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Digi&Mind: Development and validation of a multi-domain digital cognitive stimulation program for older adults with cognitive decline

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Abstract

Older adults present a decline on their cognitive function. Digital cognitive interventions are related to the maintenance of cognitive function and are associated with better health-related outcomes. This study aims to describe the development process of a multi-domain digital cognitive stimulation program for older adults with cognitive decline. The digital program was developed in four phases: preliminary phase (conceptualization), modeling (experts panel), field test (usability tests), and consensus conference. To ensure software suitability the development process followed also software guidelines for mobile and web applications for older adults. The result was the Digi&Mind digital platform made of a mobile application a backoffice web application. The backoffice web application usability test was conducted with 7 healthcare professionals through the Post-Study System Usability Questionnaire System (PSSUQ). The mobile application test was conducted with 4 older adults and 7 professionals through direct

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observation user testing. Healthcare professionals considered that the system, the information and the interface had quality. Older adults considered the mobile application as appropriate, useful and easy to use, despite of their low digital experience.

Keywords: Older Adults; Cognitive decline; Cognitive stimulation; Digital Solutions; Complex Intervention; Digital health

1. Introduction

The global phenomenon of demographic ageing is considered one of the XXI century challenges [1]. Considering the technological evolution that all generations are facing, it is clear that the future of the ageing process is even more associated to the use of several digital solutions.

Among older adults, the decrease of neurocognitive domains is responsible for a general cognitive decline that induces functional incapacity and loss of autonomy [3]. To develop and validate non-pharmacologic interventions that effectively induce active, participatory and responsible aging is a priority. It is important to minimize the impact of neurocognitive disorders through delaying their progression and diminish their associated symptomatology [4]. The focus should be established on stimulating neurocognitive domains to potentiate or manage cognitive capacities.

Computer-based programs and mobile and web applications are increasingly integrated into traditional cognitive interventions, mostly in cognitive training programs in which a participant is engaged in a set of standard activities with some levels of difficulty.

Evidence revealed that cognitive interventions, especially cognitive training-based interventions, provided to older adults with neurocognitive disorders from the community, have positive results in reducing cognitive frailty [6].

Several studies have shown that digital cognitive interventions have the potential to enhance global neurocognitive domains that is reflected in a positively impact on psychosocial functioning in older adults with cognitive decline. In fact, acquiring new skills and being involved in new digital experiences may improve several neurocognitive domains [7]

This paper aims to describe the development and validation process of Digi&Mind, a multi-domain cognitive-based intervention, defined as a digital cognitive stimulation program with elaborative specificities and technicalities to address and retrain neurocognitive domains deficits (e.g. orientation, memory, attentional capacity and language functioning) in older adults with cognitive decline.

Digi&Mind is a developed product that resulted from the Mind&Gait project that emerged as an answer to the actual sociodemographic and technologic context. With this innovative and economic approach for older adults that experience a loss of functionality, the project pretends to contribute for a sustainable health system that promotes and implements actions oriented through autonomous, responsible and healthy aging [8].

2. Methodology

2.1. Guidelines for complex interventions

To develop the digital cognitive stimulation program, the research team followed guidelines from The Medical Research Council (MRC) for the conception of complex interventions. According to MRC, a complex intervention is described as an intervention that contains several interacting components, which can act either independently or interdependently [9]. Educational, behavior change, and healthcare interventions are likely to be considered as complex interventions, and require specific guidelines to be reported and assessed [9,10].

The development process comprises four phases. The first phase corresponds to a Preliminary Phase (I), where it is made an initial conceptualization of the program design and its supportive materials. The second is the Modelling Phase (II), where the produced contents are presented to an experts' panel to gather different opinions and evaluations

from specialists in the area of cognitive interventions. The third is Field Test Phase (III), where the intervention is evaluated by the targeted population, that in this case and for the study purpose corresponds to the usability tests of the mobile and the backoffice applications. The last is the Consensus Conference Phase (IV) where all the contributions and analysis resulted from the previous phases are synthesized to finalize the intervention that in this case is the Digi&Mind cognitive stimulation program.

2.2. Guidelines for software development for older adults

Once older adults' capacities could be affected due to physical and cognitive impairments, it is crucial to make sure that the program conception is properly adapted and prepared for their real needs and digital interaction. Literature enhances the fact of this content's accessibility have a profound impact on older adults' engagement and motivational processes. In order to warrantee software suitability these aspects were taken into account during Preliminary (I) and Modelling (II Phases, namely on the construction of the program descriptive script. For instance, the Digi&Mind development process followed guidelines for mobile and web applications software for older adults [10]. In terms of physical impairments, guidelines are associated to sensory and dexterity impairments, in part related to their loss of visuospatial skills and accurate movements, namely haptic capacity. For cognitive impairments, guidelines focus on low praxis ability and decreased cognitive performance, as well as low orientation capacities [11].

3. Results

The results here presented correspond to each intervention development phase according to the MRC guidelines [9,10].

3.1. Preliminary phase

At the *Preliminary Phase*, Digi&Mind was developed into a script format to then be transformed into a web or mobile software application, as well as its supportive materials. At first, literature was analyzed, and strengths and limitations of existing similar programs were identified. Several focus groups where carried out by the research team who worked on the cognitive stimulation program conception and design. Social and cultural aspects as well as cognitive capacities of the target population were taken into account. The program design was stablished in order to improve cognitive functional capacity by working activities of daily living, using mechanisms and activities oriented to several neurocognitive domains. It was used a structured approach that draws its bases from the principles of cognitive stimulation that enhance a person's function according [12,13].

3.1.1. Program's structure and components

A main theme for the program was defined and all integrated sessions are relative to it. The defined theme was stablished based on Portuguese cultural aspects, and is a main event called "The dance festival". Sessions that compound the program are all associated to event's preparation and participation. The program begins with the receipt of an invitation in a letter format addressed to older adult, inviting him to participate in the event and, sequentially, all session's content turn around the received information. On total, the program has 8 individual sessions and 1 session that can be held in a group, where it is proposed the realization of a real dance festival.

Each session has approximately the duration of 45 to 60 minutes. Sessions' implementation should follow the temporal logic that is proposed, which means that sessions should be implemented sequentially. Reason why it is not possible to skip sessions once all the contents are intercorrelated.

The general structure of a session has three parts: Orientation for the event, Tasks and Proverb challenge, as described in Table 1.

Table 1. General structure of cognitive stimulation sessions

Part I	"Orientation for the event"	Initial part of session;

		Aim: To complete the orientation chart with data that is retained from the invitation letter, as well as information collected during sessions;
		Provide digital synthesis of previous sessions contents;
		Provide virtual orientation.
Part II	"Tasks"	Intermedium part of session;
		Aim: To prepare older adults event's participation;
		Relates to activities that precede the participation in the event "The dance festival".
		Two tasks per session.
Part III	"Proverb challenge"	Final part of session;
		Aim: To complete or decipher a Portuguese proverb that is presented in various presentations formats;

3.1.2. The implementer

The program could be conducted by healthcare professionals or formal or informal caregivers. Sessions are expected to be dynamic, aiming maximize and maintain a person's cognitive abilities, by respecting the cognitive stimulation principles. The program is designed to be implemented mostly at an individual format at any time with the accompaniment of an implementer - a person who will collaborate, guide and motivate older adults during all sessions.

The implementer will be an active element during program implementation. It should be a facilitating agent who assists older adults at the time, but never in a re-placement position. An "Implementer Guide" will give to relevant information relative to each session.

3.1.3. Difficulty levels

Only two levels of difficulty are defined, Difficulty depends on contents like the number of images presented, the number of associations that the person must do, the number of words omitted, the number of routes presented, among others. The general principle is that all session contents are presented to older adults at a more difficult level, regardless their cognitive decline. The difficulty level should be reduced by the implementer that is implementing the program. When the implementer considers that the person shows great difficulty in the accomplishment of tasks s/he should reduce difficulty level, by using an action button that when it is clicked will modify the way that contents are presented. For each of the session a more detailed description of how the difficulty level will be presented is given at the implementer's manual.

3.2. Modelling phase

After the initial conceptualization, in the *Modelling Phase* all the produced contents (script design and its supportive materials such as the implementer guide) were presented to an experts' panel to gather different opinions and evaluations from specialists in the area of cognitive interventions. Experts discussed about the structure, duration, proposed themes, tasks and activities; difficulty levels and the associated neurocognitive domains. They also analyzed the adequacy and the clarity of the proposed contents as well as the proposed digital mechanisms. After considering all the suggestions and incorporate the modifications the script suffered digital transformation.

A digital platform was developed, composed of a backoffice web application (Mind&Gait) and a mobile application (Digi&Mind). As such, the backoffice application has as main aim to offer to healthcare professionals/formal or informal caregivers the possibility to consult the sessions and older adult's performance results realized through the mobile application. On the other hand, the mobile application is intended for the use of healthcare professionals and older adults, in such a way that healthcare professionals will register their users and they will perform the sessions implemented in that same application.

3.3. Field test phase

During the *Field test phase*, usability tests were performed to the backoffice web applicaton and to the mobile application. For the former, usability tests were performed only with healthcare professionals, while for the mobile application' usability tests a dyad of older adults and healthcare professionals was set up. This procedure is justified by the fact of the mobile application is intended for joint usage between a healthcare professional and an older adult, in such a way that the healthcare professional guides the older adult through the sessions that s/he will have to perform.

Participants, both healthcare professionals and older adults, were recruited by convenience at a Portuguese elderly end-user organization. Regarding healthcare professionals (N = 7), sample was composed by nurses, occupational therapists and psychologists, that should have experience of caring of older adults. Regarding older adults (N = 4) 75% were female, mean age of 72 years old (aged between 68 and 78 years).

3.3.1. Backoffice web application

For the DigiMind backoffice web application, the usability testing process started with a brief explanation of its main functionalities to the participants, being these the following: View group sessions' information; Perform group sessions; View and export the group sessions' results and View and export the results of the sessions performed on the mobile application.

After this explanation, the healthcare professionals tried to perform all the tasks presented previously, exploring the application. In addition, if there were any doubts in the course of the application exploration process, the team members were around to clarify them. Thus, their experience of interaction with the backoffice web application was evaluated using the Post-Study System Usability Questionnaire (PSSUQ) questionnaire that was made available at the end of this process.

It is also important to note that all these items can be rated from 1 to 7, where 1 means that the user fully agrees with the item and 7 means that the user disagrees completely with the item.

Thus, regarding the results, it can be seen from Table 2 that the majority of the participants considered that it was simple to use the web platform (Item 1: 100% and Item 2: 83.3%), in such a way that the intended tasks were performed efficiently (Item 3: 100%, Item 4: 83.3% and Item 5: 83.3%). In addition, users were comfortable using the web application (Item 6: 100%), indicating that it was easy to learn to use (Item 7: 83.3%) and as such they believed that it could quickly become productive (Item 8: 83.4%). Regarding the graphical interface, this was considered pleasant (Item 16: 100% and Item 17: 100%), and it was considered easy to find the necessary information (Item 12: 83.3%), since the organization of this information was transmitted by the platform clearly (Item 15: 83.3%). In addition, participants felt that the information provided by the application was easy to understand and effective in helping to complete the intended tasks (Item 13: 83.3% and Item 14: 66.6%). In addition, the health professionals who participated in these tests indicated that the application provided basically all the functionalities and capabilities intended (Item 18: 100%), being generally satisfied with the tested platform (Item 19: 100%).

Table 2. Backoffice web application PSSUQ test results (%)

Question	1	2	3	4	5	6	7
1. In general, I am satisfied with the ease of use of the system	33.3	16.7	50	0	0	0	0
2. This system was simple to use	0	66.6	16.7	0	16.7	0	0
3. I was able to complete tasks and scenarios using this system	16.7	50	33.3	0	0	0	0
4. I was able to quickly complete tasks and scenarios using this system	33.3	16.7	33.3	16.7	0	0	0
5. I was able to complete tasks and scenarios efficiently using this system	0	50	33.3	16.7	0	0	0
6. I felt comfortable using this system	33.3	50	16.7	0	0	0	0
7. It was easy to learn how to use this system	50	33.3	0	16.7	0	0	0
8. I believe that I would become productive quickly if I used this system	50	16.7	16.7	16.6	0	0	0
9. The system presented error messages that clearly indicated how to solve the problems	0	0	33.3	16.7	50	0	0
10. Whenever I made a mistake using the system, I was able to recover easily and quickly	0	16.7	16.7	50	16.6	0	0

11. Information provided by the system (such as online help, on-screen messages or other documentation) was clear	0	33.3	33.3	16.7	16.7	0	0
12. It was easy to find the information you needed	16.7	33.3	33.3	16.7	0	0	0
13. The information provided by the system was easy to understand;	16.7	33.3	33.3	16.7	0	0	0
14. The information was effective to help me complete tasks and scenarios	16.7	33.3	16.7	33.3	0	0	0
15. The organization of the information that the system transmitted was clear	0	33.3	50	0	16.7	0	0
16. The system interface was nice	33.3	50	16.7	0	0	0	0
17. I liked using the interface of this system	66.7	33.3	0	0	0	0	0
18. This system has all the features and capabilities I expected	0	66.7	33.3	0	0	0	0
19. In general, I am satisfied with this system	50	50	0	0	0	0	0

Finally, observing Table 2, it can be verified that the participants only showed their disagreement regarding item 9 (66.7%), indicating that the system did not present error messages that clearly indicated how to solve the problems. However, as the team members present in these tests were not notified of problems that have occurred, this situation will have occurred due to the fact that the health professionals did not make mistakes in their actions and then they understood that they should respond in this way, being which is the same with regard to item 10 (66.6%).

Considering the items belonging to the PSSUQ, these can be grouped into 3 categories: 1) System Quality, composed by item 1 through item 8; 2) Information Quality, composed by item 9 through item 15; and 3) Interface Quality, composed by item 16 through item 19. As can be seen in Figure 1, the average of the answers (values around the classification 2.5) in the usability tests for all three categories were relatively positive, since the backoffice web application minimally satisfies almost all the categories assessed by the PSSUQ.

Taking into account that the participants were minimally satisfied with the backoffice web application and that the best expected answer in the PSSUQ is option 1, it is possible to affirm that there are still capacities to improve its usability, so that the efficiency of the work performed by health professionals increases. As such, feedback suggestions were collected from the participants during these usability tests.

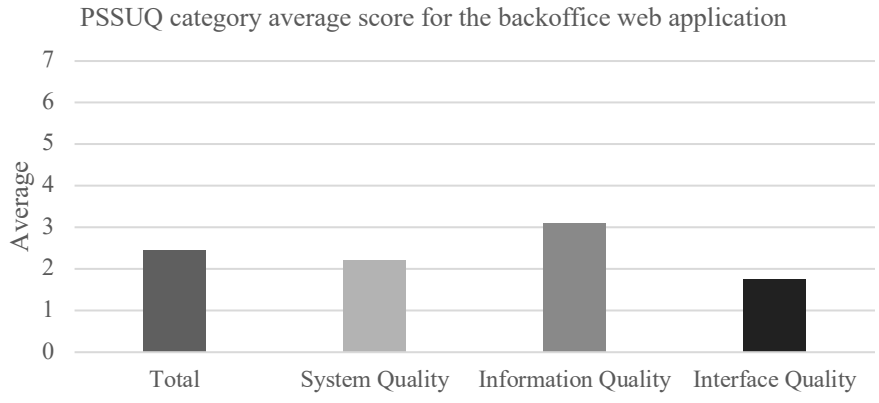

Fig. 1. PSSUQ scores for the backoffice web application of the Digi&Mind platform.

3.3.2. Mobile application

The process of performing usability tests related to the mobile application is initiated by placing the tablet in front of each participant individually, explaining very briefly what the developed application is for. Then two team members follow each participant during the testing process: one plays as interviewer and implementer roles and the other plays the observer role.

The interviewer and implementer take on the role of asking the participant to perform certain tasks, while helping the participant to continue the test in case s/he gets lost in the application or is not able to do some feature. On the

other hand, the observer checks and reports the participant's actions in order to obtain information such as: The time taken to complete the task; if the older adult followed the expected path; comments and older adults' expressions; number of wrong clicks made by the older adult and what did the user expect the application to do when older adult was feeling lost.

As such, the team members proposed a set of tasks considered as the most important ones in the interaction with the mobile application, which the participants would have to try to perform. These were:

- Task 1 - Create older adults' profile (4 healthcare professionals);
- Task 2 - Perform sessions 1 and 2 (4 older adults);
- Task 3 - Consult results for sessions 1 and 2 (4 health professionals);

Eventually, after completing all the intended tasks, the participant would have to respond to a short questionnaire so that team members could see if the application was clear, intuitive, and easy to use, as well as to get some suggestions for improvement. The questionnaire consisted of the following questions:

- How much time did you spend in the application until finding it easy going?;
- Did you find the navigation flow simple and easy to use? If not, why?;
- Did you find the questionnaires area? If yes, where?;
- Did you find the messages area? If yes, where?; and
- Additional observations and comments.

The results obtained from the usability tests performed on the mobile application reflect great differences in the use of day-to-day applications between the two types of participants. In Tasks 1 and 3, all health professionals revealed great ease in using the application, finishing them relatively quickly (Figure 2, left). Additionally, all of them performed these tasks following the expected path and did not make a single wrong click (Figure 3, right). However, one of the four healthcare professionals was confused in the accomplishment of the Task 1 (Figure 3, left).

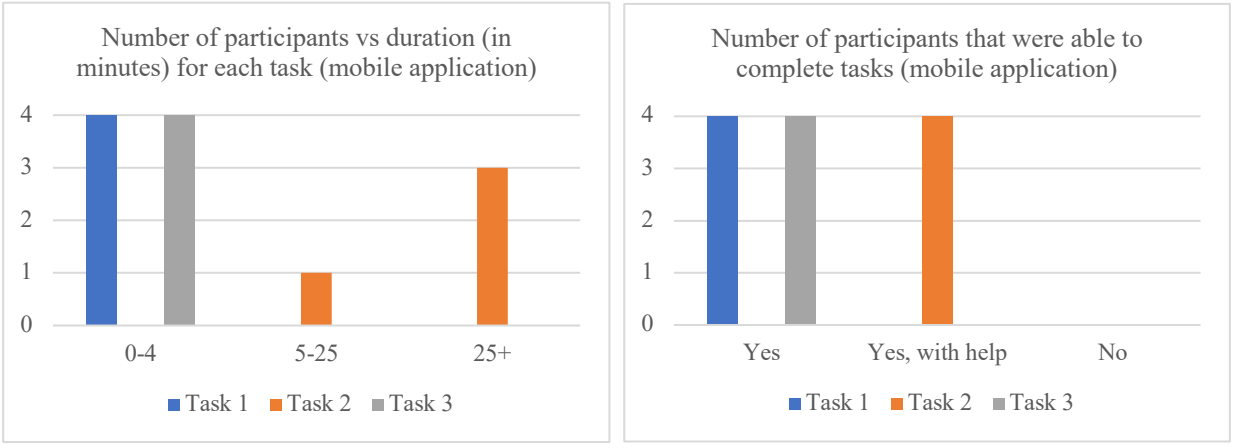

Fig. 2. Mobile application usability scores: number of participants vs duration for each task (left) and that were able to complete the tasks (right)

In relation to Task 2, executed by older adults, it was possible to identify that only 25% of them had already previous contact with this type of technology (Figure 3, left). 75% were afraid to touch the tablet screen and had difficulty in using it, requiring more than 25 minutes to perform Task 2 (Figure 2, left). However, all participants were able to complete Task 2 with the help of the interviewer / implementer (Figure 2, right). Therefore, it is possible to state that the application is minimally intuitive and ready to be used by individuals with no experience.

Finally, during the execution of Task 2, there were some wrong clicks due to the difficulty of this group of participants in the use of the tablet (Figure 3, right). Some participants wanted to click on the correct object but ended up clicking the wrong one.

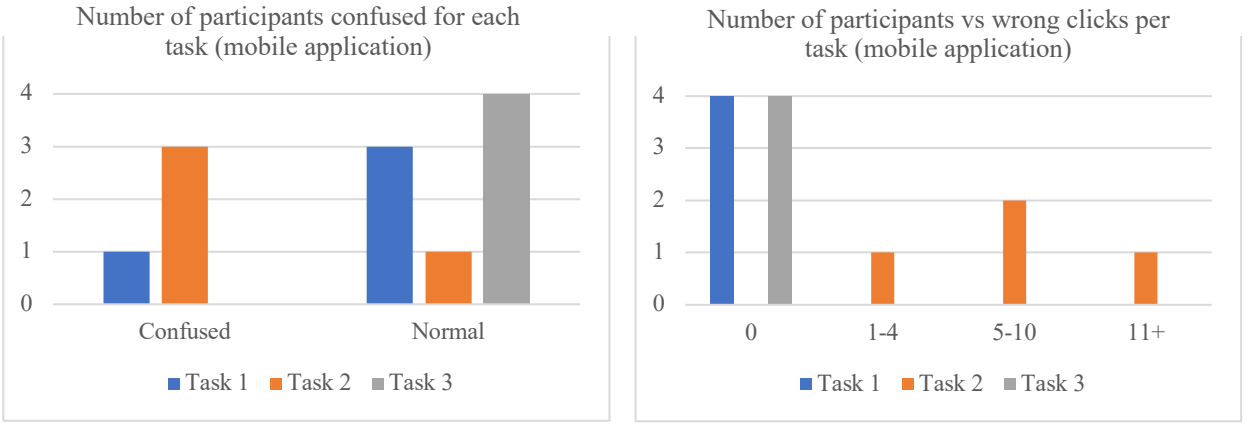

Fig. 3. Mobile application usability scores: number of participants confused per task (left) and number of wrong clicks per task (right)

4. Conclusion

Digi&Mind emerges as a new contribution to the geriatric clinical practice, since its basis is sustained by theoretical, structured and validated evidence related to cognitive and complex interventions. Through the development of this digital cognitive stimulation program the research team intended to give a response to the challenge of an increasing aged population by allying e-health to the ageing process.

Digi&Mind passed already through phases I, II and III of the adopted methodology. The first two phases revealed to be important, once conceptual and theoretical aspects of ageing and cognitive interventions were allied to older adults' digital guidelines for software development. The critical evaluation, provided by specialists in the area of cognitive interventions, resulted in a well-founded and structured intervention to be applied in older adults with cognitive decline. Throughout these phases, it was possible to gather different opinions and evaluations from specialists of the area of cognitive interventions and software developers that definitely were crucial to improve the digital transformation of the developed cognitive stimulation program, assuring as much as possible the program's therapeutic potential regarding cognitive decline.

In phase III, the backoffice web platform and the mobile application that resulted from the digital transformation were tested by healthcare professionals and older adults. During this phase, interviewers and observers identified some older adults' difficulties that were mainly associated with lack of digital literacy when they were testing the mobile application. These difficulties were associated to the fact that some of them were using a tablet for the first time.

However, overall usability results indicate that Digi&Mind was well accepted by both healthcare professionals and older adults. Both referred to the program as useful and interesting. Quantitative results proved useful for identifying small improvements. The interviews with professional users (backoffice and mobile application) and elderly users (mobile application) have contributed to the understanding of the advantages and possibilities for improvement.

During the usability tests, several aspects were pointed out regarding some digital mechanisms and graphics appointments regarding screen presentation.

All the issues, suggestions and contributions that resulted from the previous phases will then be synthesized in phase IV, where it is expected a final product proposal. On a consensus basis, experts and potential program users see this type of intervention as relevant and necessary. As usability tests were performed with healthcare professionals and older adults, future usability tests should be performed in order to analyse caregiver's digital performance.

Digi&Mind is based on the Ambient Assisted Living logic. It is supported by evidence-based practice and enhances the economic and environmental sustainability of non-pharmacological interventions for cognitive decline. The program developed, besides stimulating several neurocognitive domains, it also potentiates the elderly person for the

activities of daily living. It could be considered as an aid to motivational engagement on participatory health and improvement of participants' depressive symptomatology.

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