Cognitive Games for Healthy Elderly People in a Multitouch Screen

David Facal
Fundación INGEMA
dfacal@fmatia.net

Mari Feli González
Fundación INGEMA
fgonzalez@fmatia.net

Valeria Martínez
Fundación INGEMA
vmartinez@fmatia.net

Cristina Buiza
Fundación INGEMA
cbuiza@fmatia.net

Fotis Talantzis
Athens Information Technology – AIT
fota@ait.edu.gr

Theodore Petsatodis
Athens Information Technology- AIT
tpet@ait.edu.gr

John Soldatos
Athens Information Technology-AIT
jsol@ait.edu.gr

Elena Urdaneta
Fundación INGEMA
eurdaneta@fmatia.net

José Javier Yanguas
Fundación INGEMA
jyanguas@fmatia.net

Abstract

This paper shows the work carried out to develop cognitive training for healthy older adults based on the use of an integrated system of cognitive care. Aging produces changes on prospective memory, visual attention and bimanual coordination among other cognitive processes. For this reason HERMES Project seeks to reduce or to delay the normal cognitive decline that takes place in the elderly through active stimulation their memory. Besides, it has been developed considering the needs of older adults collected through a wide range of questionnaires, interviews, cultural probes and so on.

Cognitive games of the HERMES Project have been built to promote the autonomy and independence of the user, sense of control and flow in the games. For these games, a novel, ergonomic and motivating multi-touch interface is employed, which is in-line with the recent wave of surface computing applications.

1. Introduction.

The growth and expansion of communication technologies that have taken place on these years have given new opportunities on leisure and social activities for healthy older adults. An increasing number of studies are searching for applications and relevance of these opportunities on daily life [1, 2]

Rising life expectancy brings both challenges and opportunities in order to maximize the degree of social participation and quality of life in the whole life-span[3]. Elderly people present a series of specific needs, that will be developed deeply on section 2, and include the relevance that has for them the active behaviours on health and well-being [4]. Intellectual activity has been a relevant topic both on active aging and on cognitive stimulation scientific research. In fact, one of the findings of this study, and as previous research as set up, elderly people reported that they perceived the preservation of cognitive function as the most needful requirement for an independent living and for maintaining the security status in their houses [5].

HERMES Project is developed to provide assistance and support to healthy older adults, and its aim is to reduce the cognitive decline associated with age and thus also reduce the need for caring. It provides assistance to promote the users' autonomy and independence.

Five objectives can be distinguished:

a) Facilitation of episodic memory: in age related cognitive decline, episodic memory may show lapses, and details of the past events can be lost. HERMES will be able to capture information in audio and video, including talks, images and information on the context.

b) Cognitive training: several studies have proved that cognitive training is effective in order to maintain and to promote cognitive abilities in elderly people. The exercises in HERMES are based on material extracted from the daily life of the user.

c) Advanced activity reminding: prospective memory is the ability to remind things than should be done in the future. HERMES provides reminders through audio and visual patterns, which can be used together or separately according to the context.

d) Conversation support: The impairment of short-term memory can cause difficulties in communication with others. This system analyzes the conversation, recordings of important moments in everyday life and this information can be used in the future in order to support the conversations.

e) Mobility support: HERMES has two independent hardware components, one represented as a mobile device and the other as a home-based computer that gives support on the mobility.

As it can be seen in the objectives, a key aspect of the project is that the materials that will provide give content to different tasks and activities of the cognitive games will be taken from the daily life of the user.

HERMES will employ pervasive technology aiming at developing assistive system that will be as non obtrusive as possible. In order to achieve these five objectives, the first step in HERMES Project was to collect the elderly people's needs in their daily living and their preferences about the use and appearance of the new technologies. The aim of this first step was to guarantee that the final system will cover their needs and will be used by the target group due to its accessibility and for being ease to use. For this purpose an extensive methodology was administered to a wide amount of elderly people in Spain, Greece and Austria. This methodology was composed of questionnaires, interviews, cultural probes, diaries, a focus group and an objective and subjective memory assessment in which qualitative and quantitative approaches were taken into account. After administering this methodology, some conclusions that help to establish the basis of the system were drawn. The most important ones, regarding the cognitive games, were:

- They are reluctant to any technology that aims to reduce their autonomy or minimize their cognitive or functional effort, because it would mean dependency [5]. 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.
- Older adults do appreciate and need interaction with other people, so HERMES should provide a way for different users to play cognitive games and share information on-line. This recommendation is not applied for the first game but will be followed in the next cognitive games.
- In the memory assessment, working memory was the capacity that showed the lowest scores. This capacity is related with the immediate auditory processes, that means the information that they have to recall immediately after its presentation is worse remembered than the information they have to recall a few time later. 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.
- 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.

In Section 2, specific characteristics of older adults will be discussed, with special attention on cognitive aging. Section 3 describes the development of cognitive games based on HERMES System. In Section 4, the implementation of the multi-touch interface is illustrated from a technical perspective. Finally, section 5 addresses conclusions and future work concerns.

2. Cognitive and sensorimotor aging.

Aging produces changes on cognitive functioning, associated to both Central Nervous System and sensory-motor functions changes[6]. Related with cognitive aging, probably, the best known age-related changes are those produced in memory. The general concept of memory, including ability to store, retain, and subsequently retrieve information, is a general system which comprises different subsystems with different age-related effects. Attending to temporal organization of the information, division between retrospective and prospective memory has often been used on scientific research.

Retrospective memory is also commonly divided, attending to information to be stored and retrieved, into semantic and episodic memory. Strong evidence has been found about conservation of semantic memory on aging, which means conservation of the general knowledge acquired through the lifetime of learning [7]. In the opposite direction, episodic memory, which implies the memory of events that can be explicitly stated such as times or places, declines with aging [8].

On the other side, prospective memory goes beyond the traditional idea of memory. It refers to the ability to become aware of previous plans and executing it at the right time and place [9]. Recent research and reviews point out the variability of age-related declines on prospective memory regarding test setting and sub-domains [10]. Using meta-analysis Uttl in 2008, observes age-significant declines in: a) proper prospective memory, which implies the awareness of previous plans mentioned above, and also in; b) vigilance, in which plans remain on consciousness; significant differences were not found in; c) habitual prospective memory, in which the plan has to be brought back to consciousness repeatedly as long as the cue is presented.

On natural settings, age declines are weaker than in laboratory, probably because of contextual information available on daily routines [10]. Older adults can compensate processing decline using the information displayed by their own context in a more explicit and efficient way. It is also common an increase in the usage of external devices used as mnemonic helps, such as calendars or agendas [5].

About sensory functions, vision changes in normal aging include reduction of acuity -decrease of the ability to see well-, reduction of pupil size and pupil agility -as a result, response to light are slower-, corneas thickness increase -demanding better illumination conditions- and also reduction of retina’s sensitivity [11]. These age-related changes in vision make much more difficult to read computer or TV screens. In this sense, reduced sensibility to contrast -light/dark differences- and perception of colour are especially relevant.

Older adults are slower than younger performing visual searches, which affects performance related to screen usage. The concept of visual attention is the mechanism through which some items in the visual field are selected while others are not [12]. Older adults typically show declines on simple visual-search tasks; in more complex top-down processes the slope between reaction time and complexity of stimulus is not so consistently higher for older adults than for younger adults [13].

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 [14]. 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 older adults, but only for those tasks that activate multiple stimuli.

About motor functions, it is well known that motor skills decline with age because both osteo-muscular and cognitive-control abilities change. Older adults 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 [15]. Significant differences have been found between fine and gross motor skills, with lower gains in older adult for fine-motor tasks.

Interestingly, bimanual coordination has been found to be maintained in older compared to younger adults, particularly for simultaneous mirror-image moving called “in-phase” [16]. Older adults maintain this level of bimanual coordination increasing access to attention resources.

3. HERMES System cognitive games.

Cognitive stimulation programs, games, puzzles, computer programs, memory training groups and entertaining games in these areas are increasingly common for elderly people in their daily lives. All these games take advantage of what playing represents to engage older users cognitively and socially [17]. In order to achieve a successful development of HERMES System cognitive games, an exhaustive work has been done including: a) a widespread state of the art revision in order to detect: a1) scientific information about pedagogic, cognition, emotion and play knowledge about cognitive gaming; and a2) commercially available games targeted, at least at part, to elderly people; and also b) an empirical study on the preferences of older potential users [5].

Cognitive games should be based on Errorless Learning theories and adapt gaming to cognitive levels of the users. Errorless Learning favours the elimination or reduction of incorrect or inappropriate responses when users are receiving memory training, avoiding both frustration and interferences on materials to be remembered [18].

The occurrence of errors during learning of new episodic information interferes with the encoding of accurate information, resulting in a lowered memory performance in young as well as older people. In contrast, elimination of errors during learning is effective in improving the memory functions in healthy subjects in general, including older adults [19]

Cognitive rehabilitation programs have experienced an important development [20], which has conducted to apply them to healthy older adults. Nevertheless, this kind of programmes is not directly adapted to healthy older population since with this population computer gaming aim is more entertainment than therapy. In concrete, cognitive rehabilitation software revised does not observe suggestions on promoting flow in older players [17]. One exception about cognitive rehabilitation could be those programs addressed to attention, such as Cogmed Working Memory Training [21]. This kind of training could be successfully adapted to computerized games, keeping stimulation goals, by maintaining the attractiveness of classical puzzle games on tasks best suited for older adults.

On the other hand, commercial games that could be targeted to older adults -especially brain trainers and puzzle games- have important deficits on accessibility and usability. Common problems in older adults playing with small portable platforms are the size of the stimuli, the colour contrasts and also the use of very small pencils-like stylus. Additionally, the employment of sounds on games for portable platforms are not well suited for older adults' sensory capabilities. These parameters could be successfully used on home platforms taking into account developmental changes and lifespan experiences.

Finally, older adults themselves have emphasized that cognitive training support is very much welcomed, in the sense that enhances their sense to be active, independence and perceived control [5]. Most of the elderly are doing some forms of cognitive training –memory training courses, crossword puzzles, Sudoku, chess, card games and so on- and they are interested in the technology as long as making use of it do not reduce their autonomy nor minimize their cognitive effort.

Taking into account these considerations, HERMES concept of cognitive games is thought:

1. To have an empirical basis from scientific research, especially on interests and motivations of older adults about computerized gaming.
2. To result easy to use, being both simple and designed taking into account cognitive changes [22].
3. To promote flow and immersion in users [23] through both concentration and sensation of control.
4. To encourage autonomy and sense of independence by stimulating prospective memory, directly addressed to daily events.
5. To stimulate prospective memory, using daily-life appointments introduced into HERMES system as cognitive games stimuli.
6. To stimulate visual attention and bi-manual coordination.

The first game to be developed has been HERMES Maze (Figure 1). The aim of the game is to match appointment clues (e.g. Doctor visit) and a time clues (e.g. 10:00 h.) from two different start points to an Appointment Sheet, which is inside a maze and serve as a reaching point. Users have to move these "clues" along the maze, each clue with a hand (see Figure 1). If the user withdraws a hand, the clue returns to the start point. In a different mode of the game, a complete appointment card (containing time, content, place and accompanist) appear in a side of the screen and the user has to carry it to a Timetable. 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 lateralization (right or left-handed), best-preferred hand to be used can be considered a factor to increase difficulty.

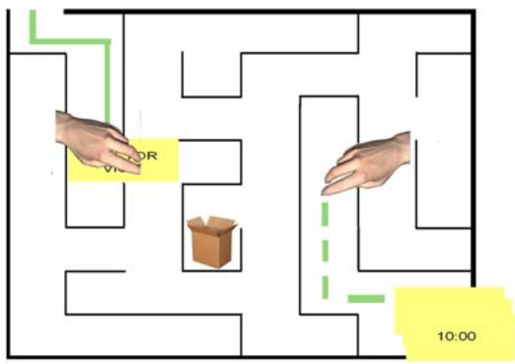

Figure 1: HERMES maze game

This same game can be complicated with a 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 extra aim of this game is to work sustained attention. A picture that summarizes the idea of this game can be seen in Figure 2.

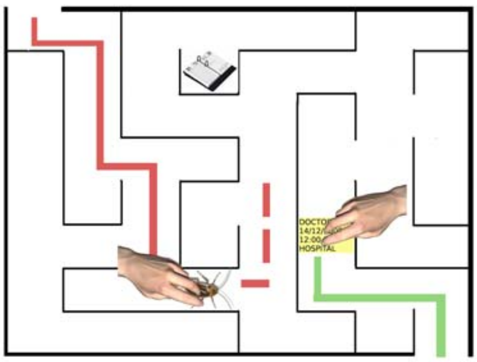

Figure 2: HERMES “monster” maze game

4. Technical Implementation of the Multi-touch screen.

The HERMES system games leverages sensors and other pervasive computing technologies towards developing cognitive support applications -such as memory aids- [24]. The HERMES systems take into account requirements of elderly users in terms of ergonomics and ease of use. Hence, HERMES remedies typical interface problems, which stem from the fact that conventional interfaces come with two main limitations for older adults, namely small buttons that are hard to press and small displays that are hard to read. Specifically, HERMES applications feature novel ergonomic interfaces, which provide to aged users comfort, flexibility and natural interaction. In particular the HERMES end-user interfaces include large buttons and are implemented on multi-touch surfaces, overall offering a mixed reality experience.

Multi-touch screens and related interfaces are acknowledged to be motivating environments for executing cognitive training games [17]. Such interfaces fall within the wider wave of surface computing [25, 26], which is gradually more and more associated with ergonomic interfaces and natural human-computer interaction [27]. In order to leverage a multi-touch surface for cognitive training in the HERMES system, we evaluated three viable options, including:

1. Capitalizing on readily available frameworks for (multi-touch) surface computing (e.g., http://www.nuigroup.com/touchlib/) and accordingly using it for building cognitive training games. This option entails using APIs (available as part of these frameworks) towards leveraging multi-touch events and accordingly binding them to applications.

2. Licensing and/or using Commercial-off-the-self (COTS) frameworks for (multi-touch) surface computing. This option involves licensing commercial frameworks for multi-touch surface computing, which typically provide more mature functionality than open source frameworks. The most popular of these frameworks is Microsoft’s Microsoft Surface product, which represents the state of the art in surface computing. It provides very robust multi-touch functionality, along with the possibility of (tag-based) object identification.

3. Building a gaming environment from scatch and delivering it on a multi-touch surface screen. Such a development requires libraries for finger tracking, as well as specialized middleware mapping low-level events from the tracker to high-level application events suitable for games authoring and development.

In the scope of the HERMES project we opted for the third option, which provided maximum control and flexibility over the HERMES cognitive games platform development. Furthermore, this option allowed us to calitalize on leading edge finger tracking technology, which is provided by one of the partners of the HERMES consortium (namely AIT, see 3).

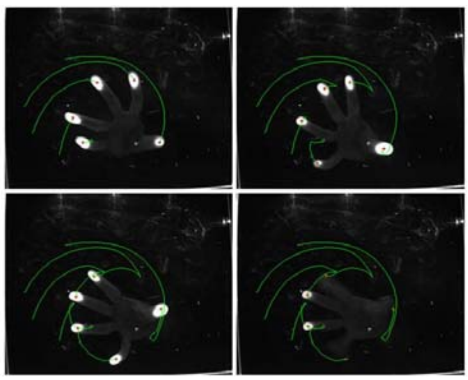

Figure 3: Finger Tracking

Specifically, we designed a special multi-touch surface interface, which operates based on fingertips movements, which are very familiar to humans. This surface enhances interaction simplicity and makes memory support applications and cognitive training games more appealing to the elderly. A surface with multi-touch potential also allows developers to implement games with complex requirements.

Figure 4: Multi-touch surface table

The surface is designed to be able to be embedded on a typical table (as shown in Figure 4). This enhances the quality of the user's interaction with the device and the cognitive support applications. At the same time it is preferable to interfaces that require users to familiarize themselves with several devices (e.g. the combination of a keyboard, mouse and computer monitor), which usually results in confusion and features a demanding learning curve. The implemented interactive surface can integrate such a design on the same physical device. Given this requirement, a TFT computer monitor has been modified in order to operate both as system input and output. Monitor layers have been separated so that we take advantage of the transparency of TFT panels when subjected to infrared (IR) illumination. The components of the interactive surface are depicted in Figure 5.

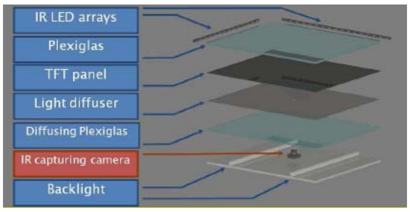

Figure 5: Components of an ergonomic multi-touch surface

An acrylic panel is placed on top of the TFT panel, the edges of which are illuminated by four IR-Light Emitting Diode (LED) arrays emitting at 940nm. A finger touch on the surface of the acrylic panel generates lighting blobs. This is due to the fact that the refractive index of skin is higher than that of the air. The position of blobs that manage to penetrate the TFT panel is captured by a USB camera through an Ultraviolet /Visual (UV/VIS) cut optical filter at 790nm. The camera feed captured is then fed into visual tracking algorithms. The description of the latter algorithms is outside of the scope of this paper. Interested readers could consult [28] instead. It is also worth noting that the amount of IR illumination emitted by the fluorescent lamps of the TFT often masked out the finger blobs. To overcome this problem the backlight has been replaced by cool-white LEDs whose IR emission does not cover the intensity of the blobs. Also, several layers of light diffusers have been used in order to generate a smooth background illumination for the TFT panel. The multi-touch surface is computationally supported by a workstation and hence can become seamlessly integrated within the rest components of the HERMES system.

5. Future work.

The first game has been already developed and the next step will be to test it with a significant number of elderly people that represent the target group of this project. Currently the definition of the testing plan is being finished. In this testing some parameters will be assessed like the response speed, accuracy and movements efficacy. But also some subjective variables like satisfaction with the game flow and immerse experience will be evaluated.

The team is working in parallel in the definition of other games that stimulate other cognitive functions. When the testing phase ends, the feedback drawn will be taken into account for these remaining games.

This project has been approved by the Ethics Committee in Social Intervention of Matia/Hurkoa/Ingema. Besides, in this project there is a special workpackage with the aim to ensure the ethical validity of the project and make sure that the user's privacy is respected throughout the entire project and in its exploitation activities.

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