Community Based Activity Center to support independently living elders

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Abstract

A novel platform that integrates an activity center and a virtual community is here described. It is part of a heterogeneous system aimed to provide monitoring, stimulation and assistance at the point of need to independent living elders, especially those who are at risk of falling into frailty. Combination of specific technological components has allowed to achieve a modular, responsive and dynamical design of the interfaces and their behaviors making their use natural. The explicit request to do activities with peers makes this platform a natural social engine. Preliminary results from use at home are reported and discussed.

Keywords

Monitoring, Community Based Activity Center, Cognitive and Physical decline indexes, Smart objects, Artificial Intelligence, Virtual Caregiver, Web technologies

1. Introduction

Counteracting physical and cognitive decline is becoming one of the top priorities of Health and Social providers, such that the longer life that we are currently enjoying, can go hand in hand with a good life. To this aim, three areas of intervention can be identified: monitoring (to early detect decline and to detect hazards and critical events), assistance (to let the elder be at ease in his/her own house) and stimulation (to avoid isolation and falling into depression, which is one of the critical issues [1]). ICT is providing several instruments that can be exploited to this aim, but no one has become yet the "Holy grail" to really improve later Human life. Several attempts have been made to improve in one of the three areas, but a few target and intervention over 360 degrees. Among such approaches, Movecare [2, 3, 4] had the goal to integrate several ICT components to provide a heterogeneous, modular and integrated platform that addresses the three areas; it is constituted of a service robot, smart objects connected into an IoT network to which domotic sensors are also connected, a virtual community and an activity center and a virtual caregiver endowed with artificial intelligence that is embodied inside the robot and orchestrates the platform (Figure 1). Such system can offer several key functionalities. It can answer call for helps inside the house combining a set of smart microphones, especially designed for a robust detection of calling for help, with the service robot that navigates to the

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user and start a video-communication with the caregiver. This functionality was maximally appreciated as gives the elder a sense of safety inside his/her house. The robot is able also to locate lost objects inside the house by RF-ID (radiofrequency tags), through a pair of stereo-antennas. Lastly, it asks spot questions to the elder designed to test orientation in time and space, memory to concur in drawing a picture of the elder state (monitoring functionality). A domotic network allows to gather information on the user behavior (e.g., hours in bed, watching TV, ...) to profile the elders habit. This is used to tune the intervention by the Virtual Caregiver with educated suggestions on one side, on the other side to provide the caregiver with the profile to better promote an active aging [5]. The virtual community and the activities are supported by a Community Based Activity Center (CBAC). This is a platform that supports several cognitive and physical activities that have to be carried out with peers. It has therefore the overt role of stimulating the elder physically and cognitive, and the cover role of stimulating socialization. It supports also monitoring support in two ways. First it supports a set of classical neuropsychological tests (Bells [6] and TMT [7]) that have been ported to tablet for home use. The integration of a virtual neuropsychologist that guides into the test embodied by the robot allows to have a reliable result[8]. The second way is by providing exer-games that can be carried out with smart objects to measure specific quantities related to frailty [9]. In particular an exer-game associated with a smart anti-stress ball has been developed to measure maximum grip force [10], as an alternative to clinical tests based for instance to Jamar accelerometer [11]. Moreover, the log of the elder interaction with the platform provides valuable data for monitoring. Its design and development will be described here.

2. Community Based Activity Center

The design of an effective Community Based activity center has to start from elders needs. And this was indeed the case [12]. A proper mix of activities suggested by elders themselves and by caregivers have been identified and prioritized according to the feasibility of their implementation. In particular, the final list of activities implemented comprehends: a puzzle game, a word game, , a drawing game, two cards games (scopa and briscola), and a set of four exer-games. The choice of the card games is motivated by their diffusion in the south of Europe. We have also added gentle exercises for mobility and strength. Finally an application explicitly designed to promote outdoor activities has been provided.

2.1. CBAC Architecture

The CBAC has been explicitly designed and developed to invite elders to do cognitive and physical activities with peers, to provide socialization.

The CBAC follows a Model View Controller (MVC) architectural paradigm in which different interacting applications, each responsible of a specific functionality provided to the user, are organized.

Software has been developed having modularity and open source in mind. It has been designed as SaaS (Software as a Service). It is based as much as possible on Open standards (e.g., WEB-RTC). The general architecture is a classical client-server architecture.

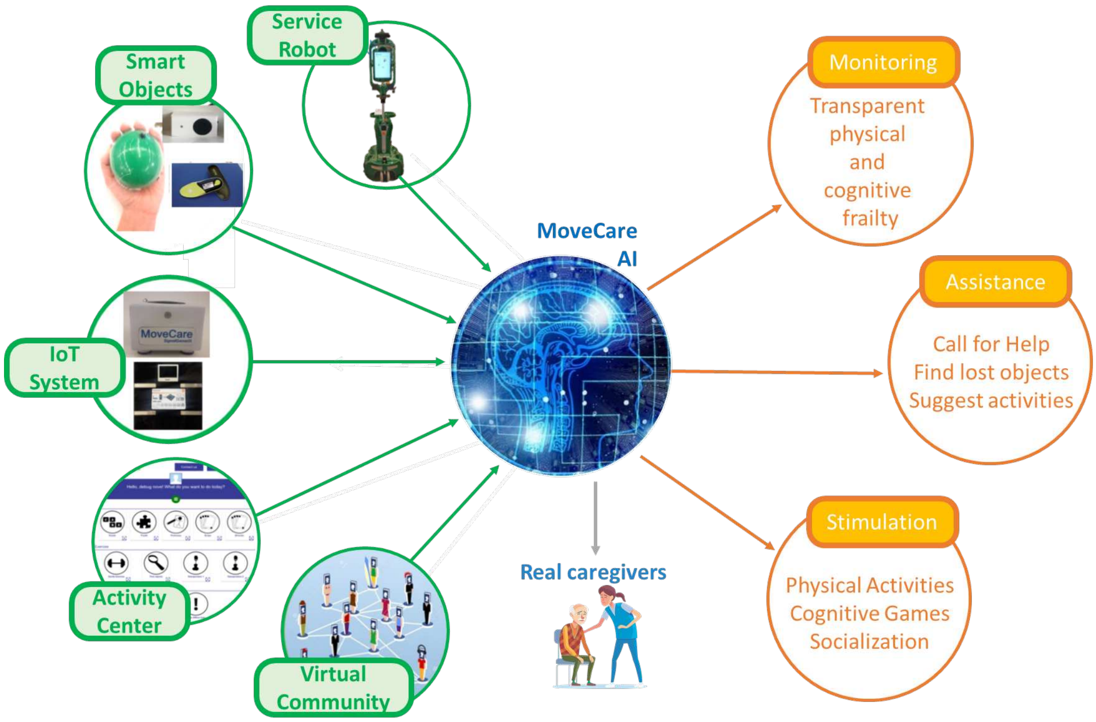

Figure 1: the ecosystem of the MOVECARE platform with the different components and the functionalities offered is shown (from the Movecare official site).

The adopted technology is that of web applications, where the system's view resides on the *client side* whereas the data model and the controller logic are deployed on the *server side*. From the functional point of view, the CBAC is organized in *virtual rooms* inside which the user can virtually enter and undertake the particular activity associated to that room. Most activities are started by users, who can also invite peers to join them. The only activity that is started autonomously is that of Gentle Exercising that is continuously available 24 hours a day.

From the structural point of view each virtual room is managed by a dedicated module at the server side. These servers coexists in the same ecosystem as they are activated when a specific activity is selected. A single central server provides coordination among the different *activity servers* (manages the choice of the activities, connect the users through the invitation systems, manages the notifications).

The client and the server communicate either through HTTP request/response or by socket via custom application protocols over socket connections. Such protocols allow to save information on the state of the communication.

Video communication is based on WebRTC. This choice offers several advantages: it is a W3C standard supported by most popular browsers, and it allows to easily setup multi-party real-time, synchronous, audio-video conferences, and data channels. Note that the content of the page provided by the activity server to the user client is user-specific (a personalized "welcome" message is shown). Moreover, the lists of the users currently in each room (and the possibility of joining rooms according to the available space) automatically changes in response of joining events coming from other users without the need of manually refreshing the page. This is achieved with the help of an external component dedicated to real-time events handling and synchronizing (socket.io).

2.1.1. The Client Side

The client side is in charge of presenting the user with the current view of an activity that is synchronized with that of all other users who are performing that same activity. Through such interface, the user can start any activity offered by the activity center, interact with other users (chat and video chat) and the Virtual Community.

The CBAC has been developed as an Android application. It has been released on Google Play Store (private link) and therefore it will be automatically updated for all users when a new release is delivered so that automatic update can take place. The application is provided for testing and therefore it is not be publicly available. This allows also easy installation and maintenance (automatic updates).

Client application has been realized as WEB pages served by the CBAC activity servers. Such pages are dynamical and have been realized through the Bootstrap framework (https://getbootstrap.com/) for front end-development based on the graphical layout defined through style sheets (CSS). JQuery and JavaScript have been largely adopted. To realize dynamical behavior we have exploited the Pug and Handlebars (http://handlebarsjs.com/) template engine that allows to instantiate a particular graphical component according to logic. Card game has been implemented starting from *DeckOfCards.js* library.

This has allowed designing interfaces that are responsive and whose elements can be rearranged by the virtual caregiver according to elders' preferences.

2.1.2. The Server Side

The CBAC system logic and data management is deployed on server side in the cloud and it is constituted of the following components:

User static profile DB : the database storing the static profile of users that is compiled at registration time. It contains their preferences and idiosyncrasies.

CBAC main server : the main server acts as a central coordinator for all the services and functionalities provided by the CBAC; this is the component where the core business logic of the activity center resides. This component contains also a local database that contains the usage statistics and the log of the user sessions. . A transparent authentication mechanism based in JSON Web Tokens (JWT) allows to identify and track the user during any interaction with the CBAC.

Activity Servers (AS) : activity servers are the most important building block of the CBAC; each activity has its own activity server, that provides the business logic of a web application in charge of implementing that activity for one or more users. Activities are handled entirely by these servers Each activity server contains a local DB to store activity-dependent data such as usage statistics, scores, logs, and other indicators.

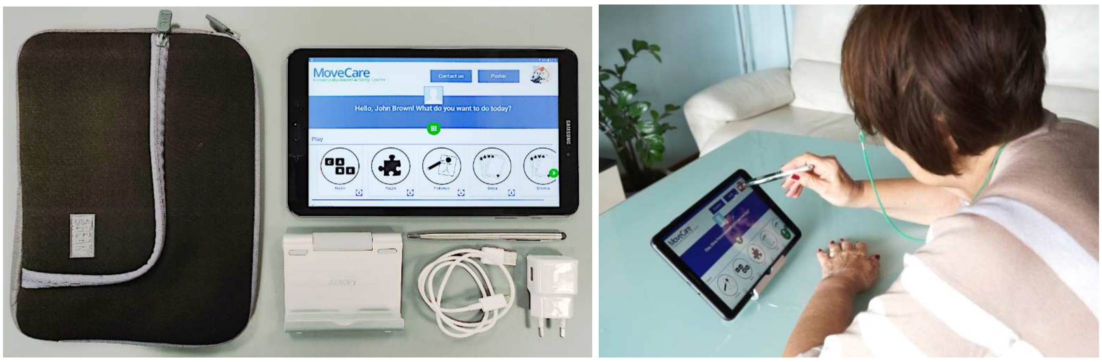

Figure 2: The tablet set-up on the left and the use of tablet for activities on the right.

A data collector module is run once a night on the Main server. The data collector is a service node written in Python that gathers raw data from the Databases inside each local Activity Server, pre-processes them to obtain activity indicators (e.g., value of a given move in cards game, time to guess in Pictionary and so forth), and uploads reports to the data center.

The installation, deployment, and maintenance of all the server-side modules is handled by system administrators and can always be done remotely and does not require any interaction with the user.

Each activity is served through a web application on the user's client device. The client communicates with the activity server (on the cloud) that serves the activity to all the users involved. Each client traps user actions (e.g., dragging an icon, clocking and so forth) and transmits this event to the server that modifies the activity deck accordingly for all users.

2.1.3. The User Side

The technology and the structure described hereabove allows to provide a simple and effective interfaces and interfacing modalities.

From the user's view, the internal architecture of the activity center, constituted of several activity servers working in parallel, is hidden as the CBAC appears to the user as a single web application that can be accessed with any standard web browser such as Google Chrome.

A consequence of this technological choice is that any platform capable of running a web browser can serve as CBAC, thus fully implementing *technological equivalence*. Specifically, we consider four different interfaces for the CBAC:

- Tablet inteface (Figure 2)
- PC interface (no particular requirement)
- TV with home station interface (Figure 3, left panel)
- service robot (Figure 3, right panel).

In particular, we have chosen a Galaxy Tab A (10.1, Wi-Fi, 32GB) for the large size of its screen. It has a WIFI, Bluetooth, ANT+ (integrated) to communicate wireless. Moreover, we

Figure 3: On the left the TV set-up at home: notice the WEBcam on the top. In the middle the PC set-up and on the right the robot set-up.

complement the tablet with some accessories: a support, a case, and a capacitive pen, that were required by users in a first round of pre-pilot. End-user reported that they were not comfortable in using the tablet flat on a table, and that they felt that the tablet was too heavy to be held in one hand for several minutes, as it happens when the tablet is used.

For physical activities the preferred device was the home TV. We require a standard TV with a HMDI port connected with a NUC Intel® Core™ i5-7260U (this is a configuration that can be easily found inside a SmartBox TV in the next future). A web-cam to be put on top of the TV (Logitech C270 HD, Figure 3), a remote air mouse to control the activities (Rii mini i7 wireless air mouse), an Intel® Wireless-AC 8265 with Bluetooth 4.2. Windows 10 in kiosk mode is installed on the NUC. Moreover, a Nintendo Balance Board was used as main control mechanism for the exer-games, in order to provide real-time measurements of the users' center of pressure and stability while playing such games.

As far as the robot is concerned, a modified version of Giraff robot has been adopted, that is endowed with autonomous navigation capabilities[13, 14]. Its display is touch and therefore it works similarly to that of the tablet. However, it has not been fully tested because it the touch display was tiltable using a dedicated motor, and the tilt motor limited torqu ewas thought to be at risk of braking if an elder was pushing too hard.

The display of the four types of devices is characterized by a different screen size and resolution. Therefore to provide the same view of the interface on the different devices a full parametric has been carried out such that all interface elements can be scaled and positioned in the same relative position.

2.1.4. The Interfaces

The CBAC main interface (Figure 4) is provided by a personalized dashboard served within a webpage (Figure 4). The dashboard can be visualized by any browser and by means of all the CBAC devices (tablet, TV, PC and robot). The user interface presented in this page has been designed considering elders as the primary target users. For such reason, the interface favors a minimalistic and regular organization of homogenous buttons, each representing one particular activity that can be carried out in the CBAC.

A limited color palette characterized by high contrast was chosen to obtain a neat display style and the number of buttons for side functionalities (like the profile and contact request) have been kept at the minimum in order to maximize focusing on the interaction and the familiarization with the interface.

The buttons on the dashboard are organize in three different groups;

- Play: a set of games that combine entertainment with cognitive training;
- Exercise and Utilities: this group collects button to start gentle exercises and provide other assistance functionalities of the MOVECARE platform that are beyond the scope of the present paper.
- Socialize: a set of activities focused on social interactions.

The main interface also features a dynamic behavior both in terms of graphical style and content organization. Specifically, to handle the difference between the various devices on which the interface could be displayed, the CBAC dashboard is dynamically reorganized: the size and position of the buttons is automatically rearranged depending on screen size and resolution. This behavior is obtained by exploiting the grid system of the Bootstrap framework used to develop the dashboard page, which provides different and modular grid classes that are associated to the type of devices on which the GUI is displayed (e.g., desktops, tablets, larger desktops).

Moreover, the CBAC's dashboard has also been designed to accommodate dynamical content organization. For example, a particular activity can be promoted or one or more peers can be suggested as partners for an activity. When one of such directives is received, the CBAC shapes the interface layout in accordance to the intent of the directive: the button of the activity suggested is shifted left with respect to the other and highlighted. Similarly, suggested peers can be put in the first spot of the user list suggested for that activity.

From the main window, all activities can be accessed: by clocking on the icon the main activity window is displayed. This has a common structure for all activities (Figure 5).

From the user's perspective, the activity interface is presented with a layout composed by two complementary modules, the activity and the social board. These two modules also correspond to the two main functionalities that characterize most activities in the CBAC.

The activity board this module, placed at the left side of the window, provides a space where the activity functionality dialogs with the user. This is where the activity logic takes place (for instance, in the case of games this could correspond to the actual game board where the user can play actions and observe the outcome of the actions played by others). Its content is a virtual table in which the activity content is shown. This content is

Figure 4: Main interface of the CBAC platform. Gentle exercise activity is promoted.

synchronized in real time for the different users who see at the same time the same content.

The social board this module, placed at the right side of the window, provides a space where the real-time audio/video chat functionality is instantiated; in this area of the interface the user can see and talk in real-time to the other participants in the activity room. Up to four windows can be opened for activities performed by multiple participants.

The two modules are activated concurrently inside the same window.

From a technological standpoint, the activity board and the social board are two modular web pages combined into a single one by means HTML iframes (Figure 5 depicts the obtained page) that is visualized as a single page. The activity board allows the user to exchange through commands and data with the activity server (an authoritative entity) through a socket connection. On the other side, the social board provides real-time communication based on a peer-to-peer network among the participants (see Figure 5) using a set of protocols based on the WebRTC standard. In particular, the social board development has been conducted exploiting the EasyRTC (https://easyrtc.com/) video-audio communication open-source toolkit.

The CBAC dynamic behaviour also extends to the language spoken by the interface by means of a flexible internationalization functionality. Labels and messages provided by the interface are parametrized by a global variable indicating the current language. Each time a label or a

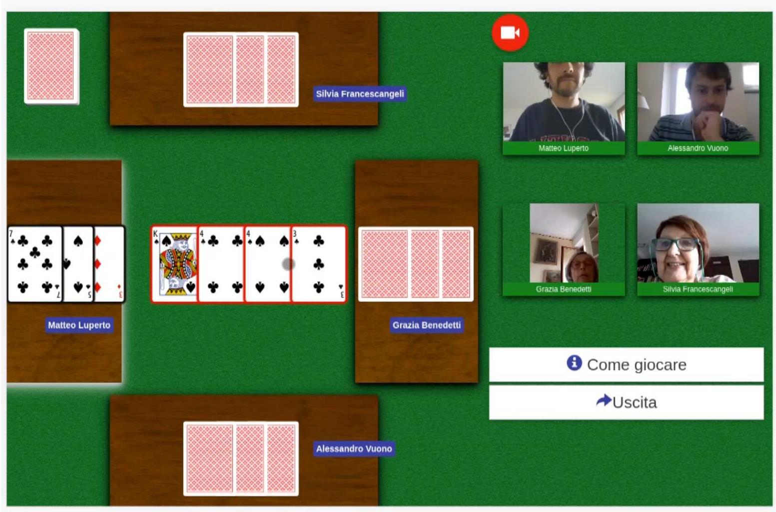

Figure 5: The typical window of an activity carried out through the CBAC is shown (a card game – scopa in Italy).

message has to be displayed, the system automatically fetches the translation corresponding to the language indicated in such parameter.

2.2. Data Log

The CBAC has not only the role of stimulating the elder, but it has also a monitoring valence. To this aim, an activity reports is generated.

Every time a user participates to an activity, the CBAC generates a report for that game in which a set of *indicators* are included. Such indicators are defined as particular performance metrics and are tailored for each activity with the intent of quantitatively measuring the cognitive skills that the user employed in playing the game. At the same time, such indicators can be exploited to enrich the cognitive assessment of the elder. Two classes of indicators have been defined: *time indicators* and *performance indicators*.

The *time indicators* describe the time took by the player to decide and perform a move during a turn of the match. Although this can be influenced by external factors like the time spent chatting with other players, some of this time is linked to the reasoning underlying the choice of which card to play and it is therefore potentially interesting for cognitive evaluation.

Precisely, for the card games, the temporal duration of a turn for a player can be represented according to the schema reported in Figure 6.

One turn can be segmented in according to these three events (Figure 6):

- Turn start: the turn is assigned to the player
- Action start: the player starts dragging a card on the game board
- Action completed: the player has completed the move on the game board

The temporal interval between the first two events (turn start and action start) can be interpreted as *planning time*. During this time the player is not physically interacting with the

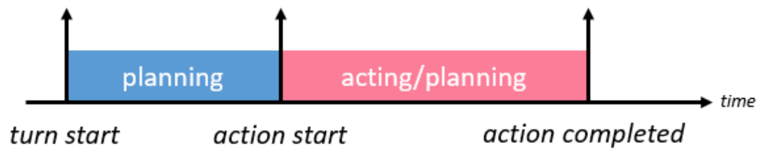

Figure 6: Temporal analysis of a play.

game board and it can be assumed that is reasoning about the current state of the deck and about which card to play.

The temporal interval between the last two events (action start and action completed) can be interpreted as *acting/planning time*. During this time the player is executing some action, dragging cards on the board to try the possible catch moves. In this case it can be assumed that the user is both performing an action and reasoning about it exploiting the board (for example, the user can rearrange the position of the cards on the table to ease the visualization of winning combinations). Planning time, acting/planning time, and the ratio between the two constitute the two time indicators that are included in every game activity report.

The *performance indicators*, describe how good the player is in selecting his/her action to win the game. These indicators are related to the player's strength, rewarding moves yielding strategic advantages and penalizing those that advantage the opponents and are game specific.

For instance, in the drawing game the number of guesses is logged, in the word game the number of word identified and the score, and so forth.

More detailed indicators have been derived only for the Scopa card game by using a rule-based mechanism. They have been derived analyzing the way in which a move is eventually results into a change in the final score in a Scopa game.

Following this reasoning, we have included in this class two indicators. The first one is the average action efficiency. For each action played during the game, its efficiency is defined as the ratio between the score provided by that action and the score of the optimal action that the player could have selected. Computing the optimal action can be computationally expensive, since it requires, in principle, to search among an exponential space of possible game realizations. To ease this task, we compute the optimal action by solving a local maxmin problem where the solution is the action that would minimize the highest score of the opponent's next move under the assumption that this last one knows of all the cards that have not been played yet (worst-case assumption).

The other adopted indicator is the average negative reward. a negative reward is assigned to a move when it is recognized as very poor. Very poor moves are modeled as patterns encoding situations where, for example, the player could have made more points but instead has played an action not yielding any or a few. Such actions could be markers of cognitive flaws during the gameplay.

3. Results and discussion

The CBAC was pre-piloted in two rounds on 12 independently living elders in Milan that has allowed to optimize interfaces and interfacing modalities for the final pilot of the Movecare project in which the CBAC was tested along with the other components of the Movecare platform. A total of 25 different elders were recruited for the pilot: 14 in Badajoz (Extremadura, Spain) and 11 in Milan (Italy). In Extremadura elders were recruited by foundation FundeSalud. In Milan, 7 people were recruited among the local association of elder volunteers "ANTEAS" and patients from the Geriatric Unit of Policlinico Hospital of Milan, and 4 among the residents of the Heliopolis Centre of KORIAN. The pilot was organized in two rounds of 15 elders each (first round September 2019-December 2019; second round: January 2020-March 2020). After the first round, 5 elders of the first round requested to continue the experimentation in the second round. Each pilot round lasted 10 weeks.

Elders enrolled were still outside the frailty state. Inclusion criteria were: a) ≥ 65 years old; b) they lived alone, without pets, in a house without stairs and without rugs, receiving assistance in activity of daily living for no more than 1 h/day; c) had a MMSE ≥ 26; d) had maximum 1 or 2 points in Fried criteria [7] or were robust people: (0 in Fried criteria) but with GDS ≥ 9 or UCLA loneliness scale > 35; e) were keen to use technology; f) had and used a smartphone; g) had an internet connection with at least 8 Mbps.

The analysis is here restricted to the CBAC. Evaluation is performed by using standardized questionnaires administer to the user at the beginning and at the end of the participation to the pilot. Results here are obtained from the evaluation of such questionnaires, whose results are omitted for brevity .The evaluation of the CBAC was very positive both for the gentle exercises and the cognitive activities (Puzzle game, Word game, card games, and the draw game). Overall people found the system easy to use, they felt confident and they would have liked to keep the system also after the pilot, with an average score close to 4 over 5 on a Likert scale. 72.7% of the participants rated positively the use of the system and 68.2% rated positively the satisfaction with the experience. For some elders mastering the different functionalities of the CBAC was demanding and felt to need some training. As expected, younger participants, ages under 80, enjoyed the graphical interface and using the system more, than the older participants, ages 80 or older. We did learn from the pilot that training has to be progressive, from simple basic game features to more complex ones to avoid providing too many notions all together.

Particularly critical is network connection, that in most houses was through WiFi and was not always stable. This was especially critical for video-communication. In general elders had the impression that a need for technical personnel was required to overcome transient failures.

In particular, especially in the area of Milan, CBAC use has steeply increased during the COVID-19 emergency, since the forced reclusion acted as an additional incentive for users to seek and find social interactions through the platform. Indeed the CBAC innovative structure that combines a virtual deck, on which activities are carried out, with real-time video communication answered the need of socialization largely increased during lock-down. Interestingly two pairs of users, one in the pre-pilot and one in the pilot, met inside Movecare CBAC and started meeting on a regular basis also outside Movecare, becoming friends. A third elder of the pilot did a lot of activity with those two thus creating a triplet of people who started to meet virtually.

Overall a form of digital divide was observed analyzing the answers by age as elder people tend to rate the system more difficult to use, less friendly and less compliant, while younger people were more enthusiastic and effective in using it.

4. Conclusion

From the preliminary result, the Community Based Activity Center can play a role in taking out the elders from isolation and promoting physical and cognitive stimulation. Moreover, the acquisition of activity data has the potentiality to provide also insights on early cognitive and physical decline thus allowing stimulation and monitoring at the same time.

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