Cognitive Stimulation, Maintenance and Rehabilitation

Designing the user interface, research and practical results

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***Abstract* — Significant demographic changes in developed countries in recent decades have reflected the worrying trend of an ageing population, including the Portuguese population. In light of this scenario, there is an urgent need to create solutions that help to mitigate the collateral effects of ageing. This paper describes the development of an occupational health component aimed at enabling technicians and specialists to define and personalize therapeutic intervention programs for cognitive rehabilitation and maintenance, specific to various types of cognitive disabilities. The occupational health component of Mind.Care is being developed under the TICE.Healthy project, whose main objective is to provide a range of activities for the cognitive stimulation, maintenance, monitoring and rehabilitation of the cognitive functions – memory, attention, language, executive functions, visual and special abilities – suited to different user profiles. In addition to the scientific framework, there is an emphasis on conceptual and development decisions, illustrated by the various stages of functional specification, with a definition of usability and accessibility guidelines, design and implementation. The work has a strong scientific foundation and has been developed with great care in terms of design and technological issues, with a view to making a significant contribution to healthy ageing.**

Keywords-mind.care; cognitive stimulation; cognitive maintenance; cognitive rehabilitation; user centered design

I. INTRODUCTION

Cognitive impairment and dementia are the major health issues among older people. By consensus, age has been considered as a major risk factor for developing dementia, including Alzheimer's disease (AD) [1 – 4] and, more recently, Mild Cognitive Impairment (MCI) [5].

It is estimated that the number of patients with dementia will double every 20 years, approaching the 42 million mark in 2020 and reaching 81 million by 2040, in the absence of effective treatments or preventive strategies [6]. In Portugal, it is estimated that there are approximately 153.000 patients with dementia [7]. The serious impact of the aging population and specifically of the AD in health-care systems worldwide [8, 9] and the dramatic projections for the coming years [6, 10], also expected in the Portuguese population, stress the need for new effective strategies able to address with this scenario.

Besides a brief description of the Mind.Care's occupational health component and the importance of cognitive stimulation, this paper describes the user-centered design methodology adopted in the project development and all the constraints of the target users. There is an emphasis on conceptual and development decisions, illustrated by the various stages of functional specification, with a definition of usability and accessibility guidelines, design and implementation. After describing a typical cognitive activity experience, Mind.Care's project is also presented as an integrated project.

A. *The importance of cognitive stimulation*

With aging, the ability to receive, process and remember information tends to deteriorate. Healthy aging and stimulation of the various cognitive skills is clearly a way to mitigate this situation. Numerous studies clearly prove that older people, with a lifestyle which includes intensive cognitive stimulation, have a better global cognitive functioning, a greater ability to think and tend to delay the onset of cognitive decline [11, 12].

Frequent cognitive activity protects and slows cognitive decline because it stimulates different parts of the brain involved in memory and information processing, making them more efficient and resilient. The resultant increase in the number of brain cells and the connections between them contribute to a greater cognitive reserve and reduces the risk of dementia.

Several studies have confirmed the increased risk for the development of dementia in patients with MCI. Currently, recent studies reporting incidence rates of MCI close to 6.4% [13] and prevalence rates about 16% [14]. In this context, the MCI phase is the ideal target for implementation of stimulating activities and cognitive training, allowing early intervention in times of incipient cognitive decline and reducing its severity.

B. *Our solution*

The component for occupational health Mind.Care is focused on stimulation, maintenance and cognitive rehabilitation of seniors. This component will provide a range of brain training activities that stimulates several cognitive functions, including: memory, attention, language, executive functions and visuospatial abilities.

Following any brain damage, cognitive disorders, in particular memory deficits, are common in patients and have a major impact on their lives and those of their caregivers.

Given the small number of platforms targeted at cognitive training, specifically for the Portuguese population, it is a matter of some urgency to create and encourage those activities that can best help experts in the field of neuroscience to stimulate, rehabilitate and maintain the various cognitive functions of their patients.

The component for occupational health Mind.Care will provide a set of services that will:

- Allow health professionals and experts to define and customize the therapeutic intervention programs for cognitive rehabilitation or maintenance, specific to various types of cognitive disorders, by selecting multiple activities that meet the needs and difficulties of each patient;
- The activities suited to different needs of stimulation/maintenance/rehabilitation of various neurodegenerative diseases, which can stimulate various cognitive functions including memory, attention, language, executive functions, spatial perception;
- Enable health professionals and experts to monitor and measure the performance and clinical evolution of each patient;
- Allow any healthy senior the access to stimulating activities and cognitive training.

The early stage of preliminary studies first surveyed the state of the art, focusing on identifying and analyzing a range of comprehensive brain training and diagnostic support, maintenance and monitoring platforms for patients with various types of neurodegenerative pathologies. It subsequently looked at the important aspects of usability and accessibility in the context of cognitive impairment and appropriate technologies to implement the activities to be developed.

After these studies, we went on to identify and define the various user profiles, associated services and the characterization of the activities to be developed.

The practical validation of all such activities will be done through a pilot study with clinical and control groups, and should be able to assess not only the preventive capacity and improvement, but the acceptance by and interaction of users. In short, we intend to find out if the activities are appropriate to the clinical profiles and really appraise what is wanted for a subsequent clinical validation.

II. User Centered Design

To create a system like the one presented in this paper, it is crucial to ensure the end result is easy to use, but it is also necessary for it to meet the needs of all the actors involved.

Therefore, from concept generation to testing, via the entire implementation phase, a user-centered methodology was adopted.

"*User experience*" was also one of the key concepts that informed the development of this system and carried significant weight, seeing as this is a system aimed at healthy seniors, but also users with a clinical profile, within the remit of cognitive impairments.

In brief, this system comprises a clear understanding of its target users, it communicates its scope and objectives in an unambiguous and straightforward manner, thus embodying something useful, easy to use and appealing.

A. *User profiles*

These activities, their degrees of difficulty and progress metrics have been defined according to the different user profiles. Each user profile is intended for individuals with different levels of cognitive impairment in the continuum between the cognitive changes due to normal aging (*Healthy Profile*) and clinical conditions of mild cognitive impairment (*Light Profile*).

The *Healthy Profile* is applicable to all healthy adults and seniors who wish to enhance their cognitive skills through cognitive training.

The *Light Profile* will include all adults and seniors who have mild cognitive impairment, clinically significant, non-normal to the aging process but insufficient for clinical diagnosis of dementia. This profile is designed for all patients with a clinical decline beyond that expected for age and education of the individual and which may precede various clinical conditions, particularly but not exclusively dementia diagnosis.

Each activity will always be presented with a level of increasing difficulty (variable in each of the profiles) and accompanied by simple guidelines to follow.

B. *Designing for older adults*

When creating systems for older adults it is essential to consider the changes that occur naturally with ageing, in particular regarding mobility, hand-eye coordination and motor coordination, the senses, such as hearing and vision, or cognitive abilities, such as short-term memory [15, 16].

In terms of vision, this includes difficulty in distinguishing certain colors, adapting to changes in lighting levels, and a growing difficulty in concentrating, especially when reading, since the ability to focus decreases and so the ability to see close-up becomes increasingly difficult [15].

Changes in the musculoskeletal system can also very often restrict people's functional ability and even prevent them from performing basic daily activities unaided. As mentioned in [17], the review of clinical studies carried out in Portugal up to 2002, which quantified the prevalence of rheumatic diseases and their economic and social impact, showed that rheumatic diseases were the most prevalent chronic pathology (accounting for 28% to 37% of chronic illnesses). This makes them the foremost reason for Portuguese people attending primary healthcare facilities: 20% of general practice appointments are prompted by rheumatic diseases.

These changes are important and should be taken into consideration because they may make it hard for some people to use certain devices such as the computer mouse or keyboard.

Understanding the main characteristics and limitations of healthy senior users was extremely important. While creating the system, these factors influenced the definition of usability guidelines and clearly interfered in areas like human-computer interaction, browsing (user experience design), information design, functional model, graphic interface (user interface design) and definition of content.

C. Designing for people with cognitive disabilities

Cognitive limitations cover a vast field, with specific needs that depend on the type of pathology. They give rise to a wide range of characteristics/limitations that need to be considered when creating systems for users with this clinical profile. Nevertheless, it is possible to identify the abilities that are most affected by limitations of this type and the main difficulties experienced by individuals with cognitive disabilities [18]. Among them are perception and processing, memory, ability to solve problems, and attention.

We therefore face several challenges:

- Individuals with learning difficulties usually have serious limitations in terms of interpreting and understanding texts, numbers, spoken instructions and difficulty with spatial orientation [19].
- Individuals with a brain injury or cognitive impairment often need more time to interpret and respond to online stimuli [20].
- Individuals with memory problems find it harder to deal with sequential operations or understand and retain information inserted into a complex interface and presented in a haphazard manner [21].
- Individuals with low reflexes or memory and perception problems have a greater difficulty in using buttons on a computer mouse for separate actions [21].

III. CONCEPT

During the whole process of conceiving (functional design, graphic design and technical development) special specificities were taken into account [22]. Design was focused on following concepts - User Centred Design (UCD), User Experience (UX) and User Interface Design (UID) - and a special attention was given to high level of usability.

The most relevant tasks considered during Mind.Care´s concept process were:

- During the specification phase, functional mockups were designed with the main objective to ensure that all users will be able to simply and accurately manipulate all interface and navigation components of cognitive training activities.
- General usability guidelines were also defined to ensure that all interface components were designed so that users of all ages can understand them, even if they have vision impairment or cognitive disabilities.
- A library of simple icons, easy to understand and appropriate to all main actions, was created.
- To guarantee good readability and increase legibility, different typefaces were tested to select those fonts which were best suited to complement the icons and ensure clarity.
- A contrast analyzer was also used to check the combination of colors, based on the requirements of the Web Content Accessibility Guidelines (WCAG) 2.0, ensuring there is sufficient contrast between foreground and background elements.

Following analyses and development of these requirements, the base interface was designed for use in all activities.

A. User interface

Much of the literature related to senior users and the internet eventually suggest guidelines that are reflected in best practice in the creation of systems for any age group and any type of user, from the consistency of browsing, to how to write clearly or how to handle the whole graphical interface [23].

Overall, the approach to reconciling to the full the requirements of the different target audiences of the system to be developed concerns the adoption, where possible, of the principles of universal design. Thus, the end result is meant to deliver a system that is suitable for both healthy senior users and users with cognitive limitations.

The authors of the principles of universal design specify seven principles to consider during the design process and as a way to evaluate products, systems or environments already created - Equitable use, Flexibility in use - Simple and intuitive, Perceptible information, Tolerance for error, Low physical effort, Size and space for approach and use [24].
The main guidelines identified and considered to put into practice the principles mentioned above were:

- To create an interface as intuitive and simple to use as possible, with information organized and structured in a clear, logical and relevant manner for those who use it, but attractive to atract the attention of various types of user.
- To create a system that, whenever possible, is flexible and adaptable to aptitude of each user;
- To integrate a system for speech recognition that could be an alternative mode of interaction through commands made by you.
- To clearly provide multimodal sequential instructions that would help with performing complex operations.
- To create a browsing structure consistent throughout the system, maintaining the coherence

of elements that perform the same type of functions, using graphics and easily recognizable icons, which should aid understanding and browsing.

- To use familiar pictures and graphics that are easy to understand and retain, alongside a simple, clear language – short, concise sentences.
- To ensure maximum contrast between the interface elements (content / background).
- Within the navigation menus and buttons that trigger actions, to associate (whenever possible) graphics with words in order to facilitate understanding.
- To use graphic elements that efficiently communicate what was intended and that are as simple as possible.
- To use sound to supplement the information presented.
- To use sounds that reflect the interaction of the user interface elements, and catch the attention of the user.
- To limit the number of options to avoid overwhelming the level of understanding and retention of information.
- Where justified, to allow the user to cancel accidental and wrong interactions.
- To avoid simultaneous tasks and keep to a minimum the number of steps required for the interaction.
- To increase the size of the clickable areas so as to facilitate interaction for people with impaired vision or motor coordination.
- To allow sufficient time for the user to interact with the content.

IV. PROTOTYPE

Each cognitive activity has an introduction (e.g., name of the activity, cognitive domains to stimulate, the level at which the user is located), a brief presentation, the proposed objectives and is accompanied by a demonstration (Fig. 1).

Before beginning an activity, the user has access to the different levels of difficulty available, and can refer to the parameters that vary between them (Fig. 1).

In performing each activity, the user receives instructions on how to proceed (Fig. 1).

At the end of the activity, the user always has access to an evaluation of performance and may consult, when appropriate; responses are marked as correct or incorrect, when applicable (Fig. 1).

A. *The cognitive activity "Spot the differences"*

In this activity [22], two seemingly identical pictures are presented simultaneously. The participant must identify and flag the differences between the two images. As the level of difficulty increases, the number of differences increase and these differences become less and less apparent. Additionally, at lower levels of difficulty, images specifically designed for the activity are used, while higher levels of difficulty use images from real situations.

This activity involves predominantly attentional capacities. The task of finding differences between two seemingly identical images implies a flexible mediation between concentration, inhibition of distraction and the ability to shift consciousness from one focus to another. Through the attentional cognitive processes, there is a selection of relevant stimuli to perform a comparative analysis of the details of the figures, while irrelevant information is inhibited, i.e., the various aspects of the images that are not different.

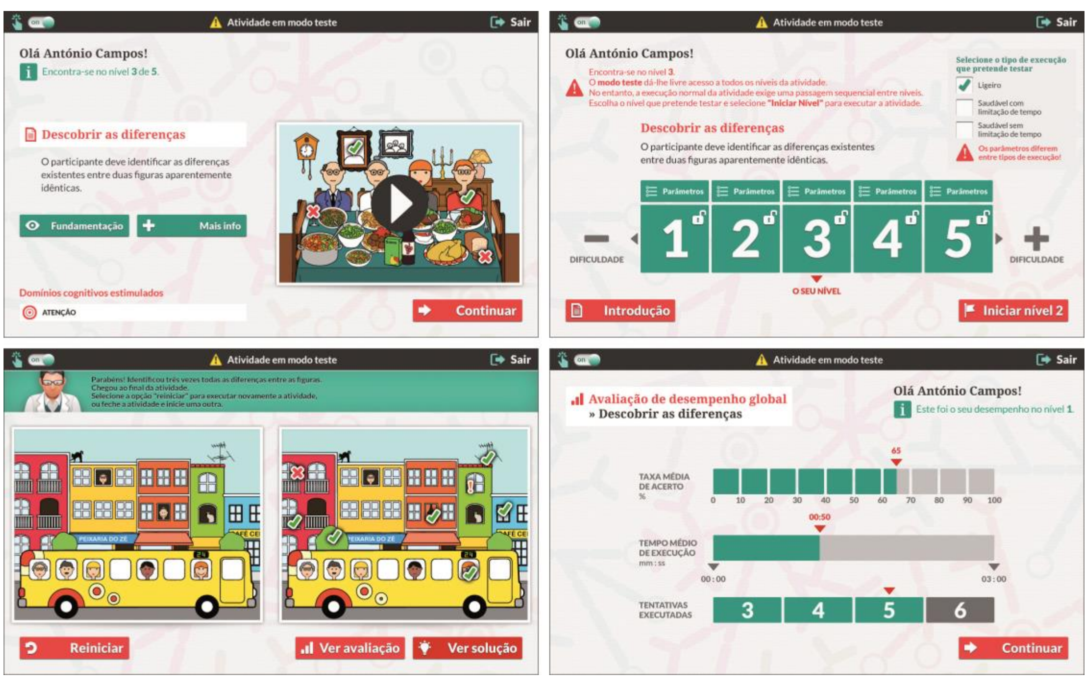

Figure 1. Mind.Care - The cognitive activity "Spot the differences"

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V. MIND.CARE'S PROJECT

The Project, Product or Service (PPS) named Mind.Care is framed in the mobilizing project TICE.Healthy. This project, according to the mission and goals of the main TICE.PT, is aimed at enhancing the contribution of Portuguese companies and organizations in global markets of the strategic area "Health and Quality of Life".

TICE.Healthy, where MediaPrimer (www.mediaprimer.pt) is the leading partner, represents a collaborative initiative of Portuguese companies and entities of the Scientific and Technological Sector for the development and marketing of innovative products in the field of e-health.

The Mind.Care project aims to provide services, equipment and aids for the relatives, caregivers and healthcare professionals of persons affected by dementia diseases. The goal is to improve the quality of life and well-being of people suffering from Alzheimer's and Parkinson's diseases, while at the same time significantly reducing the cost of treatment and follow-up of these patients. All is intended to be achieved through the use of a system supported by internet and mobile communications technology.

VI. CONCLUSION AND FUTURE WORK

Mind.Care, is being developed with professional input at all levels. The Centre for Neuroscience and Cell Biology (CNC) of the University of Coimbra provides the scientific support and MediaPrimer is responsible for the design and implementation of the occupational health component, in its various aspects, from graphic design to technological solutions.

Currently, clinical and functional validations of the cognitive activities of the Occupational Health component are being planned. In the near future, the validation of the activities will be initiated expecting to:

- Be carried out through a pilot study with clinical groups who underwent a comprehensive neuropsychological assessment and complete clinical evaluation, either at the beginning or at the end of the validation period;
- Perform psychometric and clinical validation studies, in order to confirm that the several activities of cognitive training are appropriated and useful both user profiles;
- Evaluate the improvement capacity;
- Evaluate the preventive capacity through a longitudinal study;
- Evaluate the acceptance and interaction from users.

After completing the analysis of the data from the clinical observation, technical observation and personal experience of all the actors involved in the pilot study, the next step will be to correct and improve the usability and functionality. These will look at all the difficulties expressed and the improvements suggested that are deemed relevant and essential.

The number of levels for each activity, the respective parameters and degree of difficulty, the type of content and its characteristics, the execution time, and functions available will be reviewed according to the findings of the pilot study.

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REFERENCES

[1] J. L. Barranco-Quintana, M. F. Allam, A.S. Castillo, and R. F. Navajas, “Factores de riesgo de la enfermedad de Alzheimer” [Risck fators for Alzheimer's disease], Revista de Neurología, vol. 40, no. 10, May 2005 pp. 613-618.

[2] J. Chen, K. Lin, and Y. Chen, “Risk factors for dementia” Journal of Formosan Medical Association, vol. 108, no. 10, Oct. 2009, pp. 754-764.

[3] M. Herrera-Rivero, M. E. Hernández-Aguilar, J. Manzo, and G. E. Aranda-Abreu, “Enfermedad de Alzheimer: Inmunidad e diagnóstico” [Alzheimer's disease: immunity and diagnosis], Revista de Neurología, vol. 51, no.3, Aug. 2010, pp. 153-164.

[4] S. Seshadri et al., “Lifetime risk of dementia and Alzheimer's Disease: The impact of mortality on risk estimates in the Framingham study”, Neurology, vol. 49, no. 6, Dec. 1997, pp. 1498-1504.

[5] T. Luck, M. Luppa, S. Briel, and S. G. Riedel-Heller, “Incidence of mild cognitive impairment: A systematic review”, Dementia and Geriatric Cognitive Disorders, vol. 29, no. 2, Apr. 2010, pp. 164-175.

[6] C. P. Ferri et al., “Global prevalence of dementia: A Delphi consensus study”, Lancet, vol. 366, no. 9503, Dec. 2005, pp. 2112-2117.

[7] European Comission (2009). Estimated number of people (2006) with dementia. [Online]. Available: http://ec.europa.eu/health/ph_information/dissemination/echi/docs/dementia2_en.pdf [retrieved: may, 2013]

[8] A. Comas-Herrera et al., “Future costs of dementia-related long-term care: exploring future scenarios”, International Psychogeriatrics, vol.23, no. 1, Feb. 2011, pp. 20-30.

[9] K. M. Langa et al., “National estimates of the quantity and cost of informal caregiving for the elderly with dementia”, Journal of General Internal Medicine, vol. 16, no. 11, Nov. 2001, pp. 770-778.

[10] A. Wimo, B. Winblad, H. Aguero-Torres, and E. von Strauss, “The magnitude of dementia occurrence in the world”, Alzheimer Disease and Associated Disorders, vol. 17, no.2, Apr. 2003, pp. 63-67.

[11] K. Ball et al., “Effects of cognitive training interventions with older adults: a randomized controlled trial”, Journal of the American Medical Association, vol. 288, no. 18, Nov. 2002, pp. 2271-2281.

[12] C. K. Casel, “Use it or lose it activity may be the best treatment for aging”, Journal of the American Medical Association, vol. 288, no. 18, Nov. 2012, pp. 2333-2334.

[13] R. O. Roberts et al., “The incidence of MCI differs by subtype and is higher in men: The Mayo Clinic study of aging”, Neurology, vol. 78, no. 5, Jan. 2012, pp. 342-351.

[14] R. C. Petersen et al., “Prevalence of mild cognitive impairment is higher in men: The Mayo Clinic study of aging”, Neurology, vol. 75, no. 10, Sept. 2010, pp. 889-897.

[15] A. Arch (2008, May 14). Web accessibility for older users: A literature review [Online]. Available: http://www.w3.org/TR/wai-age-literature/#whatvision [retrieved: may, 2013]

[16] AgeLight (2001, Sept. 10). Interface design guidelines for users of all ages [Online]. Available: http://www.agelight.com/webdocs/designguide.pdf [retrieved: may, 2013]

[17] R. Lucas and M. T. Monjardino, "Revisão da epidemiologia da patologia reumática em Portugal" [Review of the epidemiology of rheumatic disease in Portugal], in O estado da reumatologia em Portugal, Observatório Nacional das Doenças Reumáticas, 2010, ch.4, sec. 4.3, p. 42.

[18] WebAim. Cognitive disabilities part 2: Conceptualizing design considerations [Online]. Available: http://webaim.org/articles/cognitive/conceptualize/ [retrieved: may, 2013]

[19] J. Brewer (2005, May 5). How people with disabilities use the web: Working group internal draft [Online]. Available: http://www.w3.org/WAI/EO/Drafts/PWD-Use-Web/ [retrieved: may, 2013]

[20] M. Serra and J. Muzio, “The IT support for acquired brain injury patients: The design and evaluation of a new software package”, in HICSS-35, Island of Hawaii, Proc., 2002.

[21] K. Jiwnani (2001). Designing for users with cognitive disabilities. Universal Usability in practice [Online]. Available: http://www.otal.umd.edu/uupractice/cognition/ [retrieved: april, 2013]

[22] J. Redish and D. Chisnell (2004). Designing web sites for older adults: A review of recent literature [Online]. Available: http://assets.aarp.org/www.aarp.org_/articles/research/oww/AARP-LitReview2004.pdf [retrieved: may, 2013]

[23] The Center for Universal Design (1997). The Principles of Universal Design, Version 2.0. Raleigh, NC: North Carolina State University.