Towards Digital Therapy for Alzheimer's Disease and Other Forms of Neurocognitive Disorder: the INFORMA Software Platform

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ABSTRACT

In this paper, we present the INFORMA software platform, designed to administer therapy to people with a neurocognitive disorder (NCD). The platform includes an app for tablets through which people with NCD can access, while at home, personalized activities based on a pool of twenty multisensory serious games. The activities follow the Cognitive Activation Therapy rehabilitation protocol. The platform also includes a web application through which therapists can customize activities, assign them to patients, and, thanks to the telemetry collected by the app, monitor their progress. A key advantage of a platform like INFORMA lies in the fact that home therapy can last longer and reach more people. Further innovations of INFORMA lie in its activities, in the number of such activities, and in the customization options. Indeed, to the best of our knowledge, the flexibility and scale for which INFORMA has been designed, in terms of activities and users (people with NCD and clinicians), are unprecedented in the open literature. Addressing this scale required a specialized design. In the paper, we also present preliminary data on the use of the app by a first group of people with NCD.

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CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**; • **Applied computing** → **Consumer health**; *Health care information systems.*

KEYWORDS

neurocognitive disorder, dementia, Alzheimer's disease, digital therapy, cognitive stimulation, serious games, mobile devices

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1 INTRODUCTION

Dementia, renamed Neurocognitive Disorder (NCD) in the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders, is a clinical syndrome that gradually and irreversibly impairs cognitive functions and functional abilities. NCD is one of the leading causes of disability worldwide and carries a great emotional, social and financial burden [16]. In 2012, the World Health Organization defined research in this area as a "global priority" [7]. In the early stages of NCD, cognitive functions are partially preserved and, particularly in Alzheimer's disease, they are susceptible to stimulation and rehabilitation. In the context of cognitively oriented treatments, psychosocial and rehabilitation interventions have been studied

and, among them, cognitive stimulation has shown consistent evidence of efficacy [3, 17] in improving the cognitive status and quality of life of people with dementia (PWD). In recent years, international associations led by PWD have been calling for access to rehabilitation as a right for people living with this diagnosis [12]. However, the spread of cognitive stimulation and rehabilitation is currently limited by cultural, geographical, social and economic barriers [14]. Furthermore, there is still a lack of interventions for people diagnosed before the age of 65 (Young Onset Dementia, also referred to as YOD).

To extend cognitive stimulation and rehabilitation to as many PWD as possible, innovative solutions are needed. In this direction, technology and telerehabilitation are tools that can potentially benefit people with NCD and their caregivers [9] by expanding the number of people who access rehabilitation pathways. The use of digital technologies makes interventions in the living environment of PWD possible, overcoming limits and barriers. The need for innovative tools for continuous, long-distance assistance has been further increased by the SARS-CoV-2 pandemic. Currently, there is still a lack of understanding of the needs of PWD related to the use of telerehabilitation. As we move towards an inclusive society, and the use of software applications or ubiquitous "apps" and devices becomes an integral part of everyday existence, there is an implicit need to design digital systems that can be used by everyone, regardless of their physical or cognitive abilities and impairments. It is therefore important that the design and development of digital systems and apps formally involve the intended target user group, and that their contribution is highlighted in the usability protocols.

In this scenario, the INFORMA project developed a software platform for the cognitive stimulation of PWD in the early stages of the disease, including younger people living with YOD. The platform is based on a cognitive-communicative stimulation protocol called Cognitive Activation Therapy (CAT). The creation process, although not entirely systematic, borrowed from participatory design: the platform was devised by a multidisciplinary team together with PWD and their caregivers, with the aim of including a larger number of PWD in personalized cognitive stimulation programs, supporting and maintaining their cognitive-functional abilities, and providing clinicians with an adaptive, person-centered tool.

The rest of the paper is organized as follows. Section 2 recaps the state of the art on software tools for cognitive stimulation. Section 3 elaborates on the principles and objectives of the INFORMA project, which are introduced in [10], and summarizes the advantages provided by the INFORMA software platform over the state of the art. Section 4 provides details about the software platform. Section 5 presents preliminary data on the use of the cognitive stimulation app, which is part of the platform, by a first group of people with NCD. Section 6 concludes the paper with some final remarks and directions for future research.

2 STATE OF THE ART

Software tools for people with NCD have received significant attention in the open literature. As far as software tools for cognitive stimulation are concerned, however, the number of studies that had a significant impact on the scientific community seems limited. A 2021 survey found only nine highly cited papers on the topic, with the least cited paper in the shortlist collecting 14 citations [11, Table 5]. Actually, four of the nine papers are older surveys. The remaining five studies are not comparable to ours, chiefly because they do not target mobile devices (indeed, some studies adopt devices that are no longer for sale, e.g., Microsoft's Kinect or Nintendo's Wii), or do not target cognitive stimulation at home, or both. Not content with these findings, we did our own literature search and found some works, specifically targeting mobile devices, that, we believe, should be mentioned.

In [19], the interesting approach is taken of investigating the potential of virtual reality with a tablet-based game called Virtual Supermarket (VSM). As the name suggests, VSM asks the player to enter a virtual supermarket, locate items provided on a shopping list, put them in a virtual basket, and pay at the virtual cash desk. Even if the study also involves people with Mild Cognitive Impairment (MCI), its aim is to investigate whether MCI subjects can be distinguished from healthy older adults through their in-app behavior, hence the aim is different from ours.

The paper [6] documents the adaptation for Android tablets of a pre-existing, non-computerized cognitive stimulation therapy. The therapy consists of fourteen sessions, each comprising an introductory video, then one of four games, and, in the end, the activity of the day. Unfortunately, the games and activities are completely undocumented.

In [18], an app called Stim'Art is introduced. Similarly to the INFORMA app, Stim'Art incorporates a usage tracking module that sends data to a remote server for later analysis. Details about the games themselves are, again, very scarce, and, most importantly, the users enrolled in the study were not PWD.

Similarly to INFORMA, in [4] experts from different domains are involved in the design of an app with notable attention to theoretical principles. The final prototype, named Brain Win, includes six games organized into four types of cognitive tasks: discrimination (three games), visuomotor, respelling, and calculation (one game each). Differently from the previous papers, game mechanics are thoroughly documented and screenshots are provided. An evaluation of the prototype was performed with five older adults. However, none of them was living with NCD.

In [8], a novel game for iPads is developed with the aim of improving episodic memory in people affected by amnestic MCI; hence, the therapeutic goals are more limited than in INFORMA, with a very specific cognitive area targeted by a single game. The game asks the player to associate different geometric patterns with different spatial locations. The development process was based on the collaboration between psychologists, a game developer, and older adults, both affected and unaffected by MCI. The experiments showed that, after eight hours of gaming, the test group exhibited a statistically significant higher score than the control group (twenty-one people with MCI in each group) in the first trial memory score on the CANTAB PAL test.

The iBeni app [5] is designed to stimulate a wide range of cognitive areas: memory, attention, comprehension, perception, and visual-spatial processes. As for the INFORMA platform, particular care was paid to the characteristics of elderly people: for instance, the user interface adopts only large elements, which are easier to interpret and tap. However, the number of different games is much lower than in the INFORMA app, and the games are based only on

visual stimuli. The iBeni app faced a pilot test with 22 elderly adults who did not live with NCD.

The ElasticaMente tablet-based app [13] was developed for mental training in the domains of memory (five games), attention (four games), and logical thinking (six games). No details about the games are available: the focus of the authors is on evaluating and reporting the efficacy of the app. Furthermore, people with a confirmed diagnosis of neurodegenerative disease were excluded from the experiments by choice.

All in all, we can say that none of the aforementioned studies perfectly matches the objectives of INFORMA, because the games are developed for a different or more limited purpose or they do not target PWD. Furthermore, none of the software applications described in such works matches the flexibility and scale of INFORMA, chiefly in terms of the number of games and customization options; details supporting this statement will be provided in Section 4.1.

3 THE INFORMA PROJECT

The INFORMA project is animated by a multidisciplinary team that includes PWD, neurologists, geriatricians, speech therapists, psychologists, engineers, and designers. The rehabilitation protocol followed by INFORMA belongs to the area of *cognitively oriented treatments*, which refers to a group of non-pharmacological treatments for PWD that stimulate thinking and cognition at different levels of depth and specificity. More specifically, INFORMA embraces the Cognitive Activation Therapy (CAT) rehabilitation protocol [3], developed at the Clinical Regional Center for the Aging Brain (CRIC) in Padua, Italy, since 2001. The activities provided by the protocol cover every cognitive domain, but are organized by semantic topic. Topics are potentially unlimited in number and move from patient's personal interests and therapeutic needs. For example, if a patient is interested in food and cooking, stimulation activities can semantically refer to this topic and stimulate different cognitive domains at the same time. Following CAT, the INFORMA software platform consists of two main modules: a tablet app for PWD, which provides interventions with a Plan - Do - Check - Act model, and a web application through which therapists can modulate the therapeutic pathway analyzing patient's performance and interests, fostering engagement, adherence to therapy, and the consequent reduction of dropout phenomena. Further technical details on the platform will be provided in Section 4. In what follows, we briefly elaborate on the principles and objectives of INFORMA and summarize the advantages provided by the platform.

The INFORMA software platform has been conceptualized [10] to offer novel forms of cognitive stimulation to PWD, to assist people who cannot reach the clinic, and to provide clinicians with the ability to plan customized therapeutic pathways, quantitatively monitor results, and keep in touch with PWD. In the INFORMA platform, these principles originated novel activities that exploit the features of mobile devices, a tablet app that can be used by PWD at home while unobtrusively collecting performance data, a web application to customize the activities, a dashboard to look up performance data, and a bidirectional messaging system. As sketched in Section 1, using a software tool to administer therapy leads to several advantages, which are achieved by the INFORMA platform for CAT. First of all, therapy can be offered to a larger number of people, including people living with YOD. Moreover, the therapeutic offer can be expanded, that is, more sessions can be offered to each person than possible with a conventional approach. Autonomy and self-management in PWD are fostered as PWD become an active part of their therapeutic pathways. Lastly, the fact that PWD – also those unfamiliar with IT tools – learn how to use a software application promotes an educational approach. Furthermore, the INFORMA platform provides additional advantages over other software solutions documented in the open literature.

- The platform adopts tablets, which are a better choice than other hardware tools: they are easier to operate than personal computers, easier to carry than laptops, and less expensive. Moreover, tablets fit older adults' visual abilities better than other mobile devices such as smartphones [4] due to the larger screen. They are also ideal for home use, promoting rehabilitation in the context of daily life, and reducing medicalization.
- The platform includes innovative therapeutic activities using multisensory channels (sight, hearing, touch) that exploit the features of mobile devices.
- The platform allows therapists to customize activities and create person-centered therapeutic pathways based on personal interests, adjusting the level of difficulty, help, and intensity of treatment and language. Activities can be designed in all languages that adopt an alphabetic writing system.
- The platform is designed to be used by several groups of therapists, even in different locations, with separate groups of PWD.
- Therapy progress can be monitored remotely via telemetry data collected through the platform.

The significant amount of performance and usage data collected has implications beyond progress monitoring. In fact, such data will be the source of future research on the effectiveness of the treatment, either for a single person or, in aggregate form, for groups of PWD.

4 THE INFORMA SOFTWARE PLATFORM

As discussed in Section 3, the INFORMA platform was designed so that therapists can administer personalized CAT sessions to PWD, interact with them during therapy, and monitor their progress. To fulfill these functions, the platform provides two main modules: one targeting PWD (*Training Module*), and one targeting therapists (*Planning Module*).

The Training Module consists of an app for mobile devices (tablets) that makes CAT activities defined by therapists accessible to PWD through intuitive and functional interfaces. Furthermore, the app logs data on patient performance, data that are then sent to the Planning Module when a network connection is available. It should be remarked that the app does not take automated decisions, e.g., it does not dynamically adapt the difficulty level of activities without the intervention of a professional [8]. The therapist is front and center in every decision about therapy. Finally, the app offers a bidirectional communication channel with PWD; both text and audio messages can be exchanged.

The Planning Module allows therapists to customize and combine different activities to create personalized pathways that meet both the rehabilitation needs and the tastes and preferences of

PWD, in order to maximize acceptance and effectiveness. Furthermore, the Planning Module displays the data collected by the app, in order to offer each therapist an up-to-date and timely summary of the situation for her patients. Therefore, the therapist can evaluate the effectiveness of the therapy and modify it if necessary. Finally, the Planning Module allows a therapist to export the data in anonymized form for statistical studies on the evolution of neurodegenerative diseases.

4.1 Training Module: an App for CAT

So far, twenty different activities have been devised in the INFORMA project and are available in the INFORMA app for tablets. Some of them are an evolution, in tablet form, of activities (hence the name) that CRIC is carrying out with PWD during conventional CAT sessions managed by a therapist. The other activities are novel, in whole or in part. By all means and purposes, the activities are serious games, which are defined as games that have an additional goal besides entertainment [15], or as applications that incorporate elements of game design in non-game contexts [2]. In what follows, we first provide the name of the activities together with a one-line description. Then, we provide details on prominent features of the activities, with the aim of illustrating the possibilities for customization that have been implemented and, where appropriate, the exploitation of the features of mobile devices. Lastly, we list the data collected while the activities are carried out, for monitoring purposes and for off-line analysis. Although the usefulness of telemetry in software is well known, we explicitly mention that the data collection process is another aspect in INFORMA that leverages on the computerized approach. Indeed, it would be impossible to manually collect the data logged by the app.

Twelve of the twenty activities are in use during non-computerized CAT sessions at CRIC, and have been ported in tablet form with the innovation of supporting multimedia data, where possible.

(1) *Guided Conversation*: personal preferences are expressed in a guided way by answering a series of questions.
(2) *Crossword Puzzle 1*: a classical crossword puzzle, with words aligned over a square grid.
(3) *Crossword Puzzle 2*: a crossword variant in which each row contains a single word. Upon completion, a new word appears in a specific column.
(4) *Quiz*: a series of questions must be answered. There are right and wrong answers.
(5) *Transforming Words*: the letters in a specific word must be used to form other meaningful words (Fig. 1).
(6) *Sort The Proverb*: a series of words must be sorted in the correct order to form a proverb.
(7) *Arranging Money*: banknotes and coins, or items, must be sorted by value.
(8) *Shopping*: the correct amount of money to buy a set of items must be selected.
(9) *Estimate The Value*: the value of an item must be estimated, either by placing it in a price category or by choosing an appropriate amount from a list.
(10) *Mandala*: the white areas of a black-and-white geometric figure can be freely colored.

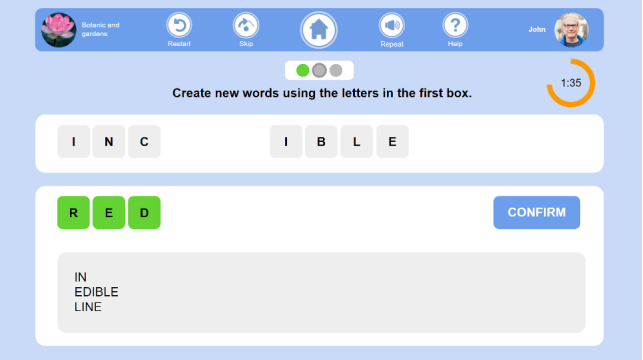

Figure 1: A session with the Transforming Words activity.

(11) *Find The Word*: a single definition is given and the corresponding word must be provided.
(12) *Classify*: provided stimuli (textual, visual, auditory) must be classified into two categories, e.g., images of fruits must be separated from images of vegetables.

Three of the twenty activities were previously in use but received some form of innovation in the digitization process.

(13) *Jigsaw Puzzle*: a classical jigsaw puzzle. Tiles are square.
(14) *Find The Intruder*: the intruder in a series of similar entities must be pointed out. The entities can be words, pictures, or audio excerpts.
(15) *Look For The Detail*: one or more details must be located in a complex image (e.g., a pear in a still life).

The main innovation in Jigsaw Puzzle is the possibility of having distractors, that is, tiles that are not actually part of the solution. The novelty in Find The Intruder is that the entities can be audio or video stimuli. The innovation in Look For The Detail is a contextual hint system that highlights the zone where a detail is.

Five of the twenty activities are completely new.

(16) *Insights*: a collection of activities (reading excerpts, listening to music, watching videos) that require no interaction.
(17) *Describe The Picture*: the person with NCD is asked to name objects, colors or actions in the given picture.
(18) *Mobility Training 1*: an object falls from the top of the screen and must be collected in a basket at the bottom. The basket is moved horizontally by tilting the mobile device.
(19) *Mobility Training 2*: an object must be guided along a path to reach a destination. The object is moved horizontally and vertically by tilting the mobile device.
(20) *The Adventures Of*: a story composed of multiple activities on the same topic. For example, one chapter of the story may ask the person with NCD to locate Venice on a map, and the next chapter may ask her to calculate the change for a train ticket to Venice.

Mobility Training 1 and Mobility Training 2 have been specifically developed for tablets and exploit the accelerometer enclosed in such devices. All twenty activities profit from the touch screen of the tablet as an interaction medium. For instance, in Sort The Proverb the words can be rearranged by touching and dragging them. Similarly, in Classify the stimuli are moved by dragging

them to predefined areas of the screen. A custom, simplified virtual keyboard was designed for the activities that need text input.

The computerized medium makes it possible to simplify the user experience, and care was applied to reduce the cognitive burden for PWD. For example, in Crossword Puzzle 2 a definition disappears once the corresponding word has been placed on the grid. The user interface also makes it easy to change an answer or correct mistakes. In Mandala, changing the color of an area is just a matter of tapping a different color on the palette, and an eraser function is also available. In Sort The Proverb, when a word is positioned incorrectly, it automatically moves back to its original location in the list of available words. For the fifteen activities that are also available at CRIC in physical form, correcting mistakes has generally become easier in the tablet version.

All the activities are augmented with an on-demand help system. All the activities offer the possibility of both reading and listening to a description of the task that must be performed.

All the activities support the possibility of defining, via the Planning Module, different variants (referred to as *repetitions*) with different data. For instance, in Jigsaw Puzzle it is possible to associate different repetitions with different pictures that must be recomposed from tiles. Repetitions can be further organized into *themes*. For example, an assignment on the theme "food" can include a Crossword Puzzle 1 repetition with names of foods, a Shopping repetition where groceries must be purchased, and so forth. The person with NCD is asked to select from the available themes when the app starts. Some activities – those where the option makes sense – offer the opportunity of *skinning*, through the Planning Module, the presentation of the activity itself, to achieve conformity with the theme presented to the PWD. For instance, in Mobility Training 2 the moving object can be any image (e.g., a biscuit, to continue the previous example) chosen by the therapist. All the activities benefit from the opportunity, made available via the Planning Module, of customizing key activity parameters on a per-person basis. For instance, in Mobility Training 1 the therapist can customize the speed and size of the moving object, in Jigsaw Puzzle she can customize the number of tiles, and so on. All in all, we can say that, from a methodological as well as from a technical standpoint, the presentation of an activity is decoupled from the activity mechanics, and the former can be heavily tweaked by the therapist via the Planning Module.

The main data collected by the app are as follows.

- Completion status.
- Time spent on each repetition.
- Number of errors.
- Number of times the help system has been invoked.
- Number of times each assigned repetition has been restarted.
- Rating: after selected repetitions, the person with NCD can express her appreciation on a three-level scale.
- Activity-specific parameters (e.g., speed of the moving object in Mobility Training 1).

The app is implemented with the Angular framework, which allows it to run on both Android tablets and iPads. The activities are implemented with Bootstrap, therefore using CSS, HTML and JavaScript as languages. Each repetition is sent to the app as a container that packs the repetition-independent code and style sheets together with the multimedia resources and activity parameters, which are repetition dependent. This technical choice makes it possible to assign new repetitions, or even add new activities to INFORMA, without updating the app. The app can operate even without an Internet connection, postponing data synchronization to a time when connectivity is restored.

4.2 Planning Module: the CMS

To complement the Training Module – namely, the tablet app – dedicated to PWD, the Planning Module has been developed for the therapists in charge of the therapeutic pathways. The Planning Module is also known as CMS for *Content Management System*, because it fulfills the purpose of making data manageable by clinicians. The data we are talking about are the multimedia resources associated with the activities, the definitions of the repetitions, the messages exchanged with the PWD, and the performance data described in Section 4.1.

Two types of staff are supported by the Planning Module: *therapists* and *administrators*. A therapist manages the registry of her patients, defines repetitions and assigns them to PWD, uploading or reusing multimedia resources as appropriate, monitors the progress of PWD with assigned repetitions, and handles the conversation with PWD. An administrator manages the registry of her therapists and also has access to a full log of all the interactions they perform with the Planning Module. The Planning Module can handle multiple administrators, in charge of different groups of therapists, so that the software can be used in multiple sites while protecting the data at each site. Isolation of patient data is fully enforced (namely, each therapist can only see the data of her patients), while isolation of multimedia and repetition data is not: in other words, multimedia data and repetitions inserted by a therapist are visible to colleagues as well, so that they can be reused. Patient data can be exported in CSV format, both in full and in an anonymized form that is suitable for data sharing.

The Planning Module is a reactive web application, compatible with the major browsers available on the market. The user interface targets desktops PCs and laptops; it is implemented with the Angular framework, hence it relies on the TypeScript, CSS and HTML languages. Hosting is entrusted to a dedicated server; some details are provided in Section 4.3.

4.3 Backend

The Backend is an auxiliary piece of software that is required to manage the simultaneous use of the Training Module and the Planning Module by several PWD and therapists. Both the Training Module and the Planning Module adopt the client-server model, with the Backend being the server. The Backend stores repetitions and sends them to tablets. It also stores messages, and data collected by the tablets. The Backend also serves the web pages of the Planning Module to therapists and administrators, so that they can perform the tasks described in Section 4.2 wherever a web browser is available.

The Backend is implemented in TypeScript and runs in a Node.js execution environment relying on a MySQL database for data storage. Access to the server features takes place via predetermined

routes. Communications take place via HTTPS, and access is protected by an authorization protocol based on JSON Web Token credentials issued at the time of login. The execution environment and the database are hosted on the AWS cloud computing platform.

5 EXPERIMENTAL RESULTS

So far, the INFORMA platform has been tested with a restricted number of therapists and a pilot group of seventeen PWD, who used the INFORMA app at home, assisted by fifteen caregivers (two PWD did not have a caregiver) for four weeks. Seven PWD were male and ten female, with an average age of 70.5 years (min: 64, max: 82). PWD were in the mild to moderate stage of NCD at the time of experimentation. To learn how to use the INFORMA app, PWD and caregivers attended one or two training meetings with a speech and language therapist (average number of meetings: 1.8). During the four weeks of usage, the PWD received a daily number of repetitions (from Monday to Friday) organized on weekly topics.

At the end of the four weeks, PWD and caregivers completed questionnaires designed to measure their experience. Both questionnaires included questions about the relationship with technology before and after experimentation, questions about the user experience with the Training Module, and questions about the experience at large. The questionnaire for caregivers also included questions about the assistance provided to their relatives. We do not provide the full list of questions due to space limitations. The questionnaires were custom designed: we are aware of the implications [1], but the aim of the test was to collect specific feedback about the INFORMA platform, not to compare the platform with other tools. In addition to the questionnaires, the app collected four weeks of telemetry data. Telemetry from two of the PWD is better ruled out: due to their therapeutic needs, such PWD were assigned slightly different repetitions.

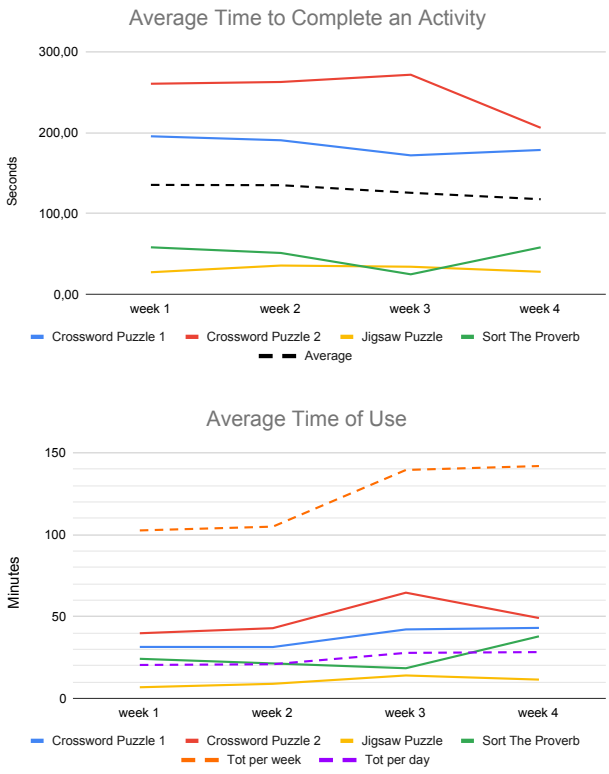

Figure 2: Experimental results from in-app telemetry. Top: average time to complete an activity. Bottom: average weekly time spent with all assigned repetitions.

Relationship with technology. From the results of the questionnaires, before the test approximately 29% of the PWD were afraid of using technology, and 71% of them had never used a tablet before the INFORMA experience. However, all but one of them reported that they were more comfortable using the tablet at the end of the testing period than at the beginning, and considered the tablet a functional / easy-to-use device. All the PWD felt their autonomy in using the tablet growing week after week, and less than a quarter of them reported that they needed assistance "often" or "always". In their answers, caregivers agreed on the growth of autonomy, but their perception was skewed toward higher involvement: 43% of them reported that their relatives always needed assistance, and 14% that they often needed it. Approximately 86% of the caregivers reported that assistance during the usage of the INFORMA app allowed them to better understand how to help their relatives during daily life. 65% of the PWD never felt uncomfortable during the testing weeks, although 71% of them encountered some difficulties with the activities. All the caregivers but one never felt uncomfortable during the experience.

Evaluation of the Training Module. From the results of the questionnaires, all the PWD and caregivers considered the opportunity to use the app from their home environment as an advantage. 59% of the PWD regarded the repetitions assigned through the INFORMA app as "good", and 29% of the PWD regarded them as "very good". In corroboration with such answers, 53% of the PWD rated their entire experience as "good", 24% as "very good", and 23% as "excellent". On a scale of 1 to 10 (1 = minimum, 10 = maximum), 82% of the PWD gave a score of at least 8 to their appreciation of the experience as a whole. 71% of the caregivers found it "very useful" to see their relatives involved in the INFORMA experience. All the PWD and caregivers involved in the experimentation would repeat the experience and would recommend it to other people. Even if the usage of the INFORMA app required time and effort from PWD and caregivers, both reported interest in continuing the experience for a longer period, with a greater number of repetitions per day.

Analysis of telemetry data. As shown in Figure 2, the average completion time for each activity decreased during the testing weeks. This effect may be related to the acquisition of skills while using the INFORMA app and completing the repetitions. In Figure 2 it is also possible to observe an increase in the average time of use during weeks 3 and 4. The increase is influenced by the number of repetitions provided by the therapists through the INFORMA app: in weeks 3 and 4 the number increased, and so did the time of use. All PWD completed more than 95% of the repetitions assigned to them except one, who started late because a peculiar memory difficulty hindered the recognition of the assigned therapy at home.

However, the consistency of the time of use during the weeks of testing indicates a high level of adherence to therapy.

6 CONCLUSIONS

In the INFORMA project, the synergy of multidisciplinary competences has led to a software platform for cognitive stimulation of PWD. The contents of the stimulation can be flexibly adapted to match users' abilities and preferences. The software is an alternative/integration to in-presence interventions, reaching people in their homes while making remote interaction and remote performance monitoring possible. The platform shows innovation in the activities proposed to PWD, in the possibility of customization, in the number of PWD and therapists who can access it from different locations, as detailed in Section 4. Unlike other software tools in the open literature, the INFORMA platform has been designed for effective, actual deployment at scale. In this sense, the platform can be considered a step toward making digital therapy for PWD a reality.

After the tests with the pilot group, the INFORMA project has secured the favorable opinion of the Clinical Ethics Committee of the University Hospital of Padova. An evaluation is now underway for a wider deployment of the software platform. We believe that home care must become an integral and significant part of the treatment of PWD: to this end, the future objectives of the INFORMA project are in the following directions.

- **Feasibility:** a wider-scale test than the pilot described in Section 5 must be completed on the practical aspects of carrying out, in digital form, CAT activities at the patient's home, with the support of a caregiver. Such a test may also reveal scalability issues, chiefly in the Planning Module, that are not apparent at the current scale of experiments. At the same time, it is necessary to quantify the impact on caregivers and families of PWD, that is, the additional burden imposed on them, the usefulness and limits of participation, and the consequences on their health (stress).
- **Effectiveness:** a trial must be performed to determine if the clinical results documented for paper-and-pencil activities are reproducible with the software platform.
- **Usability:** the platform requires technical prerequisites (e.g., availability of hardware resources) and training for all involved people (PWD, caregivers, clinicians). Experiments are required to understand to what extent these factors affect the adoption of the platform, and what improvements can be implemented.

Some of the aforementioned experiments are in progress, with the support of a person with NCD who was in the pilot group and volunteered to coordinate PWD willing to collaborate throughout the project.

As a final remark, all ongoing and future experiments offer the opportunity to collect increasing amounts of telemetry data, which will pave the way for additional research activities on data analysis and pattern discovery with data mining techniques.

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