D.6.1 Cognitive Training Exercises

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Abstract
Promoting cognitive health is a major topic for active aging, since cognitive performance, directly related to daily activities, can be improved through stimulation. HERMES Project copes with this aim by cognitive training games.

In order to design useful games adapted to target group’s needs an in-deep analysis has been conducted, including an extensive state of the art about cognitive aging, computerized rehabilitation programs and video games. Usability issues have been also taken into account in order to ensure a good accessibility of these games for older adults. The information collected, as well as user requirements’ study inputs and a focus group conducted with experts have been applied to design an attractive and useful proposal for the HERMES cognitive games. Further considerations on games’ specific features and games’ evaluation plan have also been included in the present document.

In the technological side, HERMES Cognitive Games has been implemented in a multi-touch screen system that allows training bimanual coordination as well as dual tasks.
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1. INTRODUCTION

1.1 Background

One of the main concerns in the neuropsychological field is the stimulation and rehabilitation of cognitive abilities when these are impaired either because of a brain damage (e.g. stroke, etc), or lifecycle characteristics. During the last decades, a lot of studies have been focused on testing the effectiveness of non pharmacological treatments (Yanguas et al., 2008). But recently, the way in which the stimulation is provided has changed from paper and pencil exercises to computerized ones.

Currently, the main objective is to develop efficient cognitive games with an underlying therapeutic framework that is accessible for the patient / user and it is possible to apply them for the user’s daily life. This application means training cognitive functions in a way that is significant to the users by means of using contents of their live, and trying to extrapolate the results found in the cognitive sessions to user’s daily live. This task is difficult to achieve since the stimulus normally used in cognitive sessions are not significant for the user; thus, he can obtain good results in a therapeutic session in which the working memory capacity is trained. Nevertheless this does not mean that when he needs to put this ability into practice the results will be as good as the ones achieved in the session. For this reason, HERMES games use significant information for the user because this information is captured by means of audio and video from their own life.

The work exposed in this deliverable seeks to ensure validity and acceptability of the HERMES cognitive games by:
- Maximizing the usage of personal information based on persuasive technology.
- Collecting specific knowledge about scientific research on cognitive aging and applying it to the games design.
- Collecting specific knowledge about video-games, especially those developed with therapeutic and educational aims and those directed to elderly people’s (e.g. brain trainers). This process has been especially relevant for those people involved in WP6. In this regard, it has been included an extensive state of the art in this deliverable trying to be useful for the other partners of the project.
- Trying to include the users’ requirements collected in the HERMES project to the games development.

1.2 Scope of this Deliverable

This deliverable tries to establish the basis for the development of HERMES cognitive games developed within HERMES. It contains information about variables to be considered, the neuropsychological knowledge available about the topic and scientific framework to be taken into account. It also includes the user’s needs collected in WP2 that states the different user needs that cognitive games must satisfy and the way this has to be done. Therefore this deliverable is the prerequisite for the development and evaluation of the HERMES cognitive games.
This document has two main aims. First, to share the information collected and selected during the design of first wave of the HERMES cognitive games and, second, to highlight innovative approaches taken in the HERMES project regarding cognitive training.

This deliverable contains detailed descriptions of a) prospective memory stimulation regarding the usage of daily-life information and b) visual attention and bimanual coordination stimulation allowed by multi-touch interfaces.

This document is related to deliverables from different WPs. With respect WP2, the deliverable 2.1 explained the main needs of elderly people. These needs were taken into account when the games were developed. For example, the aim of the “My Who is Who” game is to avoid the tip-of-the-tongue phenomenon when elderly people try to remember and say a person’s name. This phenomenon is very common for elderly people (Facal et al., 2009).

In WP7, the deliverable 7.1 defines the way in which the first user evaluation plan will be carried out. One of the parts of this evaluation plan will be the testing of the first cognitive game, as explained in D7.1 and summarized in the last section of this deliverable.

With respect to ethical issues, they are transversal to all actions in this project, so they are always present.

This deliverable is structured as follows: sections 2 and 3 are aimed to give a general overview of cognitive training and cognitive ageing. In section 4 some of the concepts related to cognitive gaming, such as flow, immersion and so on, are described. Section 5 is more exhaustive and tries to reflect the different types of computerized games for elderly people, putting special emphasis on more recent ones. After this state of the art, the main conclusions drawn are summarized in section 6. Section 7 introduces the first HERMES cognitive games. Furthermore, section 8 also describes the way in which the games will be assessed in the first trial. Section 9 describes the technological development of these games. Finally, section 10 summarizes the main conclusions.

2. INTRODUCTION TO THE COGNITIVE TRAINING

2.1 Why is it important to develop cognitive training exercises for elderly people?

As shown in D2.1, the cognitive training is a general need perceived by elderly people, that they try to cover in different ways, such as solving sudokus, doing puzzles, reading and so on. As it will be further explained in the following section, the cognitive functions of elderly people can remain at acceptable levels but, anyway, some training is needed due to its implications for basic and instrumental daily-life activities. For example, cognitive abilities are critical for technological tasks which common in daily live, such as operating a mobile phone or buying a train-ticket at a vending machine (Slegers, Van Boxtel, & Jolles, 2009)

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, 1998):
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 preserved cognitive functioning have healthier lifestyles. In a 20-years follow-up study Gale et al. (Gale, Martyn, & Cooper, 1996), found that cognitive impairment was associated with an increase of mortality, specially in association with isquemic cerebral vascular disease. On the other hand, McGuire, Ford & Ajani (McGuire, Ford, & Ajani, 2008) examined the relative contribution of cognitive function to mortality for a 2 year period in a sample of 559 adults older than 70 years old with diabetes and without cognitive impairment by the time of the initial assessment. McGuire et al. found that elderly people with diabetes and low cognitive function, even those within the normality range, had more probability to die than diabetics’ people with a better cognitive function.

Finally, it is important to mention the concept of “cognitive reserve”. It is defined as the capacity of the brain to support more amount of neuropathology before starting the cognitive decline (Andel, Vigen, Mack, Clark, & Gatz, 2006). This implies that people with more cognitive reserves can support a greater amount of neuropathology without manifesting clinical deterioration, while other persons with less cognitive reserves start manifesting the cognitive decline before, though the neuropathology is the same for both kinds of persons. According to Valenzuela (Valenzuela, 2008), cognitive training delays the decline in the specific area trained (e.g. short-term memory) as well as the deterioration in the other areas (e.g. attention, language…), and delays the beginning of clinical manifestations of dementia.

Therefore it is important to exercise the brain through cognitive training because of the following two main reasons: 1) to maintain elderly people in an active situation that allows them to live in an autonomous way by themselves and 2) to avoid or, unless, delay dementia symptoms.

2.2 What are previous experiences in rehabilitation and stimulation of elderly people?

It has been found that cognitive training improves cognitive abilities in healthy elderly people. It includes specific stimulation regarding concrete memory or language related processes, as well as more general tasks based on broad constructs such as attention or speed of processing (Ball, Edwards, & Ross, 2007). Regarding the question about how cognitive stimulation can help to maintain cognitive functions in older adults, Tranter & Koutstaal (Tranter & Koutstaal, 2008) have determined that fluid intelligence, the portion of intelligence which implies an active resolution of problems in tasks for which simple solutions cannot be derived based on formal training or previous knowledge, frequently shows an almost linear deterioration associated to the ageing process. Nevertheless, it is not clear that fluid intelligence decline is, indeed, inevitable. According to Tranter & Koutstaal (Tranter & Koutstaal, 2008), evidence suggests that elderly people, under appropriate conditions, show a much more flexible thinking and adaptation to new situations for tem than it could be expected.

Recently, results from the Advanced Cognitive Training for Independent and Vital Elderly Trial (ACTIVE) (Langbaum, Rebok, Bandeen-Roche, & Carlson, 2009) Study have been published specifying not only efficacy, but also response patterns from different subgroups of users. ACTIVE was a large randomized controlled cognitive training trial conducted from 1999 to
2001 at six field sites with the New England Research Institute (NERI) as the coordinating centre and sponsored by the National Institute on Aging (NIA). Interventions included: 1) Reasoning training focused on inductive reasoning, the ability to solve problems that follow a serial pattern and manifest in executive functioning; 2) Memory training focused on verbal episodic memory, which deals with acquisition and retrieval of information acquired in a particular place at a particular time; 3) Speed training focused on visual search and the ability to identify and locate visual information quickly in a divided attention format, with and without distractors. Participants were assessed at baseline, immediately after training, and annually thereafter. A total of 2,832 elderly adults were enrolled in the trial, and 2,802 were included in the analytical sample. Langbaum et al found that 90% of ACTIVE participants who completed memory training improved on at least one memory measure, but identified different patterns of benefits from factors such as increasing age, baseline cognitive status and usage of specific mnemonic techniques.

In summary, a majority of the studies have found reliable effects in rehabilitation and stimulation of elderly people. Nevertheless, training has to follow some prerequisites in order to ensure efficacy:

1. 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 (Yanguas, Buiza, & González, 2009) difficult enough to mean a challenge for the elderly, but not so difficult that it becomes frustrating.

2. The exercises must be based on a neuropsychological model and must be structured. Cognitive training does not consist in doing anything without an underlying therapeutic aim. It should be based on theoretical and scientific principles. As an example, cognitive stimulation in the Donostia Longitudinal Study was based on Braak & Braak's model of Alzheimer's staging (Braak & Braak, 1991; Braak & Braak 1994; Braak & Braak, 1997), which recognizes the existence of pathological anatomical associations that affect different areas of the brain at the various stages of Alzheimer's disease (AD), with a specific disease course.

3. The frequency and length of the sessions must be appropriate. Short training programs that last just one or two months do not achieve the objectives (Yanguas et al., 2006).

4. The training should be as individualized as possible. Each person is unique, with different features and needs from the others. Hence, the training should take into account both the features and the needs.

These theoretical principles have been taken into account when the HERMES cognitive games have been designed. Some of the studies which prove the efficacy of cognitive training have been dealt with in D2.1 and will also be described in section 4 of this deliverable.

2.3 HERMES cognitive training exercises

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 on the market. Most of these programs are based on neuropsychological models of cognitive functioning and cognitive aging, but only few of them have been scientifically tested through empirical studies with healthy elderly people, highlighting the need of more research...
efforts and publications in order to empirically establish the efficacy of computerized stimulation (Buiza, González, & Yanguas, 2008).

One of the HERMES aims is to develop cognitive games based on scientific research and also usable and attractive to older adults. In this regard, the system employs pervasive non-obtrusive technology, capturing users’ daily life information through audio and video means as well as contextual information. Complementary to reminders through visual and audio patterns in order to strengthen prospective memory, HERMES provides cognitive games designed to stimulate not only processing resources and episodic memory, but also prospective memory related to users’ daily life.

One specific characteristic of the system is that, in contrast to other devices having a fixed database as a source of information, games developed in HERMES offer the possibility to use the information supplied to the system by HERMES users themselves, information related to the contents of their own daily life. This distinctive aspect will allow us to stimulate memory for incoming events directly addressing their daily situation, encouraging their autonomy and sense of independence by supporting memory in an indirect, non-explicit way.

HERMES cognitive games have been developed keeping this aim in mind. The following key principles have been taken into account:

1. Cognitive state of elderly people. Which functions are preserved? Which ones have started to decline? And, which ones do elderly people need in their daily living? 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 at the same time. HERMES training is focused in stimulating those functions that have started to decline but maintaining the ones that are preserved, and always trying to create significant exercises with useful contents for HERMES users.

2. Having an empirical basis, especially on interests and motivations of older adults with respect to computerized gaming.

3. The games are based on Errorless Learning theories as will be explained in section 8.

4. To be easy to use, being both simple and designed in accordance with cognitive age-related changes (IJsselsteijn, de Kort, Poels, Jurgelionis, & Bellotti, 2007).

5. HERMES cognitive training games are offered through novel ergonomic interfaces, which provide elderly users comfort, flexibility and natural interaction. In particular, the HERMES end-user interface for cognitive training is implemented using a multi-touch surface interface, which enhances interaction, motivation and allows for complex game features.

6. To promote the state of flow and immersion as a user experience (Sweetner & Wyeth, 2005) through both concentration and sensation of control.

7. Motivation has been taken into account, especially in order to promote users’ long-term 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).

8. To encourage autonomy and sense of independence by stimulating prospective memory, HERMES games directly address daily events. HERMES will employ cognitive training to strengthen their autonomy rather than their dependence on technology, allowing users to work with their personal information, instead of offering reminders without any cognitive effort.

9. To stimulate prospective memory, HERMES will use daily-life appointments introduced into the system as cognitive games stimuli. 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.

10. Cognitive games take into account the needs of the elderly found in the phase of collecting needs carried out in this project last year as part of WP2. Specifically, the following were the needs found and the way in which HERMES tries to cover them:

   a. Elderly people are reluctant to any technology that aims to reduce their autonomy or minimize their cognitive or functional effort, because it would mean dependency (Buiza et al., 2008). For this reason HERMES will employ cognitive training to reinforce their autonomy rather than making them dependent on the technology. Cognitive games will offer them to work with their personal information, instead of offering reminders without any cognitive effort.

   b. Older adults do appreciate and need social interaction with other people, so HERMES should provide a way for different users to play cognitive games and share information on-line.

   c. In the memory assessment, working memory was the capacity that showed the lowest scores. This capacity is related to immediate auditory processing, which means that information that they have to actively maintain and recall after its presentation is worse remembered than the information they have to recall later on. Any material should allow the elderly users to have enough time to process and draw up incoming information, as it is suggested by the better score of most of the delayed indexes when compared to the immediate indexes.

   d. Attentional processes are the ones with the lowest performance in the assessment of the users. Any task or material presented should give support to attentional processes.

As it has been pointed out, the work exposed in this deliverable seeks to ensure the HERMES cognitive games by maximizing the usage of personal information based on persuasive technology; collecting specific knowledge about scientific research on cognitive aging and applying it to the games design; and finally, including users’ requirements collected in the HERMES project to the games development. Following these aims, section 3 describes age-related changes in those cognitive processes relevant for both daily life activities and the
HERMES system interaction. Section 4 provides a brief description of research about cognitive gaming, especially about usability and its relation to cognitive aging. Section 5 introduces a deeper explanation about cognitive training programs for older adults. This section is based on a state of the art study that was conducted previous to the game design process. As the study was very detailed because of the needs of the design, a wide exposition of it is provided here. Information about serious games, educative products, European projects in this field, rehabilitation programs and commercial games are included. This study has an applied aim, according to HERMES development needs. In this regard, implications for the HERMES cognitive games design extracted from the state of the art are explicated in section 6. Resulting from the information collected and the expertise of the partners, the HERMES cognitive games proposal is shown in section 7. Information collected in the state of the art and the difficulties found in the game design process have been summarized in section 8, explaining the HERMES games features (levels of difficulty, feedback and so on). Section 9 is aimed to give an overview about the technology used for these games. The last section addresses the conclusions of this deliverable.

The information contained in these sections has oriented the work-plan for WP6 in the next months.

3. COGNITIVE AGING

3.1 Developmental changes in sensory domains in older adults

Sensory changes are critical in older adults’ interaction with their environment. These changes are also present in the interaction with technological devices. Among the elderly, the impairment in visual and auditory functions is a normal process of ageing. This decline in sensory functions is related to aging and it has been proved to affect both cognitive and motor functions (Li & Lindenberger, 2002), increasing in covariation from adulthood to old and very high age. It is also related to functional decline, depression and social isolation (Bogardus, Yueh, & Shekelle, 2003).

3.1.1 Vision

Vision changes in normal aging include reduction of acuity (decrease of the ability to see fine), reduction of pupil size and pupil agility (as a result, responses to light are slower), corneas thickness increase demanding better illumination conditions and also reduction of retina’s sensitivity (Segal, 1996).

These age-related changes in vision make it much more difficult to read on a computer or a TV screen. In this sense, reduced sensibility to contrast (light/dark differences) and perception of colour are especially relevant, because both cause important difficulties related to accessibility and usability of these technologies.

Finally, related to eye-changes but also attention declines, elder adults are also slower than younger performing visual searches, which affect performance related to screen usage.
3.1.2 Hearing

Hearing loss is also a common consequence of ageing. Auditory decline in the elderly, commonly described by Presbycusis, is the loss of ability to discriminate between medium and high frequency sounds. It has a prevalence about 30% in the population above 65 years of age (Peixoto Veras & Couto Mattos, 2007).

As the population becomes older, also the prevalence of presbycusis is higher and it interferes in the quality of life of this population. For example, rapid-speech recognition skills, which are required to cope with face-to-face conversations, have been found deteriorated in elder adults in the presence of presbycusis or other moderate hearing loss (Cervera, Solera, Dasía, Ruizá, & Marcob, 2007).

There is evidence that both genetic and environmental factors contribute to hearing loss in the mature human population (DeStefano, Gates, Heard-Costa, Myers, & Baldwin, 2003). It is generally accepted that auditory decline in the elderly is usually a neurosensory decline, thus less liable to use hearing aids because these aids amplify uncomfortable noises.

3.2 Developmental changes in motor domains in older adults

Motor skills decline with age because both osteo-muscular and cognitive-control ability change. Degenerative diseases involving damage of the joints of the body, such as arthritis and osteoarthritis, are the leading cause of disabilities of people older than fifty-five years (Segal, 1996). In a comparison of 10 focus groups with osteoarthritis patients and 6 focus group with control subjects, osteoarthritis patients reported an impact of their disease on leisure, social activities and relationships; they perceived the osteoarthritis as a part of normal aging requiring acceptance, not treatment (Gignac et al., 2006).

Bone resistance also decreases with aging. It is determined mainly by the osseous mass, which is related with the mineral density contained on the bone. It is estimated that the maximum level of osseous mass is reached in the third decade of life, and from then on it is gradually lost until menopause in women and at age 70 in men. It increases the risk of suffering a bone fracture and, consequently, the risk of loss of functionality.

Apart from physical changes, older adults also experience age-related changes on motor skills based on cognitive and learning capabilities (Voelcker-Rehage, 2008). When people age, they perform complex tasks slower and, in some cases, less accurately. They carry out these tasks in some qualitatively different ways and they need to practice harder and relearn some motor skills as a part of new tasks training. In this sense, Voelcker-Rehage (Voelcker-Rehage, 2008) found significant differences between fine and gross motor skills, with lower gains for fine-motor tasks by older adults. On gross-motor tasks age-related learning differences were found for complex tasks.

These physical and cognitive changes should be taken into account for cognitive gaming, since many computer games require subjects to respond as quick and as accurately as possible (Green & Bavelier, 2004). It improves eye-hand coordination and also the ability to brake in front of an obstacle.
3.3 Developmental changes in neuropsychological domains in older adults

3.3.1 Visual attention, alertness and vigilance

The concept of visual attention is the mechanism by means of which some items in the visual field are selected and others are not (Green & Bavelier, 2004). Better visual attention capabilities imply a bigger amount of items from the visual field to be processed and/or less processing resources needed to process the items. In this sense, items attended are processed more quickly, more efficiently and to a greater degree. Hence, the changes experimented by the elderly in visual attention must be taken into account in the HERMES cognitive games design.

Elder adults typically show declines on simple visual-search tasks, related to changes on sensory function -see section 3.1- but also caused by a decrease in information processing speed (Salthouse, 2000). In more complex top-down processes the slope between reaction time and complexity of stimulus is not consistently higher for older adults than for younger adults (Madden, 2007), suggesting remarkable degrees of preservation in bottom-up attention.

Age related deficits in selective attention are mainly caused by the increased difficulty for older adults to filter out irrelevant information (Mayhorn, Rogers, & Fisk, 2004). These age-related deficits have been consistently found in the literature as a major cause of attention distractibility in elder adults. Interestingly, these authors inform about the possibility of attenuation in this decline when the elder individual has previous experience interacting with target and distractive information. The gains from computer games on attention skills (Green & Bavelier, 2004) could be successfully used in this field.

Aside from perceptual and speed declines, some of these attention changes are related to decline in executive processing, including capacity to establish clear goals and to inhibit irrelevant information (Verhaeghen & Cerella, 2002). Using meta-analysis, these authors observed that executive processing does not directly involve increases on computational loads compared with simple tasks, but rather added additional steps or stages to the processing chain. The cost of this increase of steps is higher for elder adults, but only for those tasks that activate or imply multiple stimuli.

3.3.2 Memory changes in aging. Retrospective and prospective functions

The general concept of memory, including ability to store, retain, and subsequently retrieve information, is a general system which includes different subsystems with different age-related effects.

Retrospective memory is commonly divided, attending to information to be stored and retrieved, into semantic and episodic memory. Strong evidence has been found about preservation of semantic memory, which means conservation of the general knowledge acquired through a lifetime of learning. In relation to computer interactions by older adults, the use of previous knowledge has been taken into account using metaphors as an accountable way to improve emotional significance of new devices (Mayhorn, Rogers, & Fisk, 2004). In the opposite direction, episodic memory, which implies the memory of autobiographical events, that can be explicitly stated such as times or places, declines with aging.
Attending to the time dimension, the division into short-term and long-term memory has been also extensively used. Whereas long-term memory is maintained in aging, specially regarding to autobiographical memory, there exists strong evidence of declines in short-term memory performance (Craik, 2000). This decline is especially consistent on working memory systems (Bopp & Verhaeghen, 2005), which involves parallel storage and information processing. Working memory limitations of older adults are closely related to the changes on resource processing and attention capabilities mentioned above, having strong influence on daily activities –also using electronic devices and playing computer games, since it implies parallel processes such as remembering general instructions while performing motor tasks.

On the other side, prospective memory goes beyond the traditional idea of memory. It refers to the ability to become aware of previous plans, executing it at the right time and place (Craik, 2000). Recent research and reviews point out the variability of age-related declines on prospective memory regarding to test setting and sub-domains (Uttl, 2008). In natural settings, age declines are weaker than in laboratory setting, probably because of contextual information available on daily routines. Using meta-analysis, Uttl observes age-significant declines in 1) proper prospective memory, which implies the awareness of previous plans mentioned above, and also in 2) vigilance; 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.

3.3.3 Visual-motor and constructive functions. Fine and gross motor skills

Bimanual coordination has been found to be maintained in older adults when they are compared to younger adults. Especially, one of the abilities that they maintain is the simultaneous mirror-image moving called “in-phase” (Lee, Wishart, & Murdoch, 2002). In this sense, especially since motor-learning skills are reduced, as it has been mentioned above, elder adults maintain this level of bimanual coordination by means of increasing access to attention resources. In order to achieve a level of motor performance similar to the one that the younger adults achieve with less allocation of attention, elder adults have to focus their processing resources, decreasing the performance in any concurrent task.

3.3.4 Language and communication

Slight but statistically significant age-related differences have been found for both language production (Burke & Shafto, 2004) and language comprehension (Kemper, 1992), whereas vocabulary knowledge improves with ageing (Verhaeghen, 2003).

These language changes can reduce older adults’ confidence in their own communication skills, inducing tendencies to social isolation or, on the other side, off-target verbosity (Arbuckle & Gold, 1993). In this sense, cognitive playing based on verbal tasks could both reinforce language abilities and also increase elder adults’ confidence in their own communicative performance.
3.3.5 Executive functions

Executive functions are an umbrella term for various cognitive processes that help goal-directed behaviour. These functions are especially important in novel or demanding situations which require a rapid and flexible adjustment of behaviour to the changing demands of the environment. Therefore, these functions are specially needed for cognitive gaming in those elder adults not very accustomed to digital technologies.

Executive functions are thought to rely strongly on frontal lobes (Dempster, 1992) and have been related to changes in working memory (see point 3.3.2), divided attention (see point 3.3.1) and switching (Zelazo, Craik, & Booth, 2004).

Reasoning about familiar materials does not change with aging. In contrast, when one faced with the solving of unfamiliar and/or complex problems, elder adults have a poorer performance in reasoning capacity related to increasing ageing. Moreover, a decline in problem solving has been proved when distinctions have to be done between relevant and irrelevant or redundant information, related to declines in inhibitory processes.

Abstraction capabilities also decline with age. Older adults tend to think in a more concrete way compared with younger adults, because of the reduction in mental flexibility needed to make new abstractions and conceptual links. This reduction in mental flexibility is especially notorious for more difficult tasks, including tasks with high memory loads, new situations, new problems to solve, tasks with complex instructions and those that require changes in the focus of attention.

Decline on executive functions affects self-monitoring, initiative and emotional evaluation, potentially interfering on successful social functioning (von Hippel, 2007). It has been proved the executive processing role in the tendency of elder adults to talk excessively about irrelevant topics (off-target verbosity) and also in the reduced capability to respond in sufficiently challenging social situations.

4. COGNITIVE GAMING

4.1 Introduction

Due to the increase of our society’s average age within the next 15 years (Ijsselsteijn, Nap, de Kort, & Poels, 2007) we will be confronted with a large number of elderly citizens with the cognitive limitations as described in section 2. It is expected that the coming generations of seniors will be more computer-literate and therefore will use modern technologies more frequently. Besides the employment of these technologies in their daily life (ubiquitous computing), other areas of applications such as computer games will be explored.

Research on using computer games as therapeutic methods for the elderly started as early as the 1980s (Whitcomb, 1990). In his work, Whitcomb provides a well-structured overview of the publications in this area that were released up to 1990. There are also other works along the same lines published by (Drew & Waters, 1986), (Hollander & Plummer, 1986), (McGuire, 1984), (Weisman, 1983). Since the majority of the investigations focused on traditional video
games of that time (e.g. PacMan, Donkey Kong, etc.), researchers found out that only a limited number of those games are suitable for elderly because of the reaction times required, inappropriate sounds and the size of the elements on the screen. Nevertheless they could distinguish a significant increase in the users’ reaction time and motor skills. Furthermore Whitcomb summarizes the mentioned interest of elderly in playing games. This is mainly by a desire to spend meaningfully the leisure time, the reward of gaining skills, the stimulating aspect of the games and the social interaction between the players.

Similar results have been distinguished by Goldstein et al. (Goldstein et al., 1997) who have studied 22 non-institutionalized elderly citizens between 69 and 90 years of age over a period of five weeks. Within the group, that was regularly playing Tetris, they discovered faster reaction times and a feeling of well-being, which was higher than the one of the group that was not playing computer games.

The therapeutic value of video games in general has been discussed by Mark Griffiths (Griffiths, 2005). He has described video games to be helpful in different medical situations. For example to make boring and repetitive tasks in physiotherapy and occupational therapy more interesting or to distract users from their pain in pain management. Furthermore Griffiths has also described that video games could help develop social and communication skills in people with learning disabilities. Moreover he also describes that video games can help people with cognitive disabilities and elderly by increasing the intellectual abilities and providing the users enjoyment. Recent research from IJsselsteijn et al. indicates that a growing number of seniors are expected to play computer games in the future and that by the year 2005 about 25 % of American seniors over 50 years of age already played computer games (IJsselsteijn, Nap, de Kort, & Poels, 2007). Traditional games are already a welcome distraction for many elderly since, for example, puzzles and quizzes can provide a mental challenge, or give a sense of accomplishment. Furthermore, they can increase the player’s self esteem. IJsselsteijn et al. criticize current games as non appropriate to the older clientele since they require an interaction that is too fast and hard to achieve by the elderly.

### 4.2 Accessibility and usability for older users

As described by IJsselsteijn et al. games offer significant positive potential to elderly (IJsselsteijn, Nap, de Kort, & Poels, 2007), especially since they provide a welcome alternative to television. This includes therapeutic as well as social values. Nevertheless current games are not optimized for elderly users and different principles apply to the design of such games. This does not only include usability principles, but also guidelines connected to user experience, engagement and enjoyment.

IJsselsteijn et al. suggest not to focus on usability specific aspects only, but also to consider the motivation of the elderly to play games. According to these authors, a user friendly interface can also provide a content that may be completely uninteresting for this peer group. Therefore, games for elderly should be engaging and enjoyable for this specific user group.

Especially since current elderly users are not always computer-literate and still are insecure when using the computer, usability issues might even affect them more than they would in case of younger players. Therefore, researchers (especially IJsselsteijn et al.) call for extensive research in this area to increase the developer’s awareness of accessibility in the area of
computer games for elderly. This could be achieved through an investigation of the target group, its requirements and needs, as it was made in this project and explained in D2.1. Suggested methods are, amongst others, focus groups, user testing, user studies, interviews and cultural probes.

Current research on interfaces and accessibility for elderly is contained in the term e-Inclusion or digital inclusion\(^1\), a Europe-wide activity to use modern technologies such as the internet to include citizens with disadvantages caused by reasons of education, age, gender, disabilities or ethnicity.

The available research on accessibility for elderly mainly covers the area of the Internet and some traditional applications. Therefore, we know that elderly are still much more careful when using the computer than younger people. Because of decreased visual functions larger font size and less colour contrast is recommended. The structure of the interface should be very clear and it is better to offer interfaces that are not too cluttered. Generally, it should be avoided to visually overwhelm the user. The principle of affordance is very important to elderly, since they especially tend to click on objects that are visually easy to distinguish. The design of interfaces for elderly users should be simple and consistent. The terms employed should be fitted to the target group, especially since they are not used to rather technical terms.

The above mentioned guidelines and more are contained in the W3C Web Content Accessibility Guidelines\(^2\) whose last issue was released in November 2008. Some of the issues are not only relevant for web sites but do also concern other types of interfaces. Nevertheless, research aimed at creating a guideline especially for games for the elderly is proposed.

According to IJsselsteijn et al. there are three factors to take care of when designing games for elderly (IJsselsteijn, Nap, de Kort, & Poels, 2007). The first issue is that the interface must compensate abilities that might have declined with age, such as memory, visual abilities and motor functions. Next, the games should be able to adapt to limitations by the users and third, the users should be given benefits from playing the game, in order to motivate them to re-play it.

### 4.3 Digital game experiences: On flow and immersion

In the previous section we recommended to offer the users a unique and motivating experience when playing a game, to give the users benefits from playing it. Therefore the user experience of such a game has to be rewarding and highly engaging.

The term “user experience” has recently increased in usage as well as in popularity. It is seen as a counter-reaction to the rather task and work related paradigm (Hassenzahl & Tractinsky, 2006). Although it is used quite frequently, a clear definition and founded understanding of this term is still missing (Law, Roto, Vermeeren, Kort, & Hassenzahl, 2008).

According to Effie Law the main problem is that user experience mainly focuses on affect and sensation – two very subjective impressions, which encompass traditional usability as well as beauty and hedonic, affective or experimental aspects of technology use (Forlizzi & Battarbee, 2004).

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\(^2\) [http://www.w3.org/TR/WXAG20/](http://www.w3.org/TR/WXAG20/)
A leading researcher in this area, Marc Hassenzahl offers the following definition for user experience: “It is a momentary, primarily evaluative feeling (good-bad) while interacting with a product or service” (Hassenzahl, 2008). Therefore user experience is designing for joy and fun instead of designing for the absence of pain (Hassenzahl & Tractinsky, 2006).

Since user experience focuses on subjective, hedonic impressions, the area of games is an area of major interest for many researchers (Bernhaupt, Eckschlager, & Tscheligi, 2007), (Bernhaupt, IJsselsteijn, Mueller, Tscheligi, & Wixon, 2008), (Marsh et al., 2005).

General factors influencing the user experience of a game are immersion, fun, enjoyment, playability and flow. The latter was introduced as a concept in 1975 by Mihaly Csikszentmihalyi (Csikszentmihalyi, 1975) and is seen as the optimal experience when playing a game (Sweetser & Wyeth, 2005). According to many researchers, the concept of flow is tightly connected to user experience and Mark Hassenzahl even describes flow as “a positive experience caused by an optimal balance of challenges and skills in a goal-oriented environment” (Hassenzahl, 2008).

In order to be able to measure whether a state of flow is caused by a game, Sweetser and Wyeth have adapted the eight original steps of flow as conceptualized by Csikszentmihalyi to video games (Sweetser & Wyeth, 2005). This newly created model is called GameFlow and is mainly based on previously introduced heuristics for video games. Using the heuristics Sweetser and Wyeth are able to point-wise evaluate a game for its user experience.

More recent approaches to measure flow have been undertaken by Cowley et al. (Cowley, Charles, Black, & Hickey, 2008) and Kalle Jegers (Jegers, 2007). While Cowley et al. have introduced a framework to map flow to the game play, Kalle Jegers has proposed the so-called “pervasive gameplay model” that enhances the game flow idea from Sweetser and Wyeth with aspects that are particular to pervasive games.

Another concept that is tightly linked to flow is immersion. One definition of immersion and its stages has been proposed by Brown and Cairns (Brown & Cairns, 2004). Through a semi-structured interview with seven gamers they could distinguish immersion into three phases: engagement, engrossment and total immersion. Engagement is the first stage of immersion. According to Brown and Cairns the players have to be interested in the game to reach this state. When the user continues to play a game after the stage of engagement he will reach engrossment. When a player is engrossed in a game, his emotions are directly affected by the game. Total immersion (the third stage) is the most immersed a user can get. He will be completely involved in the game and experience absolute presence, where only the emotions produced by the game matter.

In a follow-up work Cheng and Cairns have further investigated the different stages of immersion (Cheng & Cairns, 2005). They tested a game with changing graphics and behaviour on 14 different users. Through this experiment Cheng and Cairns found out that when a user is immersed in a game, he would oversee usability issues and even not notice changes in the game’s behaviour.

### 4.4 Pervasive Games, Advanced Interaction Games
Advanced interaction games and pervasive games are characterized by novel interfaces and interaction technologies. Such multimodal interfaces combine different modalities of input such as gestures and speech. These kinds of games are known to make human-computer interaction in games more natural, efficient and enjoyable. Within the last years numerous different systems basing on these principles have been created – some of them even commercially such as the PlayStation EyeToy\(^3\) or several games for the Nintendo Wii\(^4\).

Research in this area has concentrated on detailed hand gestures and full body (pose) gestures (Hilton & Fua, 2001). Pervasive games that have become popular are Human Pacman (Cheok, Fong, Goh, Yang, & Farzbiz, 2003) or ARQuake (Thomas et al., 2002). These pervasive games integrate traditional mixed and augmented reality environments with computer games. A commercial game that offers these possibilities is the Eye of Judgment\(^5\) for Sony’s PlayStation.

Since they offer more natural ways to interact with a system and therefore help minimize the fear of elderly people to interact with modern technologies, pervasive games and advanced interaction games can provide this peer group the unique user experience needed to create an engaging and successful game.

4.5 Neuropsychological constrains.

With the aim to ensure the accessibility and the design of both the cognitive games and the interface, we must take into account the sensory and neuropsychological changes associated with age. As mentioned in section 3.1.2, ageing brings changes in auditory, visual and motor systems.

Regarding to changes in hearing capacity, elderly people lose their ability to discriminate between high and medium frequency sounds (Peixoto, Veras & Couto Mattos, 2007). For non-speech audio signals lower frequency are easier to listen. Similarly elderly people may also have difficulty for understanding the messages of a voice synthesizer, that can be heard distorted (IJsselsteijn, Nap, de Kort, & Poels, 2007).

In relation to changes in visual abilities, the design of games has to take into account the loss of retina’s sensitivity, the increased susceptibility to glare and the reduced contrast adaptability. This changes may make it harder for elderly people to perceive small elements on a display, read instructions or to locate complex information on the screen (IJsselsteijn, Nap, de Kort, & Poels, 2007). In this sense, ETSI Guide, (ETSI, 2002) provides guidelines on contrast and font size. The guide suggests a minimum font size of 12pt to 14pt. Nevertheless that size could prove difficult to read (depending on the user), so the size of the letter must be adapted to the needs of users, in fact the visual acuity problems can be solved using large characters (Lopes, 2001). On the other hand, some elderly people can’t distinguish between foreground and background due to insufficient contrast; the better the contrast is, the better the users can clearly distinguish between figure and background (ETSI, 2002). Finally, colour and movement should be considered very important dimensions for game flow and immersion, but not for basic dimensions of the design.

\(^3\) [http://www.eyetoy.com/](http://www.eyetoy.com/)

\(^4\) [http://wii.com/](http://wii.com/)

\(^5\) [http://www.eyeofjudgment.com/](http://www.eyeofjudgment.com/)
The size of the icons must also be taken into account because elderly’s fine motor skills are less accurate. The reaction time is slower for elderly people so that the success of tasks should not depend exclusively on the execution time. Regarding to the difficulty it is important to match the player’s skills and the challenged posed by the game, with the purpose to avoid the frustrating the player.

One of the main objectives of the HERMES project is to counteract the decline in prospective and episodic memory by training the users as well as the support of other cognitive abilities. In this regard, one of the skills preserved by elderly is the bimanual coordination. Drew and Waters carried out a study which demonstrated that video games increase hand-eye coordination and improve scores of general and verbal intelligence (Drew & Waters, 1986). Therefore, it is necessary to develop cognitive games that stimulate these functions.

Elderly people respond slower when performing tasks that require divided attention, which involves the ability to do two tasks at once. The positive effects of video games, especially on divided attention skills as well as in the reduction of the reaction time has been demonstrated (Greenfield, De Winstanley, Kilpatrick, & Kaye, 1994).

Although cognitive training can improve the perceptual and cognitive functioning, is important that the interface is adapted to the needs and requirements of the user.

5. COGNITIVE TRAINING FOR OLDER ADULTS

As it has been pointed out before, this section provides a deep explanation about training programs for older adults and video games including explicit cognitive effects. The State Of The Art (SOTA) of cognitive training for older adults is a peculiar contribution of the HERMES project since the information contained here has been specifically collected according to game design needs. Conclusions and implications for designing will be stated in section 6 from this work and applied in elaboration of the HERMES cognitive games in section 7. Moreover, SOTA has provided important inputs for the construction of the HERMES games specific features contained in section 8.

Each one of the sections includes information about one concrete type of video games. Section 5.1 includes information collected about personnel training and educative applications. The video games in section 5.2 are the ones developed with cognitive rehabilitation and stimulation aims. Finally, section 5.3 introduces the commercial games.

5.1 Serious games and educational applications of computerized games

Serious games are software or hardware applications developed with game technology and ideas but the objective of providing entertainment. Traditionally, this kind of games have a wide use for army training, including first person shooters games, role-playing games, vehicle simulations and games including command responsibilities.
More recently, serious games have gone beyond that and numerous companies have developed simulations that immerse the players into political systems by having them take political decisions. Democracy6 is a political game in which the player is the President or the Prime Minister and has to take decisions to govern his country. Based on a complex neural network, the game takes into account the motivations, loyalties and desires of different kinds of voters.

Games have also been developed with the aim of sensitizing players about humanitarian emergencies: Darfur Is Dying, developed by MTV about the crisis in the south of Sudan7, or Food Force, from the World Food Programme of the United Nations8. The serious games company TruSim has also developed a division for humanitarian interventions training called Virtual Peace9, a multi-sensory game-based environment that simulates real disasters to learn necessary tools for sensitizing on crisis responses.

5.1.1 Use of computers in personnel training

Apart from military training, one of the main objectives of serious games is their use with health workers, mainly medical specialists such as surgeons (Rosser et al., 2007). Several games allow players to make appropriate decisions related to an urgent treatment, focusing on technical knowledge but also on the cognitive skills needed.

Simulation games are also used for this kind of training. A simulation game is a game that contains a mixture of skill, chance, and strategy to simulate an aspect of reality (e.g. The Sims). Pulse!! The Virtual Clinical Learning Lab10 (see Figure 1) is a virtual learning platform produced on the Texas A&M University and designed to simulate health-care facilities and procedures (Johnson & Whatley, 2005). It presents different pathologies, life-threatening patients and rare emergencies.

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Figure 1. Image from “Pulse!! The Virtual Clinical Learning Lab”.

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6 http://www.positech.co.uk/democracy/faq.html
7 http://www.darfurisdying.com
8 http://www.food-force.com
9 http://www.virtualpeace.org/
10 http://www.sp.tamucc.edu/pulse/info-multimedia.asp
Another field of simulation gaming for health professionals is the usage of virtual reality implemented on the distortions of reality perception that experienced the people who suffer from schizophrenia. For example, The UC Davis Health System has developed an application that allows to experience hallucinations using Second Life.\textsuperscript{11}

5.1.2 Edutainment: Games as educational activities

An educational computer game is an electronic game with all the characteristics of a gaming environment but with educational goals. These types of games are called Edutainment because they combine education and entertainment. These games are created to improve different cognitive skills and to reduce time needed to learn. Hence it allows formal education to be centred around social concerns such as critical thinking or emotional intelligence.

In many different ways, computer games are one important key aspect to social success in childhood. Just by playing computer games, children can actually learn, apart from the educational content of the games. Therefore design challenges are about to find the synergy between pedagogy and flow (Van Eck, 2006). Nevertheless, for elder adults this is very different since they have learned through human interaction and the use of games as learning tools is a very new concept -but also a very challenging experience for them.

5.1.2.1 Fast ForWords, Progress Trucker, Reading Assistant, Brain Quest and so on

Scientific Learning\textsuperscript{12} is an Oakland-based company that provides educational software for schools, educational institutions and rehabilitation centres. The company was founded more than 30 years ago by Dr. Michael Merzenich and Bill Jenkins at the University of California and Dr. Paula Tallal and Dr. Steven Miller at Rutgers University; it commercializes products such as the Fast ForWord, the Scientific Learning Progress Tracker and the Reading Assistant.

Fast ForWord is a program aimed to maximize reading capacities through the development of memory, attention, processing rate and sequencing –cognitive skills needed for reading. The training of these skills results in an improvement of critical reading skills which has been empirically proved (Wahl, Robinson, & Torgesen, 2003).

Three versions of Fast ForWord Language series are available: Fast ForWord Language Basics, which is focused on basic parameters related to reading such as sound sequencing, fine motor skills, hand-eye coordination, pattern recognition, and colour-shape identification; Fast ForWord Language v2 which is focused on reading skills, specially listening accuracy, phonological awareness and language structures; and Fast ForWord Language to Reading v2, that emphasizes the link between spoken and written language for proficient grade level readers.

For secondary students and adults, Scientific Learning has published Fast ForWord Literacy and Fast ForWord Literacy Advance. Both are reading-intervention softwares that build reading and language and accelerate reading progress by the development of critical brain processing

\textsuperscript{11} http://www.ucdmc.ucdavis.edu/ais/virtualhallucinations/

\textsuperscript{12} http://www.scilearn.com
efficiency in memory, attention and capacity to comprehend orally and visually presented stories. Finally, Fast ForWord READING Series are directed to accelerate reading acquisition. Games included in Fast ForWord have a cute, attractive presentation, and although sold separately, each game is quite short and simple. Putting them all together makes the entire series of games provide valuable results. It also allows online data analysis and reporting through the Scientific Learning Progress Tracker, a specific tool that enables professors to monitor performance of students working with Fast ForWord products. It provides simple, action-oriented information, showing students’ progress over time, for specific reading tasks and in cognitive skills areas.

In January, 2008, Scientific Learning acquired Reading Assistant, from Soliloquy Learning13. Reading Assistant combines speech recognition technology with reading contents to help students stimulate fluency, vocabulary and comprehension to become proficient readers. Although the program is pretty smart and has the potential to be very useful for children and adults with reading impairments, it finally includes no much more than language trainers available for Nintendo DS.

Brain Quest is a recently realised computerized quiz game, based on a famous educational card game14. Both Brain Quest: Grades 3 & 415 and Brain Quest: Grades 5 & 616 are basically the same pretty good educational game as long as users enjoy playing a quiz game. Six categories are included: English, math, science, history, geography and “grab bag”, a miscellany of culture, music and food questions. Points are awarded for right answers and accounted depending on how fast the player answers the question. Sudoku puzzles for kids are also included. The game also includes a multi-player, which is weak since players just answer the same questions and compare scores at the end.

Finally, SMART Technologies17, a company expert in interactive whiteboards, has announced a multi-touch computer table for school learning. Microsoft’s multi-touch computer table - Microsoft Surface- is quite expensive, causing the developments of business only applications. For educational goals only, SMART has announced SMART Table18, which will be available in the spring of 2009 and will host learning applications designed for children to train visuospatial abilities (see Figure 2).

13 http://www.scilearn.com/
14 http://www.brainquest.com
15 http://www.nintendo.com/games/detail/tmcXg7wdYQtdEwZoODDtEYD4Ke4L6oQ2
16 http://www.nintendo.com/games/detail/2xEnuS8nsGSHJrGBqRHIYrtZe79ncfnb
17 http://smarttech.com
18 http://www2.smarttech.com/st/en-US/Products/SMART+Table/default.htm?WT.mc_id=Table_spotlight
SMART Table has a 27 inch diagonal screen. Children can drag things around the screen by touch interaction and play different word and picture games with other children by dragging images, making basic tasks such as reading, writing, counting or matching colours easier and much more interesting. Another important point of this device is the possibility of collaborative learning, involving groups of children in educative (while engaging) tasks.

5.1.2.2 Age Invaders: Inter-generational mixed-reality family game

Age Invaders is a “novel interactive intergeneration social-physical game that allows the elderly to play harmoniously together with children in physical space while parents can participate in the game play in real time” (Khoo & Cheok, 2006). It is specifically designed to encourage intergenerational relations and uses an intuitive floor display with predefined patterns of lights that gamers have to follow (see Figure 3).
D.6.1 Cognitive Training Exercises

Age Invaders is a cognitive and physical stimulation for older adults, as well an enjoyable game for children who have to trigger rockets and bombs to the other players and collect extras to gain or lose score points. It also allows younger people to check off the game display from an on-line PC. In this sense, inter-generational opportunities are maximized offering adaptable game parameters to cope with specific difficulties for both children and older adults.

Age Invaders has many valuable aspects compared to classical 3D simulation games. Using the floor display, it does not require the user to perceive the world through a device, decreasing the cognitive load needed to play successfully. It also requires physical engagement; players have to move around the floor display, eliciting real social interaction as an integral part of the game, which is especially valuable taking into account intergenerational differences.

The major weakness of Age Invaders might be found in the aforementioned intergenerational aim, making it not attractive enough for children and too demanding and new for older adults at the same time.

5.2 Computerized cognitive rehabilitation and cognitive stimulation

5.2.1 ELDERGAMES Project

ElderGames19 is a project funded by the European Union project in the framework of "Ambient Assisted Living" from the Seventh Research Framework Programme (7FP). The partners of this project are AIJU20, a technological non-profit-making center attending toy sector, Gaia, Human Centered Technology – LabHuman at Universidad Politecnica de Valencia, Lappset, Brainstorm Multimedia or the University of Padova.

The starting assumption of the project is the advantage of playing to engage older users cognitively and socially (Gamberini et al., 2006). ElderGames is focused on the research of

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19 [http://www.eldergames.org](http://www.eldergames.org)
effects of play in the old age and the adequacy of advanced technologies to develop games oriented towards older adults. These aims will be achieved developing interactive-play board prototypes adjusted to specific abilities of the older adults. Hardware and software specifications for the ElderGames application have been developed in order to create a user-driven application. The new hardware uses innovative gaming technology, such as mixed reality, displayed on a large LCD screen. The system, with the preferred number of players is four, also includes four cameras and a wooden table on which the game and four pointers are mounted.

ElderGames considers social engagement as one of the major areas that technology for older adults can be applied to. In this sense, the ElderGames interactive board is thought to integrate an alternative communication system. In addition to usability barriers specific for elder users, the project states to overcome linguistic barriers between different European languages, allowing on-line games between users from different European countries. Potential users, experts on ageing, and the engineers from AIJU and the University of Padova have started game sessions to evaluate the first version of ElderGames.

5.2.2 FUGA Project

The FUGA is funded by the European Commission under the 6th Framework Program\(^\text{21}\). FUGA is a three-year project that runs from May 2006 to April 2009.

The main objective of FUGA is the creation of new methods of measuring and improving existing methods in order to assess the various aspects of the gaming experience such as emotions and cognitions. It also aims to establish the construct validity, reliability and predictive validity of these measures, which will be based on different measurement techniques such as psycho-physiological recordings, brain imaging electrocardiography, electrophysiological activity, respiration, functional magnetic resonance imaging, and eye movement recording. Another objective of FUGA is to design a prototype of a video game to change a user’s behaviour according to the player’s emotional state, reported by psycho-physiological measures. They were carried out the conceptual definition of the dimensions of the experience of the game and the construction of a theoretical framework, which describes the relationship between the different dimensions of the gaming experience and potential measures.

In the first part of the study, the Game Experience construct measures will be validated against thinking-aloud and self-reporting methods as well as against each other. The validation will be carried out in different places and contexts of everyday life such as tram stops, coffee shops and so on. In order to study validity, a test-retest was conducted after a period of 6 months. Moreover, in order to study the predictive validity, the different dimensions of the experience of the game were assessed while players were playing the game. It is expected that the investigation conducted by the project FUGA could be used in the design of different games, which have different purposes (educational, recreational, psychotherapeutic...).

\(^\text{21}\) [http://project.hkkk.fi/fuga/]
5.2.3 Games_@_Large Project

This project was funded by the European Commission under the IST priority of the European Union’s FP6. It aims is to generate the necessary technology to guarantee access to ubiquitous video game, without the need to have traditional devices, creating software that allows access to video games in different environments. In order to achieve this, the necessary infrastructure will be developed, so that a single server can serve different devices simultaneously.

It will also seek to promote and explore the use of video games in different areas – the users’ home, hotel, Internet café and so on (de Kort & IJsselsteijn, 2008).

5.2.4 VitalMind Project

Vital Mind23 is a project funded by the European Union in the framework of "Ambient Assisted Living" from the Seventh Research Framework Programme (FP7). It is lead by CogniFit and partners such as Philips Innovation Laboratory, Czech Technical University and the Universities of Genoa, London, Dundee and Hradec.

It is dedicated to support the elderly population by means of developing brain fitness contents and providing Information Computer Technologies for them. Related to cognitive games, one of the most important aims of Vital Mind is to create novel training programs based on scientific theories. VitalMind designs tasks to train three cognitive functions supported by frontal regions that are particularly compromised by age: cognitive flexibility, fluency and regency judgments. 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.

Technologically, VitalMind seeks for the use a USC Flash Device in addition to the broadcast delivery system, realizing a new concept of using the television like as a living-room extension of the PC. In this way, it is possible to transform the passive activity of television viewing into dynamic brain tasks plenty usable for older adults (Lessiter, Freeman, Miotto, & E., 2008). This tool could easily be integrated in the homes of elderly people; especially those handicapped individuals who specifically need cognitive stimulation.

VitalMind is a 30 months research project, which started in 2008. At the present and as far as we know, no scientific papers have been published24. One of the later tasks of the project (WP7 - Cognitive Technology Verification) is to test which is the best approach about cognitive stimulation: to stimulate each mental function separately and in isolation using the brain fitness component or to stimulate those mental functions in unison in contextualized real-world situations, using the life-skill component. Additionally, it will be studied whether activities in the personal memory are as beneficial as those in the other components.

Cognifit products for health and wellness: MindFit.

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22 http://www.gamesatlarge.eu
23 http://www.vitalmind-project.eu
MindFit25 is software designed and aimed at adults and seniors. It is created by Cognifit, which is also the VitalMind project leader (section 4.2.4). MindFit was created to exercise and improve cognitive skills, sensory and psychomotor, with the general aim of improving the users’ quality of life. MindFit stimulates the classical set of skills usually addressed by these kinds of computer programs: visual and auditory perception, divided attention, eye-hand coordination, visual and auditory memory, working memory, planning task and decision making (see Figure 4).

![Figure 4. Example of MindFit task.](image)

The interface was programmed in an easy to use way with the aim of reducing stress related to usage. The simple graphical instructions are also accompanied by audio instructions. The exercise program is personalized, and is adapted according to the user’s progress. On their website Cognifit informs 26 of improvements in the short-term memory, appointment of objects, the pattern of sensory memory, dual task, visuo-manual coordination, visual perception, ability to resist distractions, visual search, inhibition and reaction time.

5.2.5 Brain Train software: Captain’s Log, SoundSmart and Neurofeedback trainer

The Captain’s Log cognitive brain training software system, produced by BrainTrain 27, was first released in 1985 to use with adults with traumatic injuries. It is divided into 7 modules in 3 training sets: Attention Skills Training Set (Attention Skill: Developmental; Visual motor skill and Attention Skill: The Next Generation); Problem Solving Skills Training Set (Conceptual

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25 [http://www.e-mindfitness.com](http://www.e-mindfitness.com)
27 [http://www.braintrain.com](http://www.braintrain.com)
memory skills; Logic skills), Memory Skills Training Set (Numeric Concepts with Memory Skills; Working Memory).

The effects of cognitive training with The Captain’s Log on cognitive performance of Parkinson’s Disease patients has been scientifically studied (Sammer, Reuter, Hullmann, Kaps, & Vaitl, 2006). The group with cognitive treatment in executive task improved significantly after the training period, while no improvement was seen in the standard-treatment group. The results indicate that specific training is required for improvement of executive functions, while general rehabilitation is not sufficient.

SoundSmart is another BrainTrain program, consisting of auditory exercises. It stimulates listening skills, following directions, phonemic awareness, working memory, processing speed and impulse control. SoundSmart automatically adapts its outcomes to the age of the users and speaks to them in a realistic human voice. Two modules are presented: the Attention Coach, with spoken instructions becoming increasingly complex in order to stimulate attention through multi-step spoken instruction, and the Math and Memory module, which is about improving working memory by practicing math exercises. The phonemic exercises train the users to be good listeners and follow multi-step directions under all types of condition.

Finally, Smartmind is other training software from BrainTrain, targeting neurofeedback. Neurofeedback is a therapeutic technique that informs the patient about his/her own brain electrical activity so that this attempts to regulate it. It enables one to control his brain rhythms related to cognitive functions of attention, concentration and memory (Correa, 2008). In this way, SmartMind combines the effectiveness of neurofeedback with the capability of computerized cognitive training.

Both Captain’s Log and SmartMind can be easily customized to fulfill a variety of training protocols. Users can learn to stay relaxed when facing challenging cognitive exercises, thus enhancing their self-control.

### 5.2.6 Smartbrain and Smartbrain games

Smartbrain is an interactive system for cognitive stimulation developed by ACE Foundation and Educamigos and commercialized in two formats: Smartbrain Professional System and Smartbrain Games28.

Smartbrain Professional System (as called as Smartbrain Pro) is a system developed for the treatment of cognitive impairment —Alzheimer’s disease and other dementias, brain damage and so on. Its efficacy concerning the cognitive stimulation of patients with Alzheimer’s disease has been demonstrated in a single-blind randomised study (Tàrraga et al., 2006) 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 treatments 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

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his or her performance fell below 15% of correct answers 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 functions - ADAS-Cog (Rosen, 1984); MMSE (Blesa, Pujol, & Aguilar, 2001; Folstein, Folstein, & R., 1975), but not concerning functional assessment nor specific neuropsychological tests.

Later, a familiar version of the Smartbrain system, called Smartbrain Games, has been offered for sale. Smartbrain Games targets not only seniors but also young and middle-aged adults. It includes exercises of memory (e.g. Naming professions game), recognition (e.g. Recognizing silhouettes, see Figure 5), language (e.g. Find the name of the country), math skills (e.g. Counting moving numbers game), attention (e.g. Looking for the ball game), orientation (e.g. What time is it?) and executive functions, providing different levels of difficulty with the aim of covering all targeted ages.

![Figure 5. Recognizing silhouettes task from Smartbrain Games.](image)

Smartbrain Games has been developed from Smartbrain Pro, which implicates an empirical basis related to therapeutical implementations of cognitive games. Unfortunately, it also connotes a limitation concerning variety and complexity of the games. As results, Smartbrain Games are too simplistic and repetitive, and users will hardly become immersed into the game, aside from stimulation purposes.
5.2.7 Working memory training: Cogmed

Cogmed29 is a private company founded in Stockholm, Sweden in 2001, by two neuroscientists and two game developers in Stockholm. Cogmed Working Memory Training is a home-based program to improve attention by training the working memory capacity.

Three versions of Cogmed software are currently available: a) Cogmed JM for children age 4-7, b) Cogmed RM for children aged 7 to adolescents and c) Cogmed QM – adults. The introduction to the system had to be done by a trained professional in a formal way, but recently a “homemade family pricing” version has been introduced according to increasing popularity of cognitive games and new Cogmed versions available.

Cogmed Working Memory Training was first developed by a team of researchers at the Karolinska Institute in Stockholm, Sweden, and research has been continued since the foundation of the Company in 2004. Cogmed Working Memory Training was found to have an effect on brain injured patients after stroke. This includes effects 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- choose as non-trained test because it is very close but not exactly identical to tasks in the programme (Westerberg et al., 2007). After training with the software and increase in brain activity in the middle frontal gyrus and superior and inferior parietal cortices could be detected for healthy young adults (Olesen, Westerberg, & Klingberg, 2004).

5.2.8 Gradior Program

Gradior is a multimedia system developed and published by Intras30 that is implemented in residential settings and aims at neuropsychological assessment and rehabilitation. The Gradior Program has two main modules:

1- Therapist’s module: the therapist collects information about the diagnosis, sociodemographic data and clinical history. This information will be taken into account for establishing objectives and parameters for the cognitive rehabilitation. The treatment includes cognitive tasks, and controls the failures and success-rate as well as reaction and execution time. This information is used to adjust the difficulty levels.

2- The sessions: It consists of applications containing selected tasks. The user interacts with the computer via a touch screen, which provides visual and acoustic information.

The program provides positive and negative reinforcements and tries to avoid frustration by motivating the user to continue with the tasks.

Clinical trials have been conducted with users suffering from schizophrenia and with elderly people with mild to moderate cognitive impairment. At the state of publication of this report there are no conclusive results available yet (Franco, Bueno, Cid, & Orihuela, 2001).

30 http://www.intras.es/index.php?id=669
5.3 Commercial games: Brain trainers and beyond

5.3.1 The rise and falls of brain trainers

5.3.1.1 Dr. Kawashima’s Brain Train. How old is your brain?

The Brain Training series of video games for the Nintendo DS (known as Brain Age in North America), developed by Dr. Ryuta Kawashima, has become really popular and reaches out to people who do not usually play games.

Dr. Kawashima is a professor at the Tōhoku University (Japan), trained in neuropsychology. One of his primary research topics is mapping the regions of the brain to study domains such as emotion, language, memorization, and cognition (Ikuta et al., 2006; Kawashima et al., 2006; Sugiura, Sassa, Jeong et al., 2008; Sugiura, Sassa, Watanabe et al., 2008). The book Train Your Brain: 60 Days to a Better Brain (Kawashima, 2006), became an instant hit in Japan, selling millions of copies. The principles of that book have been developed into Brain Training, released in 2006.

To determine the kind of exercises that would be contained in the Brain Training software, Dr. Kawashima conducted a series of tests to discover which exercises demonstrated an increase of brain activity in the prefrontal cortex, which is considered the most relevant area of the brain by Dr. Kawashima’s theory. Unfortunately, as far as we know, this study has not been published.

Brain Training was included in the Touch Generations of video games, a series that featured games for a more casual gaming audience. Quick language and math tasks are presented with the aim to stimulate the brain for only a few minutes each day (see Figure 6). It also includes the popular sudoku game and a multiplayer option with a game called Calculation Battle.
Games from this series and other related games use the touch sensitive technology of the Nintendo DS. The gamer has to write the answers on the screen with a stylus just like using a pen and paper; unfortunately the size of the screen and, specially, the size and the shape of the pen do not adhere to accessibility principles for elder adults. Anyhow, usability is better in Brain Training than more recent similar games. In order to avoid frustration, games include a key to go forward – anyway risk of frustration is a variable not specially observed for these series and others similar games.

Adaptation is observed for left-handed. At the start of the game, Dr. Kawashima’s avatar asks your laterality and left-handed games can rotate the device in order to avoid hand intrusions on the screen.

It also includes a calendar to plot engagement and progress; progress is reinforced by means of unlocking new tasks and extra difficulty levels. Because of the slow progression of the game through unlocking, it could be rather unattractive for younger s hardcore gamers but probably this problem does not exist for older adults.

More Brain Training from Dr Kawashima: How Old is Your Brain? Features new language and numerical tasks, and also a musical challenge -Masterpiece Recital- which is quite interesting but requires musical knowledge (the touch screen features a piano keyboard, players must follow a music sheet shown on the other screen and press the corresponding keys on the keyboard, see Figure 7). The game also improves multiplayer option from the original Brain Training and includes a new puzzle task, Germ Buster, similar to the Nintendo classic Dr. Mario (see section 4.3.2). Nevertheless, substantial and valuable changes from the original device are not included, and the usability problems are mainly the same.
The Nintendo DSi is the third iteration of the Nintendo DS, released in Europe on April 3, 2009. This iteration retains many attributes such as the design with two LCD screens inside with only the bottom one being a touch screen. Furthermore, some minor features such as its two cameras - the character “i” in DSi is symbolic of representing an "eye" and also the subject "I" - and its personal individuality are added to the devices. The unit has improved speakers and its two screens are larger measuring at 3.25 inches instead of the previous 3 inches. A built-in software called "Nintendo DSi Camera" lets users modify photos with several options; it also allows new game opportunities, like DS Face Training, to exercise face recognition.

5.3.1.2 **Big Brain Academy vs. Brain Challenge**

Big Brain Academy was the second title of Nintendo’s brain games which is similar to Brain Training. It includes three ways of feedback: the "brain weight", areas of strength and weakness from five categories (represented in a pentagon) and occupation related to weight score. Games belong to five categories: memorize, compute, identify (visual-based questions), think and analyze (logic and reason-themed questions).

Presentation differs from Brain Training, in the friendly and colouristic graphics that nevertheless do not limit it to a younger target population especially because of the simplicity and attractiveness of the game design. In fact, the conception is much more similar to a puzzle game than to a personal trainer -brain exercise puzzles. Unfortunately, visual-design changes do not mean improvements in the accessibility (see Figure 8).
Brain Challenge also addresses a younger target group and is more oriented to teenage gamers (e.g. for physical characteristics of the instructors, see Figure 9). As in Big Brain Academy, many of the tasks (categorized into logic, math, visual or focus) are similar to those from Brain Training and also similar to classical puzzle games. Again, the game features two models (Test and Free Training), but it also features additional modes such as Creative (it allows to doodle drawings or shoot fireworks) and Stress (it present tasks with distracting noises and visuals, such as forcing the player to do two disparate actions at once, or dealing with distracting images or insects on the screen). Both mobile phone and iPod versions of the Brain Challenge are available and have sold very well. For mobile phone, also a second version concentrated on stress management was realised.

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Brain Challenge does not present any evolution on this kind of games, and design improvements are not actually valuable for older adults. More realistic characters could not be more enjoyable for older adults because of the lower level of experience on video-gaming. Instructions are displayed in a very inaccessible way even for people with good perceptual and cognitive skills, because of the amount of text and the concurrence of animations and text at the same time in one or both screens. Finally, the presentation of feedback such as percentage of activated brain is not very clear and could even result frustration.

5.3.1.3 Mind Quiz and the spastic controversy

Mind Quiz continues the way of Brain Training and Big Brain Academy. It presents 49 exercises from 4 cognitive functions - calculation, reflex, judgement, and memory. There is a cohesive visual theme around a dog and a man with a rainbow where his brain should be, and graphics are more accessible but simple. It is available as PSP (PlayStation Portable) version with gamers entering in a Japanese school with an avatar guiding the access to the games.

Tasks are again very similar to other brain games, with some really difficult tasks that do not include any kind of clue or “go forward” function. Interestingly for older adults, Mind Quiz includes some dual tasks based on cognitive functions that should be stimulated in aging.

As seen before, feedback given to gamers is one of the most used strategies to promote engagement in this kind of games (e.g. brain age and brain weight). In MindQuiz, after poor performance one of the labels given to the gamers was “Super Spastic”, which is considered to
be very abusive to people with disabilities (in the UK). This matter caused a big controversy and, on 29/6/2007, Ubisoft pulled the game from stores in the UK, as seen in Figure 10.

Brain game pulled over 'offence'
A video game which uses a term abusive to people with disabilities is being pulled by its manufacturer.

MindQuiz, a brain training game for the Nintendo DS handheld console, was released in the UK by French software giant Ubisoft in March 2007. However, poor performance in one section sees the player labelled in an offensive manner. The company has apologised "to anyone who was offended by the game" and said it will withdraw it. "As soon as we were made aware of the issue we stopped distribution of the product and are now working with retailers to pull the game off the market," a spokesperson said.

"The game was developed in Japan, and we unfortunately did not pick up on the offending word in our quality assurance. We are currently working with the developer to find a way to rectify the issue."

The problem emerged after a Belfast woman contacted BBC Radio Ulster's Nolan Show. Nicola told the show she had been playing the game - aimed at ages three and above - to pass the time while in hospital giving birth to her baby son, Austin, four weeks ago. (...) Nicola was shocked when she had performed poorly at one part of the game and it rated her efforts in a manner derogatory to the disabled. "I thought it was absolutely appalling that a word like this should be used to describe someone who has not achieved very well," she said. "My daddy also has cerebral palsy and he is in his mid-50s and this is a word that really offends my dad."

Figure 10. Notice about "Mind Quiz controversy"

5.3.1.4 Visual attention stimulation: Flash Focus

“Flash Focus: Vision Training in Minutes a Day” was developed in North America under the supervision of Hisao Ishigaki from the Aichi Institute of Technology.

The training exercises are split into two groups: the "Core Training" and the "Sports Training" (see Figure 11). Sports Training games involve strengthening of vision through sports games such as table tennis, basketball or football. Furthermore they are more visually attractive than the Core Training games. The Core Training is divided in five different categories: dynamic visual acuity, eye movement, momentary vision -comprising perceptual memory on section 2.3, peripheral vision and hand-eye coordination.

33 http://newsvote.bbc.co.uk/1/hi/northern_ireland/6253688.stm
Although it is advertised as a way to relax the eyes and improve visual acuity, Sight Training is mainly concentrated on the stimulation of visual attention. Hence, apart from the use for people there are training sports, this kind of games could be used for older adults with the aim of training basic cognitive abilities necessary for more complex every-day tasks. Unfortunately, the usage of the Nintendo DS stylus and size and design of visual stimulus make Sight Training quite inaccessible for elderly people.

5.3.1.5 Brain Boost, Brain Voyage and so on

After the success of Brain Training, a lot of games related to cognitive gaming have been published. Brain Boost is a series of three brain games, each one consisting of five related mini-games: 1) Brain Boost Beta Wave, subtitled "Improve your concentration", also called The Professor's Brain Trainer: Logic, 2) Brain Boost Gamma Wave, subtitled "Improve your memory", also called The Professor's Brain Trainer: Memory and 3) Mega Brain Boost, subtitled "Boost your brain power with 3 games-in-1", which includes Brain Boost Beta Wave, Brain Boost Gamma Wave and a new game training both memory and executive functions.

One of the most valuable points of this series of games is the way of feedback. The user is presented with a tree which grows up and blossoms related to performance. Unfortunately, the dimensions of the stimulus presented in this game are too small for older adults and the period of time necessary to play the game is too long.

Brain Voyage, also called Dr. Reiner Knizia's Brainbenders, combines brain games and board games. The player solves puzzles while travelling around the world, with 5 puzzles in each capital city. Brain Voyage's 16 puzzles are spread among cities across the globe. When you complete a puzzle, you earn a medal as well as coins. Coins are used to unlock cities and puzzle stages.

Figure 11. Sports Training exercise (left) and Core Training exercise (right) from Sight Training.
The puzzles were designed by Dr. Reiner Knizia, a prolific board game designer with over 500 published board games. Pricing and evaluating risk, recurring elements in his games, are keys for the stimulation of executive functions. Knizia has entered a partnership with Merscom to adapt his current games for the Xbox and Nintendo DS, as well as to develop future original titles.

The story of Brain Voyage could enable a higher degree of immersion of older adults, since they reportedly enjoy travelling even more than younger adults. Nevertheless, the game is not more than another compilation of quick tasks and puzzle games, even with more troublesome graphics when compared to the games revised above.

The following table summarizes the main features of the commercial games described above.

Table 1: Features of the commercial games
<table>
<thead>
<tr>
<th>Game</th>
<th>Age target</th>
<th>Cognitive domains</th>
<th>Theoretical background</th>
<th>Empirical basis</th>
<th>Valuable points</th>
<th>Short-comings</th>
</tr>
</thead>
</table>
| Dr. Kawashima’s Brain Train. How old is your brain? | Elderly people | - Language.                                   | Yes                     | No              | 1. Some interesting tasks
2. Good contrast of shapes and colours | 1. Accessibility
2. Touch sensitive writing |
|                                          |                | - Calculus.                                   |                         |                 |                                                                              |                                                                              |
| Big Brain Academy                        | Children       | - Memory.                                     | No                      | No              | 1. Diversity of games
2. Feedback | 1. Childish presentation |
|                                          |                | - Recognition.                                |                         |                 |                                                                              |                                                                              |
|                                          |                | - Executive functions.                        |                         |                 |                                                                              |                                                                              |
|                                          |                | - Calculation.                                |                         |                 |                                                                              |                                                                              |
| Brain Challenge                          | Adolescents    | - Memory.                                     | No                      | No              | 1. Additional modes | 1. Stimuli presented at the same time
– especially Instructions
2. Poor feedback |
|                                          |                | - Visual attention.                           |                         |                 |                                                                              |                                                                              |
|                                          |                | - Executive functions.                        |                         |                 |                                                                              |                                                                              |
|                                          |                | - Calculation.                                |                         |                 |                                                                              |                                                                              |
| Mind Quiz                                | Undefined      | - Memory.                                     | No                      | No              | 1. Dual tasks.
2. Simple graphics | 1. Difficult tasks
2. Plain graphics and bizarre visual theme |
|                                          |                | - Visual attention.                           |                         |                 |                                                                              |                                                                              |
|                                          |                | - Executive functions.                        |                         |                 |                                                                              |                                                                              |
|                                          |                | - Calculation.                                |                         |                 |                                                                              |                                                                              |
| Flash Focus                              | Athletes       | - Visual acuity                               | Yes                     | No              | 1. Visual attention stimulation can be very useful for older adults coping with everyday life | 1. Stimuli are small
2. Visual acuity required for some tasks |
|                                          |                | - Attention                                   |                         |                 |                                                                              |                                                                              |
|                                          |                | - Hand-eye coordination                      |                         |                 |                                                                              |                                                                              |
| Brain Boost                              | Undefined      | - Memory.                                     | No                      | No              | 1. Feedback is attractive and non competitive | 1. Stimuli are small
2. Too long time for each task |
|                                          |                | - Executive functions.                        |                         |                 |                                                                              |                                                                              |
| Brain Voyage                             | Undefined      | - General approach based on board games       | No                      | No              | 1. Attractive theme | 1. Complexity of stimulus
2. Poor contrast of shape and colours |
|                                          |                |                                               |                         |                 |                                                                              |                                                                              |
5.3.2 Crosswords, quiz games and puzzle games

5.3.2.1 Gaming with words: Spellbound

Language stimulation in elderly people is a relevant tag, since small declines in language production (Burke & Shafto, 2004) can precipitate narrowness in communicative exchanges, reducing social activity for older adults. This stimulation can be carried out by individual speech therapy, group approaches such as conversation meetings and also through informal interventions promoting active behaviours.

Crosswords and word search games are valuable tools the stimulation of the language capacity. Socially-driven variants in form of board games –Scrabble, Upwords and so on- have also been used in these fields. In this sense, computerized versions of these games are cheaper and easier to carry out. Furthermore, they could be easier taking into account the possibility of help modes and the automatic control of difficulty-levels.

Multiple word search games and, specially, crossword versions are available on-line and on commercial platforms such as Nintendo DS. Several computer and video game versions of Scrabble have also been released for various platforms, including PC, Mac, Amiga, Commodore 64, Sinclair ZX Spectrum, Game Boy, Game Boy Color, Game Boy Advance, Nintendo DS, PlayStation, PlayStation 2, iPod, Game.com, Palm OS, Amstrad CPC, and mobile phones. Upwords is also available in a computerized version, since Hasbro has recently licensed electronic marketing rights to Microsoft.

More specifically, Spellbound (2008) for Nintendo DS is a commercial game that includes 11 different spelling and word tasks. Most of the tasks are quite interesting, but the usage of Nintendo DS pen and sensible screen make it quite difficult to use and enjoy it. A previous children game called Spelling Challenge (2007) has similar problems concerning its usability but it provides a higher flow since its theme –a spelling bee TV show- is very attractive.

Finally, Wordtris (1992) is a classical game which combines crossword and puzzle modes. Falling letters must be placed in order to form words to clear them away (see Figure 12). Occasionally bombs will fall which might be used to clear away a single letter or an entire stack of them, depending on the type of bomb. As it happens with columns in Tetris, the larger the words you form, the more points you receive.
5.3.2.2 From Tetris to Polarium

Puzzle video games are a very popular genre of video games that emphasize solving skills including logic, pattern recognition or sequence solving, and most of them requiring visuospatial abilities.

Tetris is the most popular puzzle game. Created and designed by Alexey Pajitnov in 1985, the game first appeared on PC in 1987 and in arcades in 1988, becoming very popular in 1989 when Nintendo introduced the Game Boy. One reason for its popularity was the fact that simplicity and additive playing were even bigger in a portable device.

The name Tetris itself comes from the Greek word "tetra" which means four. Each Tetris block is made of four blocks, arranged in seven different ways. The objective of the game is to rotate falling blocks into lines without any gaps. Each completed line disappears from the game; lines with gaps remain; there is a finite sequence of pieces, so the player may implicitly know the identity and order of all pieces to be presented (Demaine, Hohenberger, & Liben-Nowel, 2002).

After the huge success of Tetris, a new genre was created around this concept, including:

- Pipe Dream (1989), which is a simple but interesting game in which the player has to put together pieces of pipes together into an unbroken chain of pipes. A green toxic liquid will run through the pipes. An actualized version has been realised for Nintendo DS in 2008, including a
visual presentation, games and also an interesting story based on the children’s adventures in its own private island against cowboy plumbers.

- Columns (1990) was the SEGA’s response to Tetris. It is another simple, easy-to-learn and very addictive game. Vertical rows of three coloured jewels fall down. The players cannot rotate them but change their order. When the players form a row of three or more same-coloured jewels, it disappears.

- Dr. Mario (1990) is one of the many puzzle games developed in the 90’s using characters from Super Mario Bros. Here, there are three types of viruses - red, yellow, and blue (or black, white, and grey on the Game Boy) - and three matching colours of pills to fight against them. Each pill is made up of two segments, each containing a single colour; the user must align at least three pill segments in a row next to a virus of the same colour in order to kill the virus and to make it disappear. You can also match four same-coloured pills in a row to make them disappear. When you kill every virus on the screen, you move to the next level. Dr. Mario requires more strategy than Tetris since you will need to think a few steps ahead to solve each level.

- Lemmings (1991) has a very addictive game-play, an ingenious premise and cute graphics. The goal is to guide a pre-defined percentage of lemmings from the entrance to the exit by clearing or creating a safe way. In order to save at least the required number of lemmings, the player must assign skills to a limited number of lemmings, so strategic thinking is needed to succeed.

- Tetris 2 (1994) looks similar to Tetris but instead of completing lines, you must match up blocks based on their colour or shade of grey.

- Puzzle Bobble (1994) is another very popular puzzle game. Players have to remove the coloured bubbles clustered at the top of the screen. At the bottom of the screen there is a randomly coloured bubble, which must be aimed at the cluster. At the bottom of the screen, the player controls a pointer which has to be moved to direct bubbles off the walls, like billiard balls on a pool table. This game is very different from Tetris and also very addictive, although it does not require as much a strategic thinking as other puzzle games.

- Mario's Picross (1995) is a very addictive and easy to learn mix of crossword puzzle and numbers game (see Figure 13). It is played on panels of cells of various sizes with the objective to reveal a picture by filling in squares. On the horizontal and vertical axes there are series of numbers representing the number of squares to be filled in that row or column. To solve a puzzle, the players have to mark a box in a window of varying sizes. Each puzzle has a time limit and the mistakes cost time.
- Polarium (2005) is concentrated on switching the polarity of cells from light to dark and back again. It is very easy to play and also quite addictive (see Figure 14). When you create a horizontal row of one colour, it disappears. The objective is to draw long lines that will create multiple solid lines at the same time, clearing as many lines as possible.

Polarium presents three modes, and for each mode the concept works differently. “Challenge mode” is similar to Tetris, with multiple rows dropping down. “Puzzle mode” is much more interesting. It presents different screen in which puzzles can be eliminated with just one movement. Most of the puzzles are difficult enough to make you think for a while, but if one puzzle is too difficult you can activate a help mode that will show you the starting and ending points for a successful movement, providing a valuable and non-frustrating help. Finally, “Versus mode” lets two players compete against each other. The lines you eliminate are sent to your partner’s screen and the first player to clear the screen wins the match.
- Picross DS (2007) is the second Picross game to be released by Nintendo in Europe and North America after Mario's Picross. Additional modes allow players to create their own puzzles and send them to friends, download classic puzzles and compete in speed competitions with friends. Although their presentations are different, both Picross DS and Mario's Picross are based on Nonograms –also called Paint by Numbers.

For older adults, puzzle games could be enormously interesting since they can train visuospatial skills, visual attention and executive functions in a single procedure. It can also be an interesting method to practice procedural and motor skills related to new devices or novel technological situations for older users.

However, in order to make this possible, we have to take into account that older users are not used to these tasks as younger and middle-aged users may be. Immersion and flow in this kind of games will be different and even harder for elder adults, so more simplistic procedures (e.g. Polarium) should be considered.

### 5.3.2.3 Manipulative and/or mechanic games: Mechanic master

One sub-genre of puzzle games with some interesting applications for older adults is physics simulation puzzles or mechanic puzzles. This kind of computer games is basically inspired by “Goldberg machines”\(^\text{34}\) and The Incredible Machine series are the most representative example of them.

A Goldberg machine is a deliberately over-engineered apparatus that performs a very simple task in a very complicated way, using wheels, gears, cups, handles, rods and so on. Nowadays, Purdue University hosts the annual National Rube Goldberg Machine Contest where a lot of American college students compete to design the most complex machine for tasks such as putting a stamp on an envelope or making a cup of coffee.

\(^{34}\) [http://www.rubegoldberg.com](http://www.rubegoldberg.com)
Strongly inspired by these devices, players of the Incredible Machine (1992) have available different objects from a rope to electrical generators, bowling balls and even cats at their position. The levels usually have some fixed objects that cannot be moved by the player, and so the only way to solve the puzzle is to carefully arrange the given objects around the fixed items. The games simulated not only simulate the physical interactions between objects, but also ambient effects like varying air pressure and gravity.

New versions of the game – such as The Even More Incredible Machine or The Incredible Toon Machine – were updated with new graphics, music, and sounds, but they were quite similar to the anterior game. Only The Incredible Machine: Even More Contraptions included an innovative service allowing players to share their homemade puzzles online. A mobile phone version was made available in 2006. The original game has been announced for a download release for the Xbox 360 via Xbox Live Arcade, but so far no price information has been released.

Mechanic master (2008) is basically a non-official version of the Incredible Machine for Nintendo DS (see Figure 15). Here the Earth has been invaded by aliens and players have to free humans creating platforms using the Goldberg machine technology. It includes both existing levels to solve and a built-in level editor to create and share new problems. Interestingly, the Nintendo DS pencil allows players to draw personal solutions to build platforms, walls or portals.

**Figure 15.** Display from Mechanic Master.

Crazy Machines is another similar PC game including graphical variations and with a recent version for Nintendo DS, Crazy Machines – The Inventor’s Workshop (2008). It includes an Action Mode, where players will have to build their complex contraption while its motor is running. The game is presented by a cartoon inspired by Albert Einstein, which makes...
introductory games more interesting. Unfortunately, the game instructions are designed poorly, with the cartoon saying a lot but explaining very little about playing the game.

Armadillo Run (2006) is an independent game developed and published by Peter Stock. The aim of the game is to get a stylized representation of an Armadillo -basically a yellow basketball like object- to a blue "Interdimensional Portal". Another goal is the creation of a structure similar to Goldberg machines (see Figure 16). Armadillo Run is a 3D game that includes much more simple and attractive graphics, making the game play a kind of virtual Meccano/Lego experience.

Figure 16. Display from Armadillo Run.

Finally, Crayon Physics (2007) is a freeware game whose objective is to guide a ball to a goal point marked by a star. Instead of allocating objects provided by the computer, in this game you draw the lines or objects. A Crayon Physics Deluxe edition has been announced and can be pre-ordered. It will feature more levels, a level editor and, more interestingly, a modification to the physics engine which better preserves drawings made by the gamers.

This kind of games requires visuospatial and creative-thinking skills. Another point of interest in gerontology is its relation to the experience of elder males with manipulative jobs: for this target group, is very difficult to find attractive training tasks.

35 http://www.armadillorun.com
36 http://www.crayonphysics.com
6. MAIN CONCLUSIONS AND IMPLICATIONS FOR GAME DESIGN FROM THE STATE OF THE ART

- Cognitive rehabilitation programs should not be directly adapted to healthy older adults. In concrete, cognitive rehabilitation software revised does not observe suggestions for promoting the state of flow for older players (Gamberini et al., 2006).

- Exceptions in cognitive rehabilitation are those programs addressed to attention, such as Cognmed Working Memory Training. Basic cognitive processes decline with aging because of a slower processing speed in elderly people (Salthouse, 2000). This kind of training could be successfully adapted to computerized games, matching stimulation goals with pleasurably of classical puzzle games.

- Manipulative puzzle games such as Mechanic Masters, which require visuospatial and creative-thinking skills, are a very interesting field of work since their gameplay is related to previous experiences of most of the older adults.

- Commercial games that could be promoted for older adults, especially brain trainers, may have however important problems concerning accessibility and usability. Problems such as the size of the stimulus, the colour contracts or the usage of pencils such as touch devices may be common for older adults playing small portable platforms such as the Nintendo DS. Although some versions of these brain trainers are available for other platforms (e.g. Big Brain Academy for Wii37; Brain Challenge for Xbox, Mind Quiz for Playstation 238), most of the games are developed and commercialized for this kind of platforms.

- The usage of sounds in games for portable platforms is not well suited for the sensory capabilities of older adults. Nevertheless, these parameters could be successfully used for home platforms taking into account developmental changes and lifespan experiences.

- Since motivations and confidence of technology usage and cognitive gaming are both pretty different for older adults, kinds and intensity of feedback given to users have to be cautiously taken into consideration.

7. HERMES COGNITIVE GAMES

The HERMES cognitive training games are based on the data that have been captured during the everyday life of the user and they relate to contextual information. Part of the functionality of the HERMES system is to allow the user to record appointments with his doctor, friends or relatives by using either a keyboard or the integrated automatic speech recognition system. Some of this information is used, later on, for the generation a cognitive game data repository.

38 http://www.us.playstation.com/PSP/Games/Mind_Quiz
The multi-touch interactive surface serves as the main interface for the cognitive training. Games presented below are designed to stimulate memory in a friendly and mostly implicit way, while doing dual tasks based on bilateral hand movements, avoiding frustration of schedule live events. The system of HERMES uses a text-to-speech engine in order to construct special messages that will propose the user to play a cognitive-training game based on everyday agenda of the user.

In this section the HERMES games are described. For the first ones, the ones which are now under development, a description is given. For the followings, a scenario is provided. In this scenario, Maria is the elder person, thinking in the same woman who was described in D2.3.

### 7.1 Match – Maze game

The aim of the game is to match appointment clues (e.g. a Doctor visit) and a time clues (e.g. 10:00am) from two different start points to an appointment sheet. This resides inside a maze and serves as a reaching point.

Users have to move these “clues” along the maze, each clue with a hand (Fig. 17). Using both hands is only possible due to the multi-touch approach. If the user withdraws a hand, the clue returns to the starting point.

Once the user puts the clues inside the Appointment Sheet, a congratulation message is displayed along with the specific appointment information. Another pair of clues is displayed if the user wishes to play again.

Difficulty levels are introduced in the game by accessing various parameters. For instance, the user has to choose two clues, from a larger stack of clues, that are related in order to play the game (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.

In a different mode of the game, a complete appointment card (containing time, content, place and accompanist) appears in a side of the screen and the user has to carry it to a timetable. Although the player may use any hand, the side of the screen where the stimulus appears will determine the hand used for each stimulus. Considering lateralization (right or left-handed), best-preferred hand to be used can be considered a factor that increases difficulty.

In order to demand the use of the two hands both at once, the Appointment Sheet could be in motion, with a faster movement when hand-movements are not being bilateral.
Figure 17. Match – Maze’s sketch.

Table 2. Match – Maze scheme.

<table>
<thead>
<tr>
<th>Prospective memory</th>
<th>Bimanual coordination</th>
<th>Other cognitive function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Stimulus/ appointments</strong></td>
<td><strong>Levels of difficulty</strong></td>
<td><strong>Reinforcement</strong></td>
</tr>
<tr>
<td>- Appointment clues.</td>
<td>- Number of couples of stimuli.</td>
<td>- Clues change in a single appointment.</td>
</tr>
<tr>
<td>- Time clues.</td>
<td>- Complexity of labyrinths.</td>
<td>- Congratulations message</td>
</tr>
</tbody>
</table>

7.2 “Monster” Maze game

An alternative-design / alternative-activity-for-users are the “Monster” Maze. A single complete Appointment card (containing time, content, place and accompanist) appears in a side of the screen and the user has to carry it to a timetable. However, kind of “demon” or “ogre” from the epicentre of the Maze increasingly approach to the appointment, and the user has to drive the “Monster” away of the maze dragging it with the other hand.
The next time that the user will select to play the maze game, the HERMES system, based on the collected cognitive gaming results, will change the mode of Maze game to the “Monster-Maze”. A “monster” object appears on the screen along with the Appointment cards. The user drives the Appointment through the Maze with the right hand, while chasing away the distraction with the left hand. When the Appointment object is placed on the agenda object, the task is accomplished.

Although the player could use any hand, the side of the screen where the stimulus appears will determine the hand used for each stimulus. Considering lateralisation (right or left-handed), best-preferred hand to be used can be considered a difficulty variable. Other dimensions that can be manipulated with regard to difficulty are “Monsters” number and the speed of it/them.

Finally, in order to remark prospective memory practice, the user has to assort the appointment into the timetable. HERMES only shows an ending message (e.g. colouring the area around the appointment) when it is placed at the precise place according to the real sequence.

![Figure 18. Monster-Maze's sketch.](image)

**Table 3. Monster Maze scheme.**

<table>
<thead>
<tr>
<th>MONSTER MAZE</th>
<th><strong>Prospective memory</strong></th>
<th><strong>Bimanual coordination</strong></th>
<th><strong>Other cognitive functions</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Assort the appointment in the timetable.</td>
<td>1. Appointment clues go back when withdraw.</td>
<td>Sustained attention</td>
</tr>
<tr>
<td></td>
<td>- Appointment clues.</td>
<td>2. “Monster” set up the cues.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Speed of their movement.</td>
<td>- Number of “monsters”.</td>
<td></td>
</tr>
</tbody>
</table>

- Reinforcement
  - Appointment area coloured when it is well placed.
7.3 The Restless Puzzle game

The Restless Puzzle uses pictures related to future appointments (e.g. the picture of the users’s son supposing that there is a date scheduled for the next day) already stored at the HERMES database.

The game initially presents a photo album on the multi-touch screen. The user is able to browse among the photos using simple gestures to move, rotate, shrink or magnify the photos. The puzzle game is initiated when the user double-clicks on the photo of his preference. The picture gets fragmented on several pieces that have to be merged in order to complete the puzzle.

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 (rotation) according to the difficulty of the task. Besides the number of pieces, additional difficulty dimensions could be introduced by encapsulating a timer, so that the user has limited time available to complete the task. Additionally, the user could be asked to place as many puzzle pieces as possible at the correct places of the puzzle grid playing against an artificial opponent. The latter scenario is further expanded by giving the ability to the user to play a puzzle game versus multiple remote on-line users of HERMES.

![Figure 19. Restless Puzzle’s sketch.](image)

Table 4. The Restless Puzzle scheme.

<table>
<thead>
<tr>
<th>THE RESTLESS PUZZLE</th>
<th>Prospective memory</th>
<th>Bimanual coordination</th>
<th>Other cognitive functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stimulus/ appointments</td>
<td>Implicit familiarization with info reinforced by feedback</td>
<td>Both hands are needed to pin on and connect the pieces.</td>
<td>Constructive praxis</td>
</tr>
<tr>
<td></td>
<td>Speed of movement.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rotation.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Number of pieces.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reinforcement</td>
<td>Complete appointment shown when puzzle is completed.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
7.4 The (Appointment) Waterfalls game

In this game, the HERMES system asks Maria to group pictures related to close appointments into different categories.

The visual scene behind this task is set as a river with two cascades (left and right in order to encourage bilateral movements). The picture/s fall down through the cascade. Maria has to catch it/them, before it falls down into a lake, and move it/them to one of the vaults-finished points located ashore. The minimum number of vaults will be the number of default categories for an appointment determined by HERMES; the maximum will be determined by the number of person categories introduced to the system and by the practice degree (gaming experience) of the user.

The game reinforces to catch the pictures while they are falling down, making them harder to move (e.g. they need to be touched more than once) when they are floating on the lake. Besides the number of pictures and the speed of the downfall, in an expert mode the picture would sink after a fluctuating latency.

![The Waterfalls game's sketch.](image)

**Figure 20.** The Waterfalls game’s sketch.

<table>
<thead>
<tr>
<th>Prospective memory</th>
<th>Bimanual coordination</th>
<th>Other cognitive functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Implicit familiarization with info reinforced by feedback</td>
<td>Bilateral hand movement is needed to catch pictures while they are falling.</td>
<td>Divided attention</td>
</tr>
<tr>
<td><strong>Stimulus/ appointments</strong></td>
<td><strong>Levels of difficulty</strong></td>
<td><strong>Reinforcement</strong></td>
</tr>
<tr>
<td>Pictures related to appointments.</td>
<td>- Speed of presentation of pictures.</td>
<td>Complete appointment shown when picture is into the correct vault.</td>
</tr>
<tr>
<td>- Speed of falling down.</td>
<td>- Number of vaults.</td>
<td></td>
</tr>
</tbody>
</table>

**Table 5.** The Waterfalls scheme.
When the user categorizes the pictures accurately, the waterfall stops and the pictures turn around showing the text with the complete appointment.

### 7.5 The Savage Garden game

HERMES asks Maria: “Would you like to train your memory and keep in mind appointments for tomorrow with HERMES?” If she presses the Yes option, a scenario appears with some pictures related to the near-future appointments are shown (e.g. the Hospital, the Church and the Post Office; or the Doctor, the Priest and the Postman). After a variable delay in time the picture goes into hiding in a background scene representing a wood/jungle/kitchen garden consisting of leaves, plants and branches which can be moved with both hands.

Afterwards, HERMES asks Maria about the appointments (e.g. “Where are you going at 18:00 p.m.?” or “Who are you visiting at the Hospital?”) and Maria has to look for the appointment by touching the pictures, whose content is hidden but can be easily located (e.g. a corner of the picture is shown).

![Figure 21. The Savage Garden game's sketch.](image)

When the right picture is found, a congratulation message is displayed. This message will be catching and complete –containing the complete information of the appointment. A lack of hits is not penalized, but because the course of time makes the tasks harder, some kind of priming effect could be observed.
### D.6.1 Cognitive Training Exercises

#### THE SAVAGE GARDEN

<table>
<thead>
<tr>
<th>Prospective memory</th>
<th>Bimanual coordination</th>
<th>Other cognitive functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Review info.</td>
<td>Draw away leaves, plants, trees and so on.</td>
<td>Working memory</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Levels of difficulty</th>
<th>Reinforcement</th>
</tr>
</thead>
</table>
| Pictures related to appointments. | - Time to go into hiding. | Complete card with picture and appointment cues are shown.  
| to       | - Number of stimulus. |               |
|          | - Vegetation density. |               |

### 7.6. My who is who

During the last days Maria has experienced a lot of memory failures related to people’s names. For example, this evening she was walking around with her friend when she forgot the name of her doctor. She feels very bad in these situations because she knows the name, but she just cannot say it. So when HERMES asks her if she wants to play some HERMES cognitive games, she selects the game called “My Who is Who”.

In this game, two pictures of two different persons from Maria’s database appear on the screen along with the cards containing their personal information, e.g. family names, surnames, occupations and so on. Maria has to drag and drop the cards besides the right picture. She likes this game because she feels involved in it, like a participant in a TV quiz, so she can test her knowledge about her acquaintances without those annoying feelings of blocking with proper names.

**Table 7. My Who is Who scheme**

<table>
<thead>
<tr>
<th>Prospective memory</th>
<th>Bimanual coordination</th>
<th>Other cognitive functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>People close to Maria</td>
<td>Drag &amp; drop.</td>
<td>Bottom-up lexical access stimulation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stimulus</th>
<th>Levels of difficulty</th>
<th>Reinforcement</th>
</tr>
</thead>
</table>
| - People’s pictures introduced into the system by Maria. | Numbers of pictures/persons | Block-free access to names.  
| - Famous people’s picture (optional). | | |
| - Cards with personal information. | | |

At the end of this part of the game, HERMES asks Maria: “Well Maria, do you know these two person’s names already? Please type them”. If Maria knows the names after the game, which is very expected for healthy older adults, HERMES congratulates and proposes her to play one more time: “Congratulations Maria! As you have just seen, when you think on what you know about people, retrieving their names is much easier. Now, would you like to play with three persons?” Simultaneously, three pictures are shown on the screen, clearly indicating an increase in difficulty level. Because Maria feels pretty empowered, she selects the “Yes” option on the multi-touch screen and the game starts again in a bit more difficult mode.

If Maria does not know the required name, HERMES gives her some clues: “Well Maria, do not worry. I am going to give you some clues. The first letter of the name of the girl who is at the right side is N. Do you know her name?” HERMES gives as many clues as required for Maria in order to guess the right names.
7.6 Visual routines game

The first time this game is played, HERMES asks Maria where she usually puts common objects such as her keys, her glasses, her wallet and so on. She has to answer both verbally and later, by touching the according places in a 3D map of her home, dragging each object and dropping it in a proper location on a 3D map of her home.

Afterwards, the game starts by displaying the map of Maria’s home on the screen, with the three objects easily perceivable. Unfortunately, three “demons” very similar to those seen in the Monster-Maze game take the objects away from their correct locations. This is the Monster stage and Maria has to touch the objects and drop them back to their original locations, which is not so easy because there are three monsters and Maria has only two hands!

From time to time, the game stops and a relaxation stage starts. No monsters are presented, but this stage is not so relaxing after all: different kinds of common objects from the HERMES database are displayed. Maria has to touch the keys, the glasses and the wallets and put them in a safe place while she has to ignore the rest of the objects (watches, bracelets, etc.).

After the relaxation stage, the objects are not directly displayed on the map where Maria was playing. She has to remember the last position where she saw. If the place is correct, the game re-starts. If the place is wrong, the game also re-starts but HERMES shows a card to Maria: “You should put more ATTENTION on where your belongings are in order to find them!”

Table 8. Visual routines scheme

<table>
<thead>
<tr>
<th>Visual routines</th>
<th>Prospective memory</th>
<th>Bimanual coordination</th>
<th>Other functions</th>
<th>cognitive</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Every time Maria plays the “visual routine” game, the system asks her about any change in the location of the objects and checks some locations on the map before starting the game. HERMES also asks her if she wants to include more common objects, shown on the screen of the HERMES database.

When Maria agrees, she has to select the object she wants to include and place it on the map. The new item is included in the Monsters stage and also in the Relaxation stage as a target object to be touched.
8. HERMES COGNITIVE GAMES FEATURES

8.1 How do these games assess and train the cognition processes?

Basic design rules followed in the HERMES games development are:

1. If a dual task is presented, it must invoke different cognitive processes. As indicated in chapter 3, research has shown a significant age-related decline in dual processing, which will increase frustration and decrease motivation in game performance.

2. Information cannot create confusion nor interference between different sets of information that otherwise are correct. For example, you cannot mix information about two different appointments in one item; the user can get confused and involuntarily mix them in his memory. As indicated in chapter 3, inhibitory processing declines with aging, so item presentations should be clear enough to avoid confusion.

3. The cognitive games cannot include wrong information. To this end, the general cognitive theory or framework chosen for designing HERMES games is the Errorless Learning theories.

Errorless Learning favours the elimination or reduction of incorrect or inappropriate responses when users are receiving memory training, avoiding both frustration and interferences of materials to be remembered (Grandmaison & Simard, 2003). The occurrence of errors during the learning of new episodic information interferes with the encoding of accurate information, resulting in a lowered memory performance for young as well as older people. In contrast, elimination of errors during learning is effective for improving the memory functions for healthy subjects in general, including older adults (Kessels & De Haan, 2003).

In parallel to the training of user’s cognitive abilities, HERMES will explain to the user which cognitive capacity is exercising in that game and the reason because of is useful to train that cognitive process (IJsselsteijn, Nap, de Kort, & Poels, 2007). This explanation is a way to improve the motivational factors, since the user can observe the transference to play from this game to his real daily life.

One example of this explanation could be as follows:

“This game trains your prospective memory.” (next screen)

“Prospective memory is the capacity you use when you have to remember doing something in the future.” (next screen)

“When you go to the doctor and he tells you that you should come back in one moth, the ability to remember this is called prospective memory.” (next screen)

“Do you want to play a game for training your prospective memory?” (select “Yes, go to the game” or “I will play later, show my other options”)

[Page 58]
In successive sessions the avatar of the HERMES games will give the user feedback about his previous performance because of motivational reasons. Regarding the importance of keeping older adults engaged and interested in cognitive games, feedback is to be provided by the system and will be one of the key aspects to ask potential users in future focus groups and user trials. Compared to available commercial games which provide an estimated “mental age” index, we expect that the HERMES system will take a more comprehensive approach on feedback (closer to Brain Boost’s tree which grows up and blossoms related to performance than to Brain Training, Mind Quiz or Flash Focus strategies).

One example of feedback of the user’s previous performance could be as follows:

“Maria, last time you played the Maze game, you were playing the second level and you completed it very well.” (next screen)

“What do you think about playing the next level? It will be more challenging for you!” (select “Yes, I want to play the next level” or “No, I want to play my current level one more time”).

8.2. How do these games assess the user’s cognitive abilities?

It has been pointed out in the “Introduction to cognitive training” section that cognitive training has to be adapted to cognitive abilities of the potential user, being challenging enough to promote flow (Bernhaupt, IJsselsteijn, Mueller, Tscheligi, & Wixon, 2008) but also not too difficult to promote frustration. In this regard, HERMES cognitive games will specifically assess the initial state of the user’s cognition concerning concrete areas to be stimulated by the games to be played during the session. This could be done by:

- An Introductory Game addressed to obtaining information about the level that the user should start in. When the user wants to train the attention ability, the first thing he has to do is to play the game which stimulates this function but with the aim of playing it in his current adequate level.
- A Trial Phase, such as those included in commercial games currently available.
- Both “Trial Phase” and “Introductory Game”, plus interactive measurement of the system through the game session.

Regarding the importance of adjustment to the cognitive status of the user, cognitive estimation is to be provided by the system and will be another key question to be asked to potential user in future focus groups and user trials.

8.3. Levels of difficulty

As it has already been stated, while elderly user’s cognitive aging is normal, the games should be difficult and must imply a challenge for them, otherwise the aim of improving the user’s cognitive abilities will not be achieved.

Adapting the level of difficulty is a way to continue the cognitive training if the user starts a declining process. In this case, the games will decrease the level of difficulty and the user will be able to keep on playing (Yanguas et al., 2006). According to this major theoretical and
practical issue, four ways of manipulating the game’s difficulty have been designed and will be implemented: times, level choose, stimulus complexity and on-line gaming.

8.3.1. Time

The game can change depending on the maximum time the user can spend for finishing it. For the first few times, when the user plays the game, he will have unlimited time for playing. The following times, the maximum time can be set (e.g. three minutes for completing the exercise). The faster the user completes the exercise, the better score he receives (e.g. if the player spends two minutes he will receive two extra points, but if he spends one minute he will obtain four extra points). If the user needs more than three minutes for finishing the exercise, no extra points will be given. So there are two criteria for obtaining the points: (1) the accuracy or right answers to the exercise; (2) the time required for completing it. If one person exceeds the maximum time, the exercise continues but he does not receive the extra points for time, but it is still to obtain the points for accuracy. Anyway, the user can stop the game whenever he wants by pressing a button created for this end. This system promotes a dynamic balance between time and accuracy in user’s performance. It will provide the opportunity to balance processing and cognitive strategies (frequently, older adults are too conservative and tasks take them too long).

8.3.2. Level the user chooses

When the user selects a game to play, the first question he has to answer is the level which he wants to play. Three levels are defined: easy, moderate and difficult, and he can dynamically change from one to another level. This feature of HERMES games increments the user’s control feelings. It allows users to play according to his mood and cognitive state, e.g. one day Maria is tired and she wants to play the easy level. The defined difficulty levels are only guidance. HERMES will adapt stimuli presentation in order to provide a stimulating, not too difficult gaming experience. In this regard, levels will be based on the previous cognitive assessment.

8.3.3. Stimulus complexity: number of stimuli

In each game the number of stimuli can be incremented, and therefore the difficulty level increases. For example, if the number of people’s faces increases in the My Who is Who game, the difficulty is also higher.

Other games can also be increased in the level of the difficulty by increasing their structure. For example, in the Maze Game, the complexity of the labyrinths can be manipulated.

8.3.4. On-line games: against other players

If the user plays either against other players or against the “HERMES player”, the difficulty also increases because the user has to be a better a player than his opponent. Hence, playing online not only has social and motivational benefits (Gamberini et al. 2006) but also cognitive benefits from competitive insights.

8.4. Assessment of these games in the first user trial
The development and implementation phases will be considered when defining the game requirements. The developed games will be tested in three different phases:

In the first phase, an expert group composed by 6 neuropsychologist from Matia Foundation was invited to a focus group session in order to provide their opinion on cognitive games in general, and on HERMES cognitive games in particular. They work in gerontological centres, day-care centres, centres for disable people and at Matia’s outpatient department. Their professional roles include to test cognitive function (neuropsychological assessment) and to program cognitive stimulation activities.

This professional group emphasizes the relevance of:

- To include materials related to user’s daily life. These professionals have to adapt stimuli to their patients for daily stimulation activities. In this regard, they pointed out that the HERMES system will be useful even for their own stimulation programs at centres for disabled people.
- To ensure that the system is easy to use and easy to install.
- To make explicit which cognitive process is being stimulated promotes sense of safeness in older gamers. It is also relevant because it could have a pedagogical aim, educating older adults about age-related cognitive changes and the way for coping them.
- Difficulty of the games would include time, level choose, stimuli complexity, number of intrusions and speed.
- Feedback provided to the users should include both score and more graphical representations. Aggressive feedback, such as “Mental age” scores, should be avoided.
- Concrete suggestions about the game proposed (e.g. to use a city map in the maze games in order to stimulate orientation).

Similar to an external committee two or three of them will assess each game developed before starting the technological implementation and also afterwards. The information recollected in this process, as well as a detailed explanation of the expert focus group, will be included in Deliverable D6.2.

In the second phase, the user-target group (composed by seven elderly people) was invited to assess the games’ usability and subjective value by means of a focus group. Exploration of both gaming experience (W. IJsselsteijn, de Kort, Poels, Jurgenlions, & Bellotti, 2007) and assessment tools (W. A. IJsselsteijn, de Kort, & Poels) were observed.

In the assessment of the games’ usability and their subjective value, the focus group can show priorities, interests, motivations or anxieties, as well as to identify potential steps on efficacy assessment and new scenarios for potential developments. The group was asked about gaming experiences and/or motivations for playing games. The topics of the focus group were:

1. Interest and motivations for cognitive games.
   - Are they gamers? Why (or why not)?
   - Which are the motivations to play (or not to play) cognitive games / brain trainers?
   - In which situations do you start / would you start to play video games?
   - Which changes on personal circumstances will be necessary for non-gamers / older adults to become gamers?
2. Game features
   - Which changes on device features will be necessary for non-gamers / older adults to become gamers?
D.6.1 Cognitive Training Exercises

- How do they think the games should be constructed in order to adapt the difficulty to the older adult’s cognitive status?
- Which kind of feedback would they prefer about your performance on cognitive games (direct scoring, estimated mental age, others)?

3. Social concerns
- Do you think cognitive games could have implications on social life?
- Would online gaming increase your interest in cognitive games?
- Do you think you would play cognitive games with other adults using a shared-device created ad hoc?
- Do you think you would play cognitive games with children (e.g. grandchildren) using a shared device?

The main results of this focus group were:
- Two out of seven people play video games in their personal computer.
- The main reason they do not play is because of the video games are very difficult and fast and their movements are slower than younger people.
- Their reasons and greatest benefits to play to video games are to train their cognitive capabilities and also personal satisfaction and entertainment.
- Only one of the participants plays on line.
- They think some changes are necessary to adapt the computer games to their needs and characteristics (e.g. poor vision, movements, etc.).
- They propose easy games which include a scale complexity, and a demo program to start playing.
- They feel frustrated when they cannot reach the highest level of the difficulty in the game.
- Most of them preferred the intellectual games and they do not like violent games at all.
- The participants think that give a score at the end of the game can be interesting. But they do not want to receive their “brain age” as some of the current games do.
- With respect to the social concerns they think that the more video games they play the less social life they have. However, one participant thinks that to play on line can promote the relationships.
- About HERMES games, the most preferred games are the Maze Game, and the Monsters Maze Game. The participants think that these are very interesting and entertaining games and also recognized that can help them to stimulate their cognitive skills.
- According to the participants in this group, My Who is Who game is the most useful one because helps them to remember people’s name.

Finally, the efficacy of these games will be tested in a third phase using prototypes of the games and the devices developed during the HERMES Project. The way in which the games will be tested during the first user prototype testing phase has already been explained in D7.1.

It would be very interesting to assess the efficacy of the games in the improvement of the cognitive functions. That means, if there is a statistical significant change in the cognitive function after playing with the games of HERMES. However, due to the design of the HERMES project, this objective is not possible. In order to assess the efficacy of a cognitive program, it is necessary to maintain the program for about six months with certain regularity (playing once or twice a week, every week). The HERMES user trials are addressing the testing of the general idea of the cognitive games and the other features of HERMES (MyPast, MyFuture, etc.). Besides this, it is highly recommended that a significant group of participants follows the
program, since only ten participants are not enough to affirm that these games are useful for all the elderly users.

The objective aspects of the evaluation of the HERMES games, the game experience will be also assessed through the Game Experience Questionnaire (GEC) (IJsselsteijn, de Kort, & Poels). This is an assessment tool developed by IJsselsteijn, de Kort and Poels (in preparation) from the Eindhoven University of Technology, within the FUGA – Fun of Gaming project that is co-founded by the European Union. It measures game experiences in components such as immersion, flow, competence, positive and negative affect, tension, and challenge. It also allows to measure the involvement of the player with other social entities (others playing online, virtual in-game characters) as well as the feelings that the gamer experienced after the end of the game. Specifically, these parts of the questionnaire are the following:

- **Core module**, measures seven components: Immersion, Flow, Competence, Positive and Negative Affect, Tension, and Challenge.
- **In-game GEQ**, concise version of the Core Module.
- **GEQ – Social Presence module**, measures the contact with other social entities (virtual, mediated, playing online or co-located).
- **GEQ – Post-game module**, measures how the player felt.

As the Spanish version of this questionnaire was not validated, a validation process was carried out at Ingema. The first step consisted in 11 young adults (8 women and 3 men) aged ranging from 25 to 38 years, answering a Spanish draft version of the questionnaire. All of them had university education and had played video-games before, but they were not hardcore gamers. For example, one reported to be only social gamer, playing video games only when he visits his cousins. Two persons reported to having been hardcore gamers in the past, playing daily and with a high level of involvement.

They sent the responses in an electronic format including comments about the questionnaire if they felt the need to express some concern about it. Then, six out of the eleven participants assisted to a group session aimed to explain and discuss the questionnaire. From their responses, some conclusions have been extracted:

- Depending on the kind of game, different items are more or less relevant to describe the game experience. One participant suggested that it could be good to specify different versions of the Questionnaire according to different sorts of games.

- For games such as brain trainers and puzzle games, the questionnaire is too long and a lot of items are not applicable. One participant pointed out that most of the feelings described are only applicable to more complicated games with more elaborated stories.

- Depending on the kind of gamers, feelings and experiences described should be interpreted in very different ways.
  - For some occasional gamers, items such as “I felt happy” or “I felt guilty” sounded too extreme. Nevertheless, more habitual gamers pointed out that both losing your time and virtually damaging somebody could make you feel guilty while you are playing. These feelings would depend on the kind of game you are playing.
The suitability of the response scale may also change depending on the kind of games studied and the kind of gamers selected. Extreme values, especially 4, are more suitable for hardcore gamers and role playing games. For occasional players and/or simpler games, a simpler response scale could be better.

In the Social Presence Module, one participant wondered which kind of social situation we are interested in. Depending on the nature of the social interaction, items are easily applicable or not. A “Non-Applicable” box could be included in the scale for these items.

Both occasional and habitual gamers agreed that the item “I felt revived” is too extreme. The idea expressed by the authors may not be applicable to the Spanish culture. The same is applicable to other items.
9. TECHNICAL IMPLEMENTATION IN THE MULTI-TOUCH SCREEN

At this section the software platform developed to support the cognitive training games is described. Software entities have been separated in order to distribute tasks end increase future expandability. As shown in the following picture, the software platform is distributed in three layers. The ‘Finger Tracker’ that processes the input from the multi-touch device, the “Communication Server” that delivers gesture information from the Finger Tracker to the application layer and the Client which represents the cognitive games.

![Software Platform Diagram]

**Figure 23.** The software platform.

9.1 Finger Tracker

The interactive surface designed yields very good quality images of the moving fingertips, hence a simple contact-based tracker is utilized for propagating the location of the fingertips across time. According to this approach, the evidence (frames from the NIR camera) is processed to extract the objects to track. We hence avoid the more elaborate approach of likelihood tracking. We initiate a Kalman filter per detected fingertip, hence handling each fingertip independently, avoiding the complexity of joint target tracking. The images captured from the NIR camera are binarized using a constant threshold. The resulting active pixels are grouped into objects using 4-way connectivity. These objects are the pool of two types of contacts: those used for track initialization, and those used at the measurement update stage of the Kalman tracker(s). The initialization contacts are selected based on strict size and aspect
ratio criteria. This minimizes false positives, at the risk of delaying the initialization of a track in two cases: when originally a fingertip touches the surface too lightly (small object size) or more than the fingertip touches the surface producing elongated objects (large object aspect ratio). The measurement update contacts are selected using more relaxed size and aspect ratio criteria. This is safe as these contacts do not generate false positives and on the other hand facilitate the maintenance of an existing track should the fingertip temporarily produce erratic objects on the frames.

During the tracking cycle, every Kalman filter first updates the state of all targets based on a constant velocity model. The states comprise of two-dimensional position and velocity. Consequently, all the updated states are associated to measurement update contacts using an optimal greedy algorithm, the Hungarian (or Munkres) algorithm, which minimizes the overall Euclidean distance between the targets and the contacts. The associated contacts are used for the measurement update stage of the Kalman filters. Any states without contacts associated to them are kept active using the constant velocity updates for up to a third of the second. If in that interval there is no association, the track is terminated. The associated measurement update contacts are then removed from the pool of objects and the initialization contacts are selected from the remaining objects using the stricter criteria.

These initialize new Kalman filters with a unique track ID. At every frame, the fingertip tracking system reports the IDs and the positions of all active tracks (fingertips). The tracking system is very fast; 300 frames can be processed per second on a 2.5 GHz Intel Penryn processor. Typical tracks from the system are shown in following picture. IPP and OvenCV have been used in order to optimize the performance of the tracker software. The coordinates of each fingertip are communicated to the server following TUIO (A Protocol for Tangible User Interfaces) protocol standards.

![Figure 24. Tracks from the Tracking System](image)

TUIO is an open framework that defines a common protocol and API for tangible multi-touch surfaces. The TUIO protocol allows the transmission of an abstract description of interactive surfaces, including touch events and tangible object states. This protocol encodes control data from the tracker application and sends it to any client application that is capable of decoding the protocol. There exists a growing number of TUIO enabled tracker applications and TUIO client libraries for various programming environments, as well as applications that support the protocol. This combination of TUIO trackers, protocol and client implementations allow the rapid development of table based tangible multi-touch interfaces. TUIO has been mainly designed as an abstraction for interactive surfaces, but also has been used in many other related application areas. Technically TUIO is based on Open Sound Control - OSC an emerging
standard for interactive environments not only limited to musical instrument control - and can be therefore easily implemented on any platform that supports OSC.

9.2 Communication Server

The Communication server implemented as part of the software platform is based on the FLOSC Java built server that can communicate with anything that uses the Open Sound Control protocol. The server sends and receives OSC packets via UDP, translates bidirectionally between binary OSC packets and an XML encoding of OSC packets, and sends and receives XML entities via TCP in a way that’s compatible with Flash’s XMLSocket feature.

The communication Server acts as a gateway between OSC and Flash, allowing messages to go in both directions. It can accept simultaneous input from multiple OSC connections and Flash clients, and can broadcast messages to multiple Flash clients. This enables for development of networked cognitive games that give the ability to HERMES users to interact with each other through multiplayer cognitive games.

![Figure 25. The communication server](image)

9.3 Client Applications

The client applications developed (cognitive training games) are based on the TUIO decoding framework that is implemented in Actionscript 3.0 by NUI Group (Natural User Interface Group) modified accordingly to support the different needs of each cognitive training game (different gestures, multiplayer option, communication with the central database of HERMES system).

The game applications have been also developed using Actionscript 3.0 and Adobe Flash framework. User data that is used to support the cognitive nature of the games is retrieved from the HERMES data base using XMLSockets and php.
10. CONCLUSIONS

In general, the cognitive functions of elderly people remain at acceptable levels. However, to train and stimulate these functions is one of the requirements to achieve a successful ageing. There is a lot of empirical evidence that supports the efficacy of the cognitive training. That means, people who train their cognitive functions can improve their cognitive performance.

The majority of the training programs have been based in paper and pencil exercises. But the new technologies allow another kind of stimulation more individualized. In fact, the cognitive stimulation programs by computer have experienced a growth in the last years. Some of these programs are directed for elderly people. But not all of them take into account the cognitive age-related changes in this population. For example, some of these programs do not train the cognitive abilities which started a little decline; do not have an intuitive interface, etc. On the other hand, a very few programs have tested their efficacy.

The HERMES project provides an integrative approach to cognitive care with the aim of to reduce the age-related decline of cognitive capabilities. The HERMES games have been designed based on the current state of the art in this field. That means, we have tried: (a) to incorporate the main advantages of the other games into the HERMES games (e.g. an avatar explains the game); and (b) to avoid the fails found in other games (e.g. difficult words to understand for elderly people).

As a result, some games have been defined and developed. The games presented in this deliverable are mainly directed to the training of the prospective memory but also to address the needs found in the user’s requirements phase (e.g. the elderly’s complaint about the difficulty for recalling a person’s name in some circumstances).

As seen before, some of the main advantages of the HERMES cognitive games are the following:

- HERMES games use significant information for the user because this information is captured by means of audio and video from their own life.
- Errorless learning approach. As far as we know, there is no another computerized cognitive training program which use this approach.
- Multi-touch interaction with the entire hands instead of a pen. The multi-touch screen allows the user to play games in which the bimanual coordination and dual tasks are trained.
- Intuitive interface which incorporates a big screen, with large fonts, etc. These features are implemented thinking in people with sensory deficits, very common in elderly people.
- HERMES games take into account and promote the game experiences components such as immersion, flow, etc.

Finally, the HERMES games have been assessed by both, professionals in the field of the stimulation of the elderly people, and by elderly people. The two groups have proposed interesting improvements for these games that will be taken into account, but they perceived the HERMES games as useful and easy to understand and play to them.
The work in the cognitive games in this project continues and the following step will be to assess these games in the first user trial and to continue developing them.
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REFERENCES


