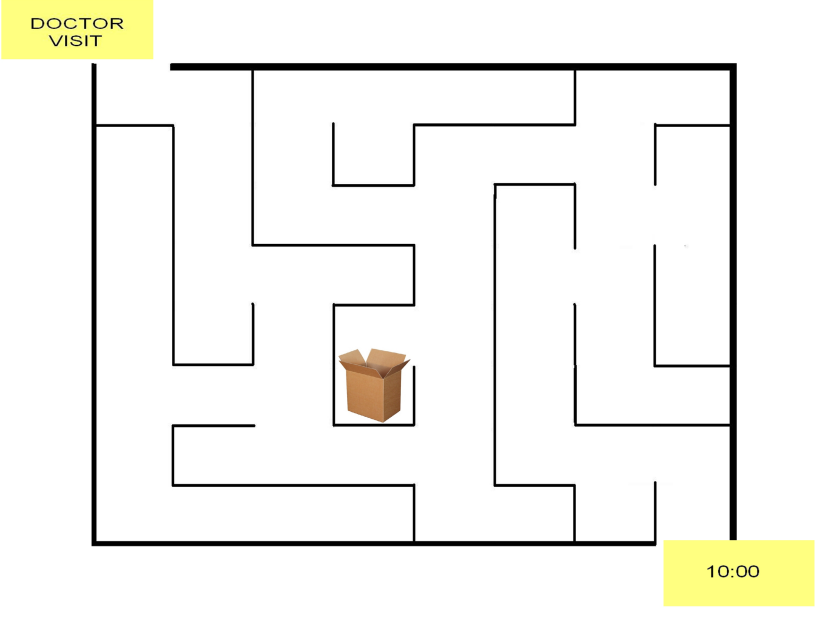

Fig. 1. "HERMES Maze" layout

The user has to move the "clues" (letters in a box or cube) along the maze, each clue with a hand (Figure 2). If the user withdraws a hand, the clue returns to the start point. Once he or she has matched the clues putting them both inside the Appointment Sheet, both clues change in a single Appointment message and a Congratulations message is displayed and another pair of clues is displayed. In this game, difficulty level is varied manipulating the number of appointments (e.g. three appointment clues and three time clues are displayed and the user has to select one appointment clue and its corresponding time clue and then match them across the Maze) and/or the complexity of the mazes.

For its part, the HERMES Puzzle (Figure 3) uses pictures already store at the HERMES database and related to the appointments of the next day (e.g. his son picture if she will meet him tomorrow). The distinctiveness of this task is the movement of the pieces of the puzzle, which can be simple (up-down or left-down) or complex

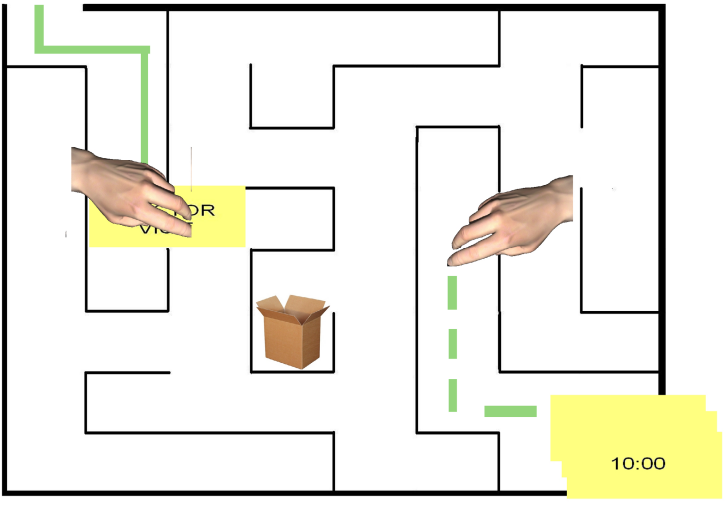

Fig. 2. "HERMES Maze" gaming schedule

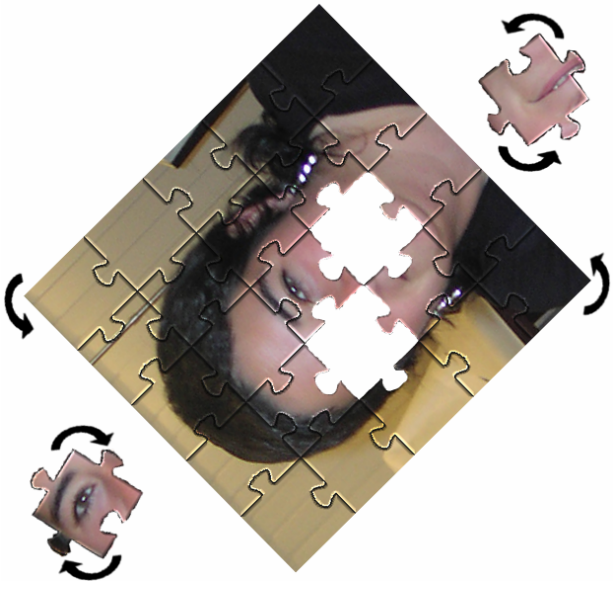

Fig. 3. "HERMES Puzzle" layout

(rotation) according to the difficulty of the task. Besides the number of pieces, other dimensions of the difficulty of the task would be the speed of the movements, and the combination of both direction and speed. HERMES direct the assembly of pieces presenting two or more pieces assembled at the start of the game. Pieces do not stop movement unless you touch them so, in order to assemble a piece into the puzzle,

users have to simultaneous touch them both. If the user does not progress towards the resolution, HERMES can facilitate the performance drawing the related pieces near each other. When the puzzle is finished, HERMES reinforces the user and stimulates prospective memory showing the appointment related to the completed picture in a marked way.

2.2 HERMES Cognitive Games Evaluation Plan

The users will be taken into account in the phases of development and implementation, defining game requirements together with them. The games will be tested in three different phases.

In the first phase, an expert group -composed mainly by neuropsychologists and gerontologists- will be invited in a focus group session in order to give their opinion about cognitive games.

In the second phase, the user-target group will be assessed in terms of games' usability and subjective value by means of a focus group and individual interviews. Exploration of both gaming experience [14] and assessment tools [25] are observed.

Focus groups are six to ten person meetings to discuss experiences or opinions around topics introduced by a moderator. This qualitative research method has been used extensively in marketing studies, social research and, more recently, in user-requirements studies [26]. In the assessment of games usability and subjective value, this qualitative technique can show priorities, interests, motivations or anxieties, as well as identify potential steps on efficacy assessment and new scenarios for potential developments.

Finally, the efficacy of these games will be tested in a third phase using prototypes of the games and the devices developed into the HERMES Project. Performance on computerized cognitive training could be a valuable tool for trend detection, complementing neuropsychological evaluation though frequent data acquisition, also avoiding biases due to education, culture and experience [27].

2.3 HERMES Cognitive Games Uniqueness

Taking the user's requirement study results into account [22, 23], flexibility and adaptability of the HERMES System have been reinforced. HERMES will employ cognitive training to strength their autonomy rather than their dependence on technology, allowing users to work with their personal information, instead of offering reminders without any cognitive effort. As older adults have pointed out, HERMES games have been designed to be easy to use, intuitive, and available highly interactive.

While other devices have a fixed database as a source of information for presented games, with the subsequent lack of any game personalization other than an arbitrary level of difficulty, games developed in HERMES have the goal of encouraging autonomy and sense of independence by means of making use of information introduced into the system by HERMES users about their own daily life. This distinctive aspect will allow us stimulate prospective memory directly addressed to daily events.

Users' motivation has been taken into account, especially in order to promote user long-term motivation and adherence to daily gaming experience. In this sense, computerized cognitive training has the potential of parallel using a big amount of visual

and acoustic stimulus and also the possibility of personalized levels of difficulty, adapting them automatically from users' previous performance (successes and failures, reaction times, gaming routines).

Acknowledgements. This work is part of the EU HERMES project (FP7-216709), partially funded by the European Commission in the scope of the 7th ICT Framework. Special thanks to CURE – Center for Usability Research and Engineering and AIT – Athens Information Technology for the great work done in the user requirements and games developments described in this document.

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