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# *primerCOG* - A cognitive training tool, functionally validated for cognitively healthy seniors

# *primerCOG* - Uma ferramenta de treino cognitivo, funcionalmente validada para seniores cognitivamente saudáveis

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ORIGINAL

**Abstract**

The population aging and its relationship with dementia and Mild Cognitive Impairment, require solutions that help to minimize the problems of an aging population. The *primerCOG* is a cognitive training tool, functionally validated for cognitively healthy seniors, that intends to be a state-of-the-art solution in the area of cognitive deterioration. Among its benefits: (i) it enables health professionals to define and adjust cognitive training plans for each patient; (ii) it provides information to allow the continuous monitoring of each patient with the comparison of the outcomes of implemented cognitive training activities; (iii) it helps the scientific community with the diagnosis, prognosis, maintenance and monitoring of patients in the various stages of dementia.

**Keywords:** cognitive training, active aging, mild cognitive impairment, dementia, eHealth system

**Resumo**

O envelhecimento demográfico da população e o incremento consequente de demência e de Défice Cognitivo Ligeiro exigem soluções que contribuam para minorar as consequências inerentes ao envelhecimento. O *primerCOG* é uma ferramenta de treino cognitivo, funcionalmente validada para seniores cognitivamente saudáveis, que pretende ser uma solução *state of the art* na área da deterioração cognitiva destacando-se por: (i) Permitir que profissionais de saúde possam definir planos de treino cognitivo ajustados e individualizados a cada paciente; (ii) Disponibilizar informação para monitorização contínua de cada paciente permitindo comparar resultados da execução das atividades de treino cognitivo; (iii) Ajudar a comunidade científica no diagnóstico ao longo do tempo, prognóstico, manutenção e monitorização de pacientes nos vários estados de demência.

**Palavras-chave:** treino cognitivo, envelhecimento ativo, défice cognitivo, demências, sistema *eHealth*

**Introduction**

Age is considered by many as one of the main risk factors for developing dementia (Barranco-Quintana, Allam, Castillo, & Navajas, 2005; Chen, Lin, & Chen, 2009; Herrera-Rivero, Hernández-Aguilar, Manzo, & Aranda-Abreu, 2010; Seshadri, et al., 1997), as well as mild cognitive impairment (MCI) (Luck, Luppa, Briel, & Riedel-Heller, 2010).

Projections of demographic aging of the population warn against a reality that needs not only quick changes (economic and social) but also an increased investment in promoting active aging. It is expected that in 2050, in Portugal, there will be 398 elderly individuals for every 100 young people and that, worldwide, 20% of the total population is made up of elderly individuals (about 2.5 billion people).

The dementia projections are also quite worrying. It is estimated that the number of people with dementia doubles every 20 years to approach 42 million in 2020 and 81 million in 2040, unless effective therapies are discovered and preventive strategies developed (Ferri, et al., 2005). In Portugal, it is estimated that there are approximately 160.287 patients with dementia (Santana, et al., 2015).

Given these data, we are faced with a clear need for solutions that effectively help mitigate the side effects of aging.

The work presented here is related to the functional validation of the cognitive training platform - *primerCOG*. The analysis and evaluation of *primerCOG*'s user experience was based on a sample of 30 adult healthy elderly individuals.

***Active aging - The importance of cognitive stimulation***

People who remain mentally and physically active may face a slower natural aging process (Clark, 1999). Several studies suggest that the basic functions, affected by aging, can be improved by training (Hosseini, Kramer, & Kesler, 2014).

Under these circumstances, increasing cognitive activity can protect and delay cognitive decline due to aging, since different parts of the brain involved in memory and information processing are stimulated, making them more efficient and resilient. As well as, in cases of dementia, the continuity of physical and mental exercises has a significant positive incremental effect on the well-being of the patients and on their quality of life.

***primerCOG platform***


**Figure 1. primerCOG: Platform for cognitive stimulation and training.**

*primerCOG* (Figure 1) is a platform of cognitive training, with strong and solid technological and scientific bases that aims to contribute towards healthy ageing and to meet the needs of stimulation, maintenance, monitoring and rehabilitation related to various neurodegenerative disorders that affect the elderly.

It provides a range of brain training activities that stimulates cognitive functions, including: memory, attention, executive functions and visuospatial abilities. The *primerCOG* presents itself as an extremely useful tool for specialists that follow up people with varying levels of cognitive deterioration due to normal ageing or to mild pathological cognitive changes, helping the scientific community with early diagnosis, prognosis, maintenance and monitoring of patients in the various stages of dementia.

This platform will allow specialists devise and personalize remotely cognitive training plans tailored to the kind and stage of their patients' illness, their characteristics and consequent limitations and track the performance and clinical progress of each patient (Figure 2).

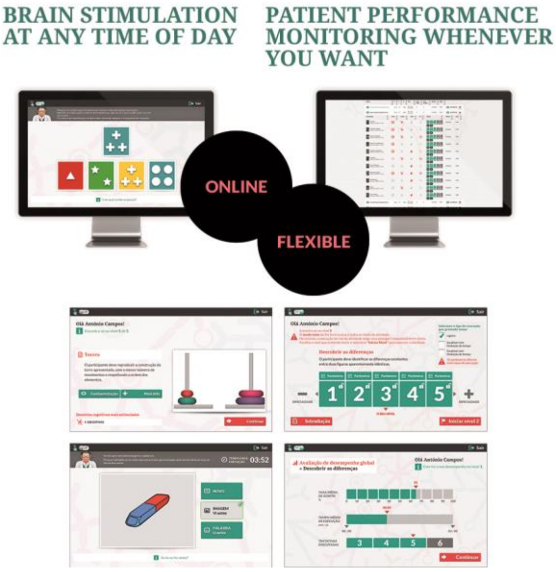


**Figure 2. primerCOG provides information that allow the continuous monitoring of each patient.**

***User-centered development***

The *primerCOG* is directed not only to healthy seniors, but also to users with a clinical profile, within the spectrum of cognitive decline. This led to the adoption of a user-centered methodology with "user experience" as one of the key concepts.

Throughout the development process, we considered the changes due to the natural aging process, namely the most vulnerable cognitive abilities, and the main difficulties of people with cognitive impairment, in particular: mobility, hand-eye coordination, motor coordination, senses, such as hearing and vision, or cognitive abilities, such as short-term memory (AgeLight, 2001).

The study of the main characteristics and limitations of the several types of *primerCOG*'s users was central in the creation of the entire system. These influenced the definition of usability guidelines and clearly interfered in areas like interaction, navigation, information, functional model, graphical interface and content creation.

Literature related to senior users and the internet, eventually suggests guidelines for a better practice in the creation of systems for any age group and any type of user. From the consistency of the navigation, to how to write clearly or how to handle the whole graphical interface (Redish & Cisnell, 2004).

Overall, the selected approach which combines most of requirements of all potential users, was the adoption of the principles of universal design. The *primerCOG* has a clear understanding of its target users and communicates its scope and objectives plainly and immediately, which makes it useful, easy to use and appealing.

## Metodology

All the R&D tasks have been performed by a wide team of professionals of neurosciences and experts in design, user interfaces, user experiences, information technology, behavioral analysis, analysis of experiments using IT systems, usability and accessibility.

Within Center for Neuroscience and Cell Biology (CNC) scientific expertise, it is remarkable the strong focus on the exploitation of the fundamental mechanisms of aging and brain diseases. CNC gave to *primerCOG* all the scientific support necessary to guarantee the scientific quality of the final result, namely in tasks such as analysis, specification and testing all the activities and cognitive training platform.

In addition to CNC, other entities, connected to the target population, collaborated in *primerCOG*'s development. With their knowledge, they contributed with problem analysis, specification, in structuring and testing the solution.

Some entities have considered relevant the involvement in this project and have collaborated in some specific tasks of the pilot study of *primerCOG*'s functional validation, namely by testing the cognitive training activities with the target users, assessing the degree of acceptance, identification of difficulties and improvements in usability and evaluation of the experience and interaction.

The pilot study began at Santa Casa da Misericórdia da Lousã (SCML), then it was implemented in Centro Comunitário de Desenvolvimento e Solidariedade Social de Coimbra (CCDSSC), and lastly, in Cáritas Diocesana de Coimbra (CDC). Table 1 shows the recruited participants. Despite all the institutions belong to Coimbra's district, participants are mostly inserted in an urban environment or in a moderately urban environment.

**Table 1**

*Recruited participants from institutions*

| INSTITUTION | NUMBER OF PARTICIPANTS WITH PSYCHOLOGICAL EVALUATION | NUMBER OF PARTICIPANTS INCLUDED IN PILOT STUDY |
|---|---|---|
| SCML | 11 | 8 |
| CCDSSC | 15 | 13 |
| CDC | 13 | 9 |

***Sample characterization***

Participants *(N = 30)* have *M = 9.53* ± *5* (A: 1 – 16) years of schooling; *M = 73.73* ± *9.86* (A: 60 – 94) years of age and 93.3% of participants were female.

***Instruments used for psychological evaluation***

Psychological evaluation of the participants was conducted by a neuropsychologist and comprised rating of memory complaints, evaluation of emotional state and implementation of objective cognitive assessment with the following: screening tests *Mini-Mental State Examination* (MMSE; Folstein, Folstein, & McHugh, 1975; Freitas, Simões, Alves, & Santana, 2014) and *Montreal Cognitive Assessment* (MoCA; Nasreddine, et al., 2005; Freitas, Simões, Santana, Martins, & Nasreddine, 2013); Subjective Memory Complaint Scale (SMC; Schmand, Jonker, Hooijer, & Lindeboom, 1996; Ginó, et al., 2008) for objective quantification of cognitive complaints; and Geriatric Depression Scale (GDS-30; Yesavage, et al., 1983; Barreto, Leuschner, Santos, & Sobral, 2008), to evaluate affective changes and exclude severe depression cases. All these instruments are adapted and validated for the Portuguese population, making it possible to interpret the results, and thus ensure the correct selection of cognitively healthy participants. The order of application of instruments followed the enumeration and was based on the principle of avoiding any influence on cognitive assessment.

### *Instruments used for data analysis*

We created several instruments to support the data collection of the pilot study: (i) for technical observers: Protocol to observe the test sessions; Form to fill in with observation data of each user experience during the test sessions; Form to fill in with the user experience during the execution of each activity; and (ii) to testers: Questionnaire for personal data collecting; Form to fill in with the individual assessment of each of the 11 activities; and Form to fill in with the individual assessment of Occupational Health component.

### *Procedures for data collection*

We established contact with partner institutions and we discussed the importance of cognitive training in the context of healthy aging. After the users' recruitment, the first step was to obtain their informed written consent. Users with cognitive normative performance for their level of education and age, and without severe depressive symptoms, tested all eleven cognitive training activities to the maximum level achieved (MLA). The environment provided was silent and had proper light conditions and temperature.

Sessions to test the activities had an average duration of one hour and the average number of sessions was six (M = 6.3; A: 4-10). The guidance of the sessions has respected the participants' autonomy. There was not a rigid time for playing the activities, and there was an adjustment to each individual and to their characteristics and limitations (e.g. people with visual impairments prefer several sessions with a shorter duration than people without any visual impairment).

***Procedures for data analysis***

For data analysis we used Statistical Package for Social Sciences (IBM, SPSS Version 20). Descriptive statistical analysis was used to characterize the sample and the sessions. Pearson's correlations allowed the analysis of the relationship between the instruments and the maximum level achieved (MLA) in cognitive training activities. We used linear regression to study the influence of age, schooling, and the score obtained in the GDS - 30 on MLA. The analysis of the evaluated parameters by the neuropsychologist who accompanied the sessions was performed using t-test Student for paired samples.

## Results

***Analysis of the relationship between the results obtained in psychological evaluation and the maximum level achieved (MLA) in cognitive training activities***

In the cognitive screening tests were obtained in MMSE: $M = 28.53 \pm 1.2$ and MoCA: $M = 21.60 \pm 4.92$; SMC: $M = 3{,}93 \pm 2{,}67$; and GDS - 30: $5{,}90 \pm 4{,}65$.

There were statistically significant positive correlations between the MoCA's total score and the MLA in all activities ($p < .01$) - a better performance in the MoCA corresponded to higher "maximum levels achieved" in the activities. It was also possible to observe positive and statistically significant correlations, between the MMSE's total scores and the MLA in 7 of the 11 activities. The values of positive correlations between the MLA and the cognitive screening tests were systematically higher in the MoCA than in the MMSE.

The MoCA's total score influenced all activities' MLA, and explains MLA of activities from 26% to 62%. The MMSE's total score influenced 7 activities. The largest percentage explained by the MMSE's total score occurred mostly often in tasks involving memory.

There were no statistically significant correlations between activities' MLA and the GDS - 30.

***Influence of education and age at MLA***

There were positive and statistically significant correlations between MLA and schooling for all activities. Schooling influenced MLA in almost all activities, except for Torres (Towers).

Negative and statistically significant correlations between MLA and age were found in almost all activities, except for Labirintos (Mazes - executive functions and visuospatial ability) and Torres (Towers - executive functions). Age influenced MLA in almost all activities, except in Labirintos (Mazes) and Torres (Towers).

The correlations between MLA and education were higher than the correlations between MLA and age. The results of the correlation and regression are in line with literature, since cognitive performance was highly influenced by education rather than age.

***Recognition of handicap, limitations and disabilities which determine the use of technological devices or systems***

In the questionnaire for personal data collecting, 36.7% of the sample reported visual impairment; 13.3% hearing difficulties; 16.7% motor difficulties; and 3.3% of the sample considered to have cognitive difficulties.

After completion of the study, the pilot's participants filled in the form of assessment of the Occupational Health component; 96.7% "rarely" have had difficulty reading content, 86.7% have distinguished colors "very easily" and 13.3% "quite easily". Concerning to understanding issues, 80% of participants considered that had understood and interpreted "very easily" the information that were presented and 20% "with some ease". All participants considered "almost always" the language used clear, simple and consistent with the content. These results suggest that the platform is very well suited to the target audience.

### *Assessment of effectiveness, efficiency, storage capacity and frequency and severity of errors that occurred during the sessions of primerCOG's application*

The analysis of these four parameters considered the average of all the parameters' items evaluated. Data collected by the neuropsychologist, who accompanied the sessions, were compared, considering the average number of sessions (M = 6.3). A comparison has been made between the first and sixth evaluation (n = 19), and the minimum number of sessions that all participants had (4 sessions). The results of the behavioral analysis showed a significant improvement between the 1st and 6th session in all parameters evaluated by behavioral observation (Table 2). Between the 1st and the 4th session the results were similar, except the frequency and severity of errors that haven't had a significant improvement up to the 4th session.

**Table 2**

*Student's t-test values for the parameters evaluated during the first, fourth and sixth sessions*

| | EFECTIVENESS | EFFICIENCY | MEMORY CAPACITY | FREQUENCY AND SEVERITY OF ERRORS |
|---|---|---|---|---|
| **1ª – 4ª sessions (N = 30)** | 3.10 ($p$ = .004) | 3.08 ($p$ = .004) | 2.85 ($p$ = .008) | 1.99 ($p$ = 0.56) |
| **1ª – 6ª sessions (n = 19)** | 2.70 ($p$ = .015) | 3.28 ($p$ = .004) | 2.85 ($p$ = .031) | 2.66 ($p$ = .016) |

### *Behavioral assessment after the participants' observation throughout all test sessions of the pilot study*

The neuropsychologist that followed the cognitive training sessions, as well as the participants in the pilot study, also assessed platform users' experience. Several items were analyzed, and grouped in order to present data by particular areas. The values shown in Table 3 represent the average of the answers given.

**Table 3**

*Evaluation of executions of the activities and interaction with the system, performed by professional in behavioral analysis*

| Calculations | Classify Cards | Collecting Buttons | Spot the Differences | Find the Twins | Mazes | Word List | In the Same Order | Slot Machine | Towers | Seen or Read Before |
|---|---|---|---|---|---|---|---|---|---|---|
| **UNDERSTANDING** | | | | | | | | | | |
| **Information presented; Operation of the activity** | | | | | | | | | | |
| (1 - Very difficult; 2 - Difficult; 3 - Easy; 4 - Very easy) | | | | | | | | | | |
| 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 4 | 3 | 3 |
| **FUNCTIONAL DIFFICULTIES DEMONSTRATED** | | | | | | | | | | |
| **Using the mouse to interact with the system; Using the keyboard to interact with the system** | | | | | | | | | | |
| (1 - Very difficult; 2 - Easy; 3 - Very easy) | | | | | | | | | | |
| 3 | 2 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 | 3 |
| **DIFFICULTIES DEMONSTRATED WITH INTERFACE AND USABILITY** | | | | | | | | | | |
| **Language comprehension; Content reading; Color distinction; Comprehension and retention of the graphics; Understanding of the auxiliary instructions; Understanding the feedbacks received** | | | | | | | | | | |
| (1 - Very difficult; 2 - Easy; 3 - Very easy) | | | | | | | | | | |
| 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **PROBLEM SOLVING CAPACITY \| OVERCOME DIFFICULTIES** | | | | | | | | | | |
| (1 - Gave up immediately and needed assistance; 2 - Gave up very easily and required assistance; 3 - Gave up relatively easily and required assistance; 4 - Very persistent but eventually need assistance; 5 - Very persistent without aid) | | | | | | | | | | |
| 4 | 4 | 5 | 5 | 5 | 4 | 4 | 4 | 4 | 4 | 4 |
| **EXECUTION (EXPERIENCE)** | | | | | | | | | | |
| **Ability to: Guidance \| Interaction \| Interpretation \| Response to stimuli \| Overall performance** | | | | | | | | | | |
| (1 - Very poor, 2 - Poor, 3 - Reasonable, 4 - Positive; 5 - Very positive) | | | | | | | | | | |
| 4 | 4 | 4 | 5 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |
| **ATTITUDE** | | | | | | | | | | |
| **Acceptance range and demonstrated interest** | | | | | | | | | | |
| (1 - No; 2 - Bit, 3 - Some; 4 - High; 5 - Very high) | | | | | | | | | | |
| 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 | 4 |

## Conclusions

Online cognitive training was deemed "needed" by 56.7% and "much needed" by 33.3% of participants. But 93.3% had never used platforms for this purpose because they were unaware that they existed (92.9%). All the participants used a mobile phone but only 48.3% have experience with computers. Positive and significant correlations were found between MLA in each activity and the total scores in the MoCA, while no significant correlations were found between the MLA in each activity and the GDS-30. The score for the GDS-30 had no significant influences on the MLA in each activity. Significant improvements were found between the first and last session of using the *primerCOG* platform in terms of efficacy, efficiency, storage capacity and frequency of errors made. At the end of the study, 66.7% of the participants said they were "very satisfied" and 26.7% were "satisfied" with the tested platform. Previous use of a computer did not influence the degree of satisfaction with its use.

In conclusion, we can say that the acceptance of the participants to the pilot study was very positive.

Participants presented behaviors that indicate motivation, such as:

- Attention and interest in the explanation of tasks;
- Carefully reading of the information and the instructions of the activities;
- Selection and click with the computer mouse in the suggested tasks;
- Interest in analyzing their own performance;
- Critical thinking about performed tasks. It became notorious with all suggestions of improvements made;
- Positive assessment of activities whose maximum level of performance was hit.

In the future we intend to carry out the clinical and scientific validation of the platform, assuming the implementation of a new longitudinal pilot study with 2 groups (control/clinical), which will determine the efficacy of the *primerCOG*, exploring and assessing: (i) the capacity for improvement of the *primerCOG* users; (ii) the preventive capacity of the *primerCOG* users; (iii) whether each cognitive training activity does in fact assess the intended cognitive field(s) and whether the activities are appropriate to the user profiles.

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