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The interplay of physical and social wellbeing in older adults: investigating the relationship between physical training and social interactions with virtual social environments

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ABSTRACT

Background. Regular physical activity can substantially improve the physical wellbeing of older adults, preventing several chronic diseases and increasing cognitive performance and mood. However, research has shown that older adults are the most sedentary segment of society, spending much of their time seated or inactive. A variety of barriers make it difficult for older adults to maintain an active lifestyle, including logistical difficulties in going to a gym (for some adults, leaving home can be challenging), reduced functional abilities, and lack of motivation. In this paper, we report on the design and evaluation of Gymcentral. A training application running on tablet was designed to allow older adults to follow a personalized home-based exercise program while being remotely assisted by a coach. The objective of the study was to assess if a virtual gym that enables virtual presence and social interaction is more motivating for training than the same virtual gym without social interaction.
Methods. A total of 37 adults aged between 65 and 87 years old (28 females and 9 males, mean age = 71, sd = 5.8) followed a personalized home-based strength and balance training plan for eight weeks. The participants performed the exercises autonomously at home using the Gymcentral application. Participants were assigned to two training groups: the Social group used an application with persuasive and social functionalities, while the Control group used a basic version of the service with no persuasive and social features. We further explored the effects of social facilitation, and in particular of virtual social presence, in user participation to training sessions. Outcome measures were adherence, persistence and co-presence rate.
Results. Participants in the Social group attended significantly more exercise sessions than the Control group, providing evidence of a better engagement in the training program. Besides the focus on social persuasion measures, the study also confirms that a virtual gym service is effective for supporting individually tailored home-based physical training for older adults. The study also confirms that social facilitation tools motivate users to train together in a virtual fitness environment.
Discussion. The study confirms that Gymcentral increases the participation of older adults in physical training compare to a similar version of the application without

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Additional Information and Declarations can be found on page 20

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social and persuasive features. In addition, a significant increase in the co-presence of the Social group indicates that social presence motivates the participants to join training sessions at the same time with the other participants. These results are encouraging, as they motivate further research into using home-based training programs as an opportunity to stay physically and socially active, especially for those who for various reasons are bound to stay at home.

Subjects Human–Computer Interaction, Emerging Technologies, Mobile and Ubiquitous Computing, Network Science and Online Social Networks
Keywords Older adults, Home-based physical intervention, Persuasion technology, Physical wellbeing, Social interactions

INTRODUCTION

Physical activity, especially in the form of structured exercises, has been linked to positive outcomes in physical, social and mental wellbeing of older adults (*Spirduso & Cronin, 2001*). Engaging in physical activities reduces risk of falls (*Thibaud et al., 2012*), slows progression of degenerative diseases (*Stuart et al., 2008*), and improves cognitive performance and mood in older adults (*Landi et al., 2010*). Research even suggests that most active older adults are twice as likely to have no disabilities related to daily activities prior to death, as compared to sedentary ones (*Leveille et al., 1999*).

However, research has shown that, despite the growing evidence that sedentary behavior can be a serious health risk factor, physical inactivity is still prevalent in older adults. *Harvey, Chastin & Skelton (2013)* reviewed 23 studies that investigate late life sedentary behavior in 7 countries (by measuring everyday activity using an accelerometer) and reports that 67% of older adults are sedentary for more than 8.5 h during their waking day. Little gender differences were found in the amount of physical activity in later life, while those older than 75 year old were found to be less active than those in the 65–74 age group.

According to the World Health Organization (*Cavill, Kahlmeier & Racioppi, 2006*), physical inactivity is also a significant economic burden for the society and the European healthcare systems, bringing about significant direct and indirect costs due to sick leave, mortality, morbidity, poor quality of life, and increased health expenses. For example, it is estimated that, in England, indirect costs of physical inactivity amount to £8.2 billion per year (*Department of Health, 2005*), while, in Switzerland, direct costs of treatment are estimated at € 1.1–1.5 billion (*Martin et al., 2001*).

There are however a variety of barriers that make it difficult for older adults to maintain or increase their physical activity level: lack of easy access to facilities and infrastructures, reduced functional abilities, and lack of motivation (*Schutzer & Graves, 2004*). Among the factors affecting motivation, *self-efficacy* (i.e., perceived capability and confidence), which is a strong predictor of adherence to physical exercises, is less exhibited in older adults compared to other age populations (*Phillips, Schneider & Mercer, 2004*). In addition, older adults and in general people challenged with physical and cognitive decline are less able to leave their homes and participate in physical and social activities on a regular basis.

Along with the physical activity decline, a reduced participation in social activities and changes in social roles put older adults at risk of social isolation. Extensive research has found links between social isolation and adverse physical and mental health, e.g., increased mortality rates for older adults, elevated blood pressure, dementia, depression, and cognitive decline (*Bower, 1997*; *Fratiglioni et al., 2000*; *Heikkinen & Kauppinen, 2004*). On the other hand, engaging in social interactions is beneficial to the health and wellbeing of older adults (*Fratiglioni et al., 2000*). Accomplishing practical activities *together* is an indirect means to stimulate and strengthen social ties, which is particularly beneficial for older adults with limited opportunities to interact (*Leonardi et al., 2008*).

In this paper we present a tablet-based virtual fitness club environment designed, in terms of interaction, metaphors and training programs, to be suitable for older adults. This environment evolved from years of research in home-based training for older adults (*Silveira et al., 2013a*; *Silveira et al., 2013b*; *Khaghani Far et al., 2012*; *Khaghani Far et al., 2014*). The specific goal of the latest version, called Gymcentral (gymcentral.net) and discussed here, is to motivate people to train by providing users with a fitness club that is both personal (the training program is personalized) and social: members can interact and have the feeling of being in the same virtual space—even if they perform different exercises. Unlike other solutions, the personalisation and monitoring of the exercises is performed continuously by a remote human coach with the support of an accompanying application.

More specifically, we study and report on an intervention designed to understand the effect of **social facilitation**, and in particular of social presence, on the desire of trainees to exercise together, and its impact in the adherence to a training program. We are interested in the following research questions:

Q1. Does Gymcentral motivate the participation of independent-living older adults in home-based training programs?

Q2. Does co-presence, our tool for social facilitation, motivate independent-living older adults to exercise together in a virtual social environment?

Finding the answers to these questions can be very beneficial in understanding if and how home-based training programs can become effective in motivating older adults to train regularly.

RELATED WORK

Virtual environments

Training at home does not feel the same as training outdoors or at the gym. Therefore many home-training settings rely on virtual environments to evoke similar conditions. *Ijsselsteijn et al. (2006)* analysed intrinsic motivation and sense of presence when exercising indoors, using a stationary bike and a projector to show a virtual racetrack. The study involved 24 Philips employees, with an average age of 41.3 years old. Intrinsic motivation scores, presence, and cycling speed were higher for high immersion settings (a 3D real-time first person view of the track, in comparison to a 2D aerial view with a dot representing the user position), and the sense of presence increased when having a virtual coach.

Other studies concur, showing that virtual worlds increase the sense of presence, or psychological immersion (*Yilmaz et al., 2013*; *Grinberg et al., 2014*). Users feel as if they are an integral part of the virtual world and get more engaged in the activities, thus making virtual worlds suitable to facilitate social engagement for the health support and physical functioning of the older adults (*Molina et al., 2014*; *Siriaraya, Ang & Bobrowicz, 2014*).

In addition, positive results have been obtained when comparing virtual training environment with traditional settings. *Sveistrup et al. (2003)* compared adaptable Virtual Reality (VR) technology for physical rehabilitation versus conventional rehabilitation program, reporting that VR can provide a more controlled and natural exercises and improve the rehabilitation process. Besides, the technology allows health care experts to create complex, controllable and, interactive rehabilitation training which, can be tailored for each individual patient either in clinics or at home.

Most of the aforementioned studies were carried out in care homes or laboratories, under the supervision of therapists or caregivers. Furthermore, physical presence was required to participate together and there were no control groups to test lone participation conditions nor co-presence for remote, independent training settings. In this paper, we measure the effectiveness of the virtual presence (co-presence) on engaging the older adults in exercising sessions.

Gaming technology has also been used to help older adults in training. Devices such as the Kinect [1] (*Kayama et al., 2013*; *Pisan, Marin & Navarro, 2013*) and the Wii[2] allow users to use their body movement to control in-game characters. Both customized (*Carmichael et al., 2010*; *Alankus et al., 2010*) and off-the-shelf solutions (*Jung et al., 2009*; *Agmon et al., 2011*; *Jorgensen et al., 2012*) have been tried to train older adults. Nonetheless, few have been tested by older adults at home (*Agmon et al., 2011*) or have used virtual coaches (*Carmichael et al., 2010*), as these gaming consoles were initially designed for the younger population.

[1] www.microsoft.com/en-us/kinectforwindows

[2] www.wii.com

Persuasion technologies for home-based physical interventions

Physical training with technology support has been explored in home-based settings for rehabilitation (*Marin & Navarro, 2011*) and physical training exercises (*Cheok et al., 2005*; *Brox & Hernandez, 2011*). The usability of a home-based training with the Kinect and video instructions (*Ofli et al., 2015*), as well as with tablets (*Silveira et al., 2013a*), has been studied with the older population. These solutions, ranging from using a computer with mouse and keyboard, to tablets and game consoles (e.g., Wii, Kinect (*Agmon et al., 2011*)), were reported to be usable and effective by healthy older adults.

However, despite the availability of usable technology, motivating older adults to exercise is a challenge. Among the factors affecting motivation, *self-efficacy* (i.e., perceived capability and confidence) is reduced in older adults compared to other age populations (*Phillips, Schneider & Mercer, 2004*; *Schutzer & Graves, 2004*). Other aspects such as the perceived drawbacks (e.g., illness, pain, discipline) and the tendency towards sedentarism (e.g., due to habits or psychological issues) also play against the motivation to engage in physical activity (*Phillips, Schneider & Mercer, 2004*).

In order to mitigate these effects, researchers have explored various types of persuasion strategies in the design of training solutions. We classify the persuasion strategies in the literature in two major categories of (i) individual motivation strategies, where the persuasion mechanism does not require the presence of a social community and (ii) social motivation strategies, where the presence of a *social group* (e.g., co-participants, family and supporters) has a positive effect on the participant's exercising behavior (*Silveira et al., 2013b*).

Individual motivation strategies range from appealing and usable interaction design, to self-monitoring, alerts and recommendations, positive and negative reinforcements, and gamification (*Fogg, 2003*; *Oinas-Kukkonen & Harjumaa, 2008*). Several studies experimented with the effectiveness of such strategies with older adults. For example, *Albaina et al. (2009)* designed a virtual coach application that encourages older adults to walk more. The study analyzed the effect of positive and negative reinforcements in motivating the elderly cohort and reports higher levels of motivation when a virtual coach is present.

Research suggests that **social motivation strategies** are more effective than individual strategies, in particular for the older adults (*Carron, Hausenblas & Mack, 1996*; *Silveira et al., 2013b*; *Jimison, Klein & Marcoe, 2013*). *Social support* given by family, friends and caregivers can improve the self-efficacy of older adults and thus increase motivation to engage in physical activity (*Resnick et al., 2002*; *Romero et al., 2010*). *Collaboration* among the peers has also proven to be persuasive. *Mubin, Shahid & Al Mahmud (2008)* describes walk2win, a collaborative game that encourages elderly people at care centers to play a game by walking. From the qualitative data collected, Mubin has reported that older adults enjoyed more when the activities were collaborative compared to when they were individual.

Using a gaming approach, Fish 'n' Steps got 14 out of 19 people to increase or change their attitude towards physical activity (*Lin et al., 2006*). Participants were given pedometers to record their step count and were put together in groups of 4, which collaborated among themselves and competed against other groups. The step count was shown to all others (even other groups) using the metaphor of fishes in a tank (the more steps, the bigger the fish), one experimental condition even made the fish tank's water get darker and loose decoration when team members' step count was not good enough.

Moreover, *Anderson-Hanley et al. (2011)* studied the effects of *social presence*, and in particular of the moderating effects of competition, in the exercise behavior of older adults in a virtual biking environment. In their study, the introduction of competitive avatars enhanced the effort of the competitive participants, without negative effects on the non-competitive ones. However, the effect of the social presence in the long term adherence and social user behavior was not explored in this work.

The aforementioned works report on a positive influence of social support, peer collaboration and competition. However, the effects of virtual social presence on both exercising behavior and long term adherence has not been explored yet in home-based training settings with older adults. In this paper we focus on gaining more insights into this type of social facilitation and its effects.

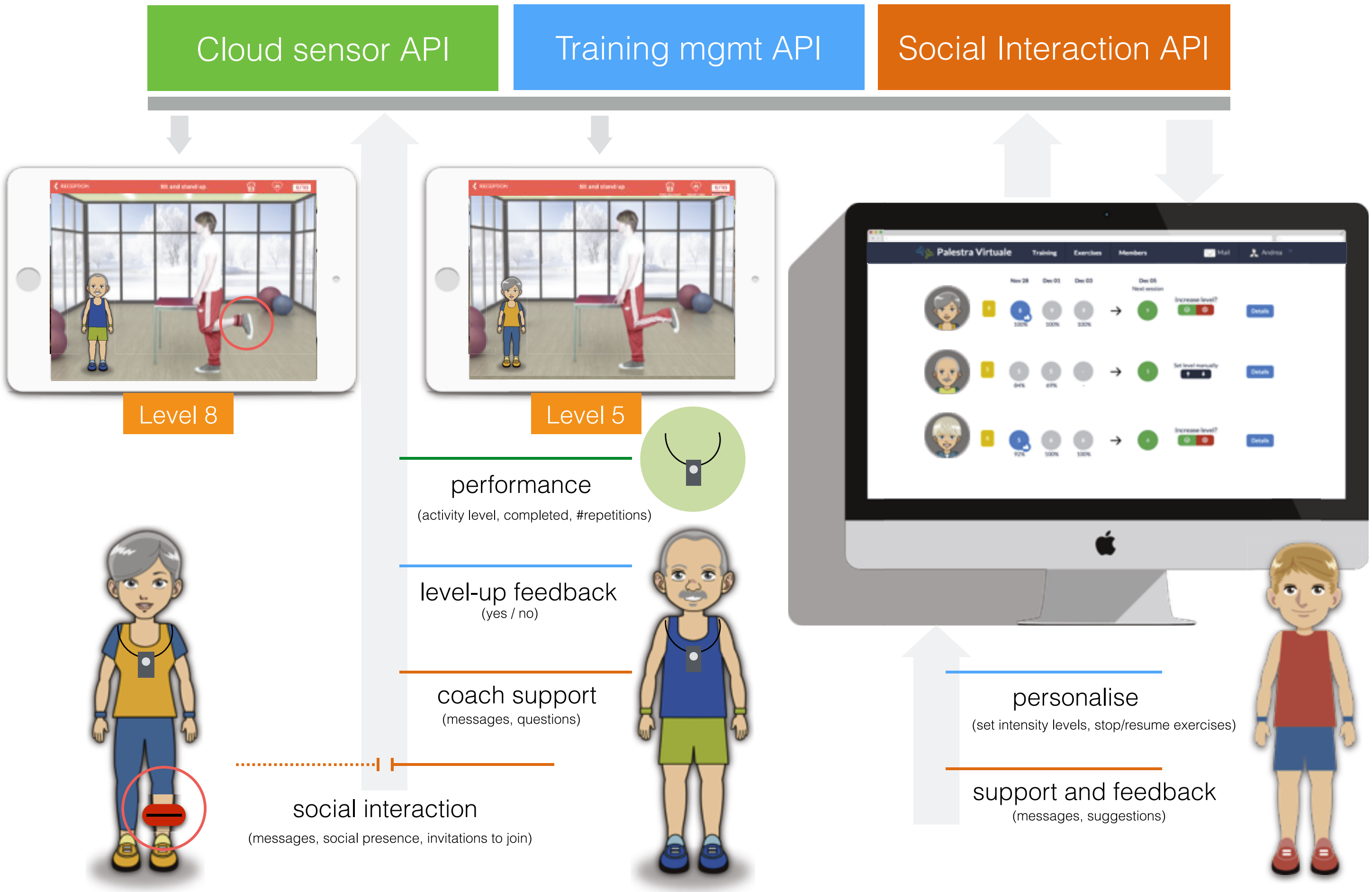


Figure 1 Gymcentral applications for home-based training.

MATERIALS & METHODS

Gymcentral applications

Gymcentral is designed to *enable* and *motivate* older adults to participate in physical training sessions from home, under the supervision of a human coach, and by using a tablet device. The application for the trainees, namely the *Trainee App*, leverages on social support, in the form of social presence during training sessions, and online and offline social interactions to motivate older adults to meet, interact and exercise. An application for the coach, the *Coach App*, allows the expert to personalise, monitor and provide support to the trainees during the training program. These applications work together as shown in Fig. 1.

The Trainee App

The design of the application for trainees is based on a virtual environment that mimics the spaces and services found in a real gym. The main features of the tool are the following:

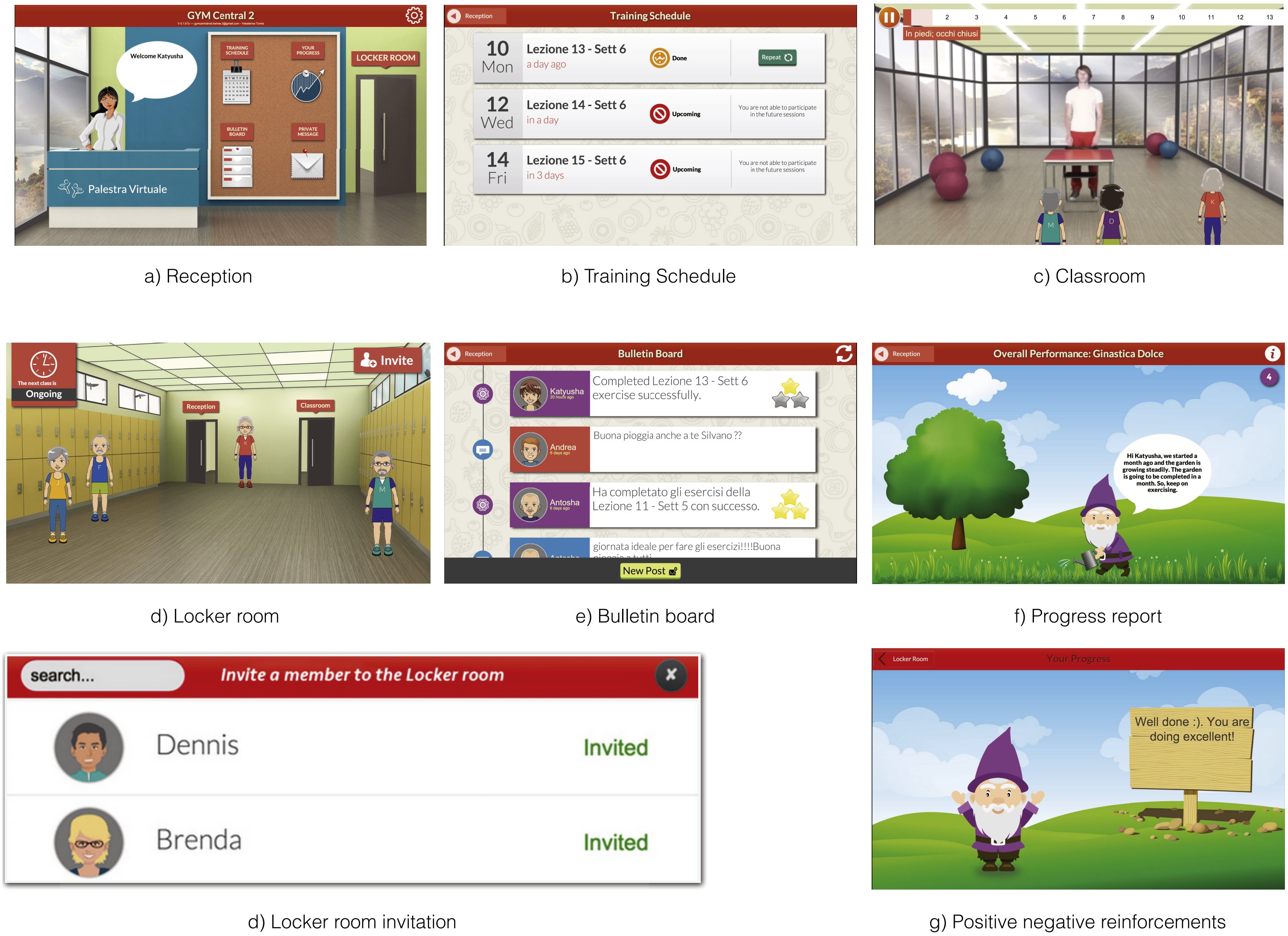


Figure 2 Features of the gymcentral trainee application.

- **Reception**. The entry point to all the services of the gym. A virtual receptionist helps the user in getting oriented and suggests courses of action (Fig. 2A).
- **Locker room**. A virtual representation of a gym locker room, where trainees prepare for the training session and often chat. The locker room enables trainees to (i) see who is online and ready for the training session, (ii) invite trainees that are absent to come online and join, and (iii) interact by sending to each other predefined messages in real-time (Fig. 2D).
- **Invitation feature**. A feature, available when a user is in the locker room, that enables trainees to send invitation messages to other trainees, inviting them to exercise together (Fig. 2D).
- **Classroom**. The virtual representation of a training room, where users have access to the exercise instructions given by a coach. Trainees are not only able to see the coach but also other trainees exercising at that moment as static avatars (Fig. 2C).

- **Progress report**. It allows trainees to check their progress within the training program. The visualization is through a growing garden metaphor. The mission of the trainee is to follow the program and, by doing so, help growing the garden. While users visit their garden (or their progress) they will see a gardener (a gnome) working there, informing them about the current status of the garden and encouraging them to keep on exercising (Fig. 2F).
- **Training schedule**. It displays the training schedule of the user, reminding them of the upcoming sessions (Fig. 2B).
- **Messaging**. The bulletin board is a social interactive tool that, allows trainees to exchange public messages and see each other's training activities. In addition, a private internal email allows trainees to have private conversations (Fig. 2E).

Persuasive strategies are a major design dimension, and we classify them in two general types (i) *individual,* referring to strategies that leverage the individual wills and natural drive and, (ii) *social*, referring to strategies that include the presence of a community of people with the roles of family, supporters and peer trainees (*Silveira et al., 2013b*). The set of strategies incorporated is derived from previous work on persuasion (among others, *Oinas-Kukkonen & Harjumaa, 2008*; *Fogg, 2003*), and implemented in the application as described below

Individual persuasion strategies:

- **Self-monitoring.** Strategies under this category are *means that provide behavior monitoring to the individual* (*Fogg, 2003*). The application provides trainees with performance monitoring and awareness about their current progress. The progress is visualised using the garden metaphor (*Consolvo et al., 2008*), and is accessible from the reception.
- **Positive & negative reinforcement.** This strategy relies on *presenting positive and negative stimulus to improve individual's behavior* (*Fogg, 2003*). The application prompts positive or negative comments about the exercising behavior of the trainee to raise awareness (*Silveira et al., 2013b*). The reinforcement message is displayed after a training session according to the number of exercises completed, with three different states: positive (completeness $\geq$75%), neutral (75% > completeness $\geq$25%) and negative (25% > completeness $\geq$ 0). The message is given by a gnome with a mood that matches the tone of the message (Fig. 2G).

Social persuasion strategies:

- **Social learning**. Also known as *comparison*, it refers to *providing means to observe other people who perform the same behavior* (*Fogg, 2003*). In the application, social features allow trainees to compare their performance with others. It offers a bulletin board where the performance of the trainees is automatically shared after a training session (*Oinas-Kukkonen & Harjumaa, 2008*; *Silveira et al., 2013b*).

- **Social support.** This category groups strategies by *providing social interaction features that leverage social influence* (*Fogg, 2003*). The application provides social features such as messaging and a bulletin board, enabling trainees to interact with each other and create a community of people supporting each other (*Oinas-Kukkonen & Harjumaa, 2008*; *Silveira et al., 2013b*).
- **Social facilitation.** It groups strategies *leveraging on the fact that people are more likely perform better when they discern others are performing the same behavior* (*Fogg, 2003*). The application implements this strategy by providing social spaces like the locker room and the classroom that allow for social awareness. Trainees can see a virtual representation (avatars) of other trainees virtually present in each space (*Oinas-Kukkonen & Harjumaa, 2008*; *Fogg, 2003*).
- **Normative influence.** Also known as peer-pressure, it refers to strategies aiming at *increasing the likelihood that a person will adopt to a target behaviour by peer pressure* (*Fogg, 2003*). The application leverages this strategy by allowing users to send and receive invitations to exercise together (Fig. 2D), thus acting as a peer pressure mechanism (*Oinas-Kukkonen & Harjumaa, 2008*; *Fogg, 2003*).

Social interactions are also a central part of the offerings of the application. Thus, the application provides the following social features:

- **Real-time interactions**: the locker room allows trainees to interact by exchanging contextual messages in real time (e.g., "Hi", "Let's go to the classroom", "Bye"). Predefined messages are sent by tapping on the avatar of the online trainees and choosing the message.
- **Asynchronous messages**: trainees can also interact by sending public and private messages. The messaging is asynchronous and behaves like an internal mail system.

The Coach App

The Coach application is designed to enable the human coach to start, manage and monitor the execution of home-based fitness programs. In a nutshell, it allows the coach to:

- **Define the exercise program,** including video exercises, performance indicators and intensity levels;
- **Assign intensity levels** (associated to the exercise program) to trainees, according to the initial physical assessment. This makes it possible for older adults of different abilities to follow the training program together;
- **Tailor the exercise program** continuously to match the progress of the individual trainees, or to prevent adverse events (e.g., stop an exercise if a trainee experiences pain when performing it);
- **Provide support and feedback**, communicating suggestions or answering questions via the messaging features.
- **Monitor the performance** of the trainees, by looking at the performance indicators defined for the training program. The indicators can be collected via self-reports,

computed automatically by the trainee app (e.g., completeness, participation) or collected from sensors.

With the above features the system incorporates a human expert in the entire coaching process.

Persuasion hypotheses

In this study we investigate the effects of Gymcentral in motivating older adults to engage in virtual training sessions with a group of trainees. We define the following persuasion hypothesis:

H1. Gymcentral increases the participation of independent-living older adults to home-based training

It proposes that Gymcentral is more effective in engaging older adults to follow a training program from home, compared to a simpler version of the same application without social and persuasion features.

H2. Social presence increases joint participation of independent-living older adults in training sessions

It proposes that social presence in the form of virtual avatars would increase meetups during training sessions, compared to the random possibility.

In the following sections we describe the participants, the study design and the outcome of the measures used to test our hypotheses.

Participants

Participants aged 65 or older, independent-living, self-sufficient and with a non-frail, transitionally frail or a mild frailty level were considered eligible for the study. These *inclusion criteria* were measured by self-reports. Participants' frailty level was measured using the Groningen Frailty Indicator (GFI; *Steverink et al., 2001*), a validated questionnaire that screens for self-reported limitations in older adults (*Bouillon et al., 2013*; *Drubbel et al., 2013*). The GFI score ranges from zero (not frail) to fifteen (very frail). Older adults were considered eligible for the study with a score lower than 7 (non-frail, transitionally frail or with a mild frailty level). Since wearable sensors and wireless connections were part of the study, participants wearing pacemakers were considered *not eligible*.

Older citizens were mainly contacted through two volunteering organizations[3] based in Trento, Italy, which offer different services to independently living older adults. Participants who showed interest in the study were contacted by the researchers to make sure that they conformed to the inclusion criteria. Forty (40) participants between 65 and 87 years old being selected for the study (29 females and 11 males, mean age = 71, s.d. = 5.7). All participants obtained a formal written approval by their family doctor to allow them to participate in the study. After the recruitment process, both doctors and participants received a written outline and explanation of the study before participating.

The gender imbalance in the initial set of participants is due to the difficulties posed by recruiting older adults and the availability in the volunteering organisations. However, studies (*Koivula, 1999*; *Ryan et al., 1997*) suggest that both male and female react to

[3] Users participation in the study, including the partnership with the mentioned volunteering organization, was managed by dedicated staff at Smart Crowds Territorial Lab, Trento RISE (www.smartcrowds.net).

sport activities equally, despite differences in initial motives for participation. Thus, these previous studies support the generalisation of the analysis proposed in this paper.

Out of the initial 40 participants, 4 withdrew at different times during the course of the study due to unpredictable health or family problems. One participant could be replaced because the withdrawal occurred just before the start of the study, while the others could not be replaced since they withdrew during the second half of the study. For this reason, the results are based on data from 37 participants (28 females and 9 males, mean age = 71, s.d. = 5.8, between 65 and 87 years old).

Volunteered participants had variable physical conditions and low familiarity with technology. Some of them were already used to "offline" physical activity (e.g., swimming pool, low-impact exercise, gardening), yet most of them were sedentary. In what regards technological skills, less than 20% of the participants had ever used a tablet before, and less than 10% used it regularly. Thus, participants were provided introductory courses on how to use the tablet along with a written presentation of the study and written instructions for the use of the tablet and the application.

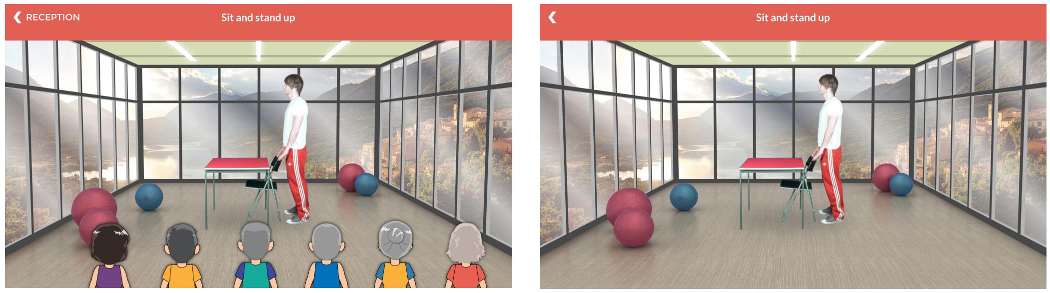
The study received ethical approval from the CREATE-NET Ethics Committee on ICT Research Involving Human Beings (Application N. 2014-001).

Study design

In this study we followed a framework for the design and evaluation of *complex interventions in health settings* described by Campbell et al. (2000). Participants were assigned to the experimental (or ***social***) condition and to the ***control*** condition using a matched random assignment procedure (*McBurney & White, 2009*; *Whitley & Kite, 2013*). This technique is particularly useful to help ensure that different groups are equivalent on one or more characteristics prior to treatment. The variables used in the random assignment were age and participants' frailty level. Pretest analysis of age, frailty, and self-reported physical activity measured with the *Rapid Assessment of Physical Activity* questionnaire (*Topolski et al., 2006*) did not reveal significant differences between the *experimental* (social) and the *control group*.

Participants in the *social* condition were given a version of the *Trainee App* that included the virtual social environment, the progress metaphor and the home-based exercise program. In the *control* condition, participants received a version of the application that focused only on the home-based program, without social or individual persuasion features. In Fig. 3 we illustrate the difference in the participation to training sessions.

Prior to the intervention, three training modules (∼1.5 h each) were offered to the participants. The first two modules regarded the use of the tablet and its main applications, while the third focused on the usage of the Gymcentral app. In this case, *control group* and *social group* received appropriate training, based on the features of their application. All participants took part in the lessons. Individual lessons were also organized for those who had questions, and community managers were available in selected days at the associations for participants who had further questions/doubts.



a) Social participation to training sessions

b) Individual participation to training sessions

Figure 3 Participation to training sessions in the (A) *social condition*, and (B) *control condition*.

In order to understand the perceived usability of both apps, we used the System Usability Scale (*Brooke, 1996*) between participants in the *social condition* and in the *control group* after a first contact with the application. Not surprisingly, the version of the app used in the *control* condition was perceived as more usable compared to the more complex interface in the *social group* (on a 0–5 range; *social*: 3.3, SD = 0.5; *control*: 4.25 *SD* = 0.6). However, we did not observe any issues impeding the normal use of the applications.

All participants received a 10.1 inch Sony Xperia tablet with Wi-Fi and 3G support, the user guide including the names and telephone numbers of the support team, and instructions about the use of the tablet and the application, one pair of ankle weights to perform the exercises and a folder to allow the vertical positioning of the tablet.

Before starting the exercise program, all participants underwent physical assessment with a personal trainer, in order to allow for personal tailoring of exercise type and intensity, and to personalize the starting level of each participant. In addition, participants' enjoyment of physical activity was measured using the Physical Activity Enjoyment Scale (PACES; *Carraro, Maria Christina & Claudio, 2008*; *Kendzierski & Kenneth, 1991*) to test for differences that might favor the participation in one of the groups. However, an analysis of variance showed no significant main effect for the groups ($p = .477$).

The study was carried out in October–December 2014, in Trento, Italy. The first week was devoted to technical deployment and application testing, followed by 8 weeks of training and 1 week of post-training measurements. The timeline of the study is illustrated in Fig. 4.

The exercise program was based on the **Otago Exercise Program** (*Gardner et al., 2001*), specifically tailored for older citizens, and consisted of 10 levels of increasing difficulty. The program includes simple exercises based on functional everyday movements that could be safely executed at home (e.g., side hip strengthening exercise, backwards walking for balance). The duration of the exercise sessions ranged from 30 to 40 min, with longer sessions in the higher levels. Participants from both groups were assigned an initial level by the Coach based on the pre-test analysis. During the exercise program, participants were asked to perform *at least two exercise sessions per week*. They could gradually progress in intensity during the program. In both *social* and *control* groups, progression was gradually

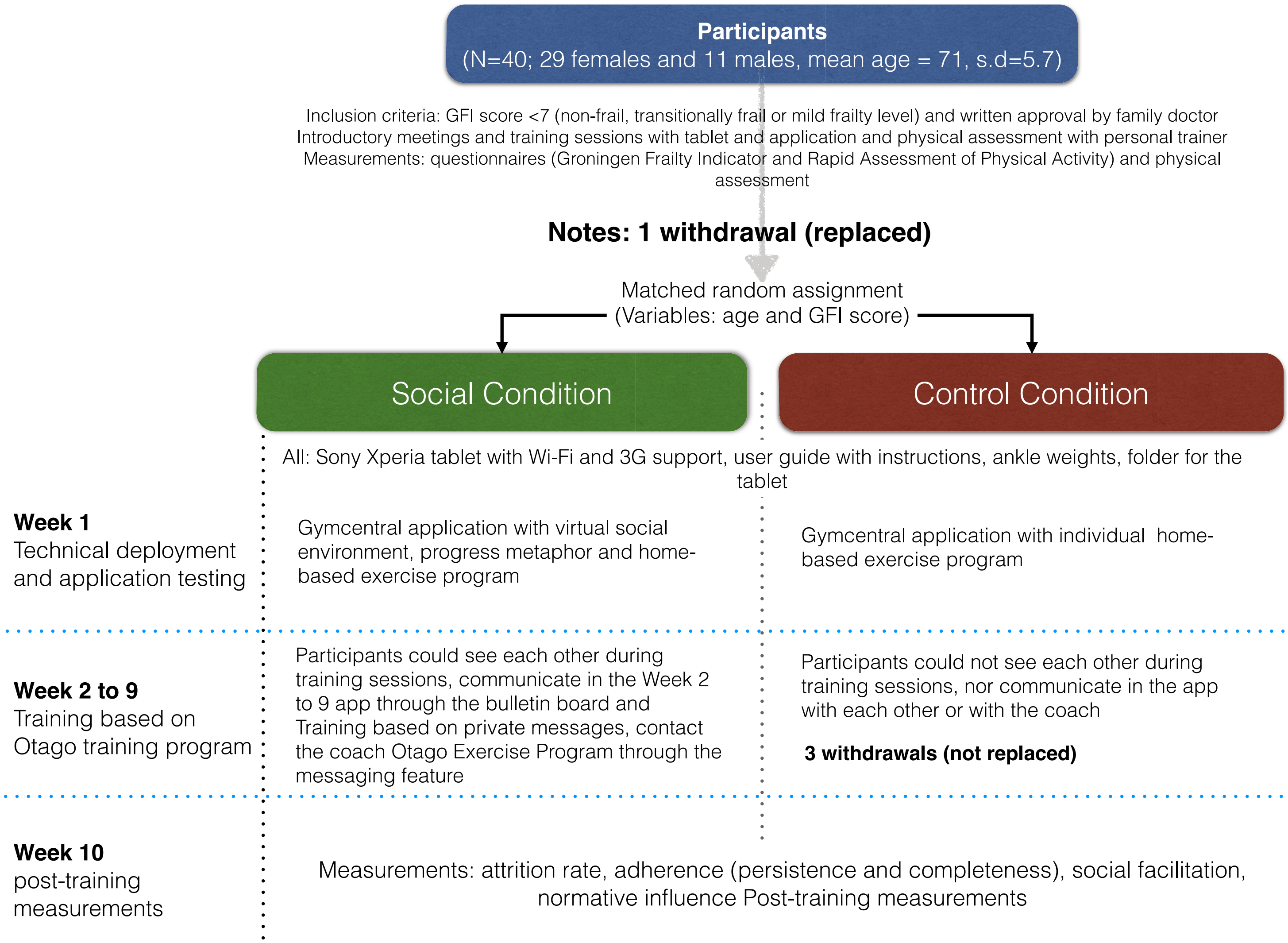


Figure 4 **Flowchart depicting the study setting and timeline.**

suggested every week. If participants agreed to level-up, the following level was unlocked, requiring a confirmation from the personal trainer in the case of the *social* group.

The interventions by the coach during the training were expected to be: (i) every week, to advance trainees in the exercise program (level-up) and give them feedback, and (ii) upon direct contact from the trainees. The *Coach App* supported the interventions of the coach with monitoring, personalisation and feedback features. However, while in the *social group* the feedback and support was done within the app via messaging features, in the *control group*, it was done via telephonic contact—due to the absence of social features in that condition.

Technical support during the study was required at one point due to intermittent connectivity problems in the 3G signal in some areas of the city. This affected both group in the same way, the only difference being that the study group could report them through the app while the *control group* was reporting by phone. No differences in support related to the app were registered.

OUTCOME MEASURES

Attrition

The attrition rate was measured with the proportion of participants lost at the end of the study. Taking into account relevant related studies on IT-based systems for healthy ageing (*Silveira et al., 2013a*; *Silveira et al., 2013b*), a 7.5% attrition rate was considered acceptable.

Adherence

The adherence to the exercise program was computed using data about usage patterns collected from the application logs, for both of the *control* and *social group*. In order to better explore adherence patterns, for each participant, two measures were considered. The first is related to **persistence** throughout the eight weeks of the exercise program, and was computed considering the ratio between the number of participations to exercise sessions by a participant and the number of the exercise sessions planned in the program. Participation was measured by logging the attendance to the scheduled training sessions in the virtual classroom, from the first to the last exercise (even if the exercises were skipped). The second measure is related to the level of **completeness** of the exercise sessions. It was calculated considering, for each session, the percentage of exercises videos that the user actually followed (watched)—excluding the time of preparation and skipped exercises—with respect to the total duration of the exercises planned for the session.

For example, participant A and participant B could both have high scores in the level of completeness, meaning that when they take part in a workout session, they tend to perform most of the exercises, completing a high percentage of the session. But, for example, participant A could score lower that participant B in the persistence measure, in case he/she took part in only few of the total number of exercise sessions planned in the program, while participant B attended a higher number of sessions during the eight weeks of the study.

In general, using as a baseline previous studies on tablet-based interventions (*Silveira et al., 2013b*), a rate of 70% was considered an acceptable criterion for success for both measures. More specifically, we expected a higher adherence for the *social group*, as a consequence of a higher motivation and engagement in the participation of the program, due to the presence of communication functionalities, and the garden metaphor for monitoring one's progress.

Social facilitation

Users could participate in a training session at any time, and they could join other users or exercise alone. The participations of all the users were logged in the system.

We consider a user participation to be "joint" if there was at least one or more users exercising at the same time for a minimum of one minute. On the contrary, if a user participated alone during the entire training session, the participation is considered as

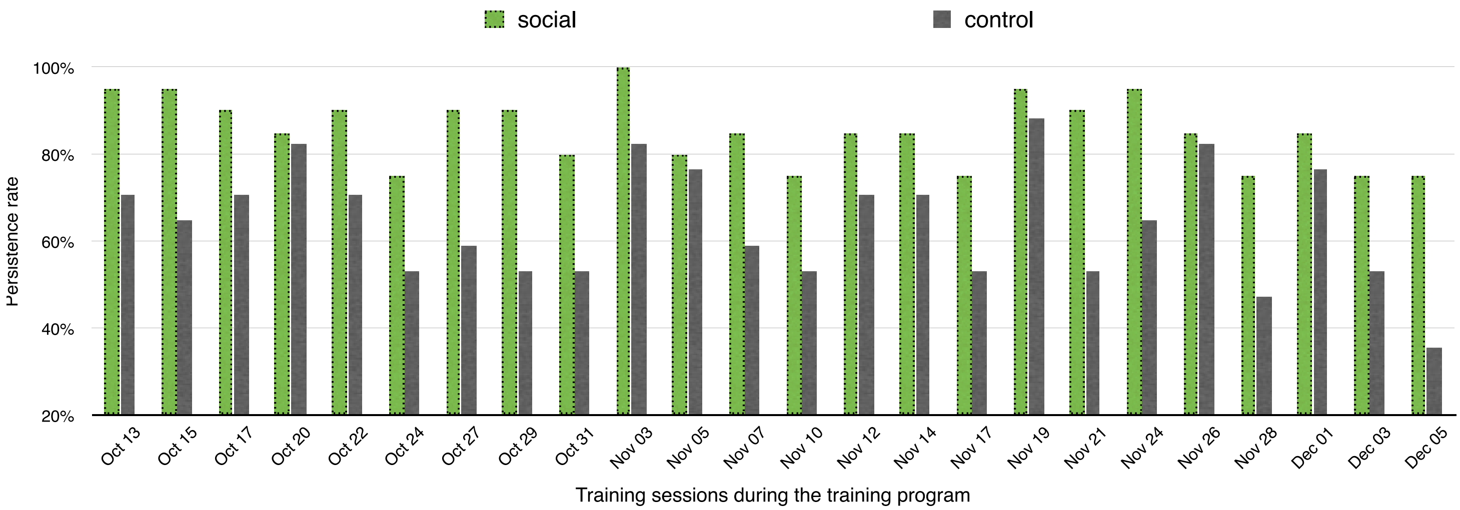


Figure 5 **Persistence rate in the control and social groups during the eight-week period of the study.**

"individual". We measure **co-presence** by computing the ratio of *joint* participations with respect to the total number of participations.

RESULTS

Attrition and adherence rates

Out of the initial 40 participants, 4 withdrew at different moments during the course of the study due to unpredictable health or family problems. One participant was substituted because the withdrawal occurred before the start of the study. This resulted in a 7.5% attrition rate, measured in terms of the proportion of participants lost at the end of the study. It should be observed, however, the reasons behind the withdrawal of these participants were solely related to unexpected health and family problems or in one case, because of technical issues regarding Internet connection problems which, could not be solved.

Adherence to the exercise program was computed using data about usage patterns collected from the application logs, both for *control* and *social group*. In order to better explore adherence patterns, for each participant, two measures were considered: (i) persistence throughout the eight weeks of the exercise program, and (ii) level of completeness of the exercise sessions.

With regard to persistence, a total number of 24 sessions were planned during the eight weeks of the study (3 sessions per week). In order for the exercise program to succeed, participants were asked to carry out at least two of the three sessions that were planned each week. To calculate persistence, the total number of exercise sessions in which each participant took part was divided by 24, the total number of possible training sessions across the 8-weeks period of the study.

The general persistence rate in the two groups was 76% ($SD = 22.6\%$). More specifically, in the *social group* the persistence rate was 85%, while in the *control* group it was 64% (Fig. 5).

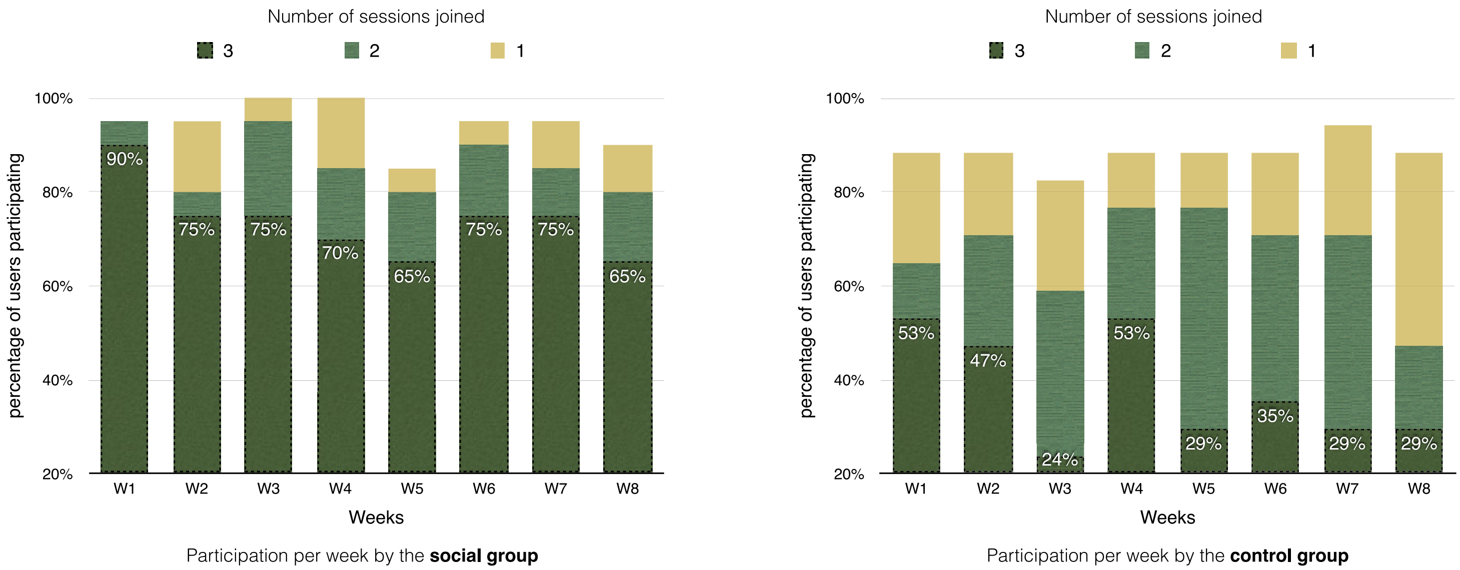


Figure 6 Attendance rates of the social and control groups per week. Participants in the social group tended to carry out more than the two working sessions per week that were required.

A t-test for independent samples was used to analyse the difference in persistence during the training program between the *social* and the *control* group. The test showed that the *social* group had a significantly higher persistence rate ($M = 85.4\%$, $SD = 16.1\%$) compared to the persistence rate of the *control* group ($M = 64.2\%$, $SD = 24.1\%$, $t(35) = 3.18, p = .003$).

Indeed, grouping the participation by week, distributing the users by number of participations (1, 2 and 3), we notice that participants of the study group did not only comply with the coach instructions (at least two sessions per week, as requested from them), but they did more (Fig. 6). This indicates that the various features of *Gymcentral* were more engaging than the simple app.

The second measure related to adherence is the completeness rate, which refers to the extent to which, participants tend to complete all the exercises included in a working session once they have begun to work out (completeness was calculated by measuring the ratio of the "duration of videos that the participant had watched" to the "total duration of videos of the session"). The overall completeness rate in the two groups was very high, specifically 90.32% ($SD = 17.4\%$), meaning that overall participants tended to complete the working sessions once they started. The completeness rate in the *social group* was slightly higher compared to that of the *control group*, although it was not statistically significant (respectively, $M = 91.75\%$, $SD = 12.46\%$ for the *social group*, and $M = 88.63\%$, $SD = 22.24\%$ for the *control* group).

In general, the data shows positive results with regard to attrition and adherence rates, providing evidence for the effectiveness of tablet-based home exercise programs. More specifically, the *social group*, who used the system, including communication features and

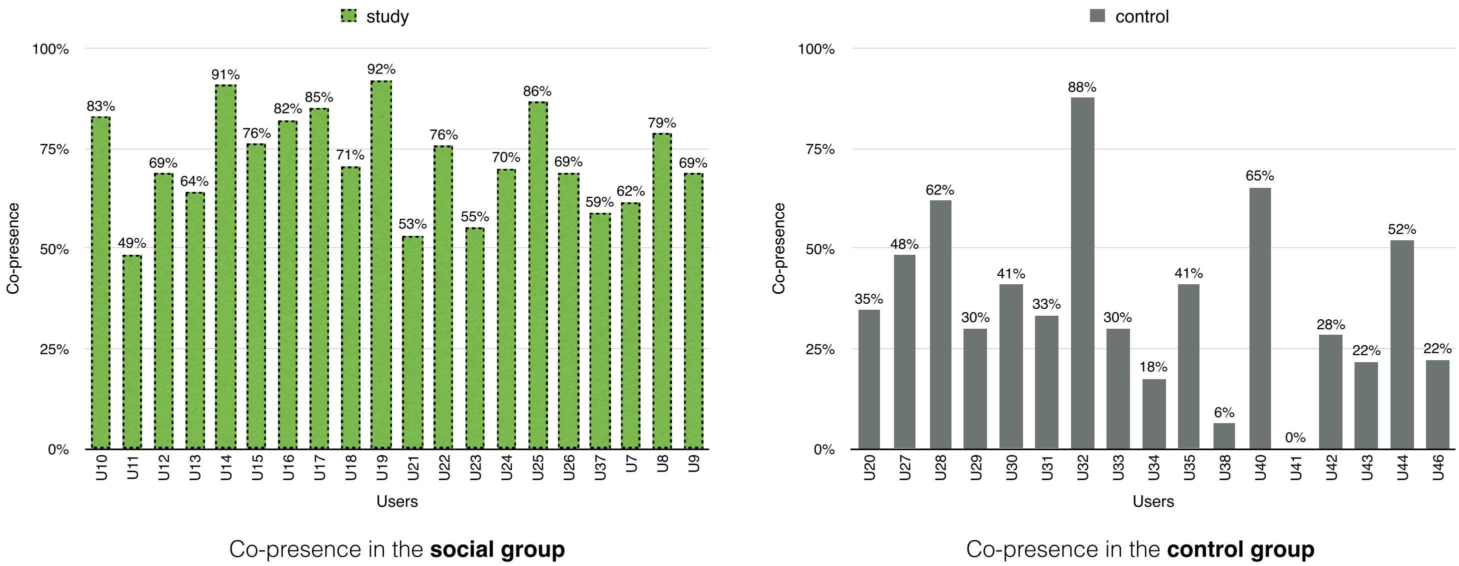


Figure 7 Percentage of co-presence in the social and control groups.

the garden metaphor to monitor one's progress, showed a significantly higher persistence rate throughout the study, indicating an increased engagement in the program.

Social facilitation

A total of 669 participations to the training sessions were registered in the *social group*, for the 20 participants, and 451 for the 17 participants in the *control group*. The co-presence in the *social group* was of 71.86% ($SD = 12.53\%$). In the *control* group instead, the co-presence was of 36.52% ($SD = 21.92\%$). In the latter case, co-presence represents the meetups by chance as users were not aware of each other. Figure 7 depicts the percentage of joint sessions for both *social* and *control* groups. The percentage demonstrates the ratio of times in which the trainee was exercising in a "joint" session.

A t-test for independent samples reveals a significant difference between the *social* and the *control group* ($t(35) = 6.14$, $p < .001$). However, to compensate the effect of a higher number of participants in the *social group* and to get a conservative estimate, we excluded the three most active participants from the *social group* (U7, U13, U26) along with all their data, and analysed co-presence in this new condition. The difference is still significant, with a co-presence of 62.68% for the remaining 17 participants of the *Social group*, compared to the 36.52% of the *control group* ($t(32) = 3.90$, $p < .001$). This result suggests that participants in the *social group* were motivated to join the sessions at the same time.

Further analysis beyond our outcome measures were done for informative purposes:

(a) Co-presence and the motivation to stay online

We further investigated if co-presence caused longer duration of stay in the classroom, by comparing the difference in the time spent by each user in the "joint" and "individual" sessions. The results shows an average raise of 10.81 min ($SD = 16.52$) in the time spent in joint sessions for the *social group*, and of 6.62 min ($SD = 10.14$) for the joint session of the *control group* (*control group* participants were not able to see each other's presence. Therefore the 6.62 min increase is due to the effect of longer sessions and not user motivation). Still, the *social group* exercised 4.19 min more than the *control group*. However, the difference is not significant according to the t-test analysis ($t(35) = 0.91$, $p = 0.37$).

(b) Co-presence and the motivation to finish the exercises in one session

In the study settings, training sessions were composed of 12 to 13 activity bouts. However, participants could optionally perform all of the designated activity at once (once in a row) or complete the session activities partially (e.g., activity 1–5) and return later to the same training session to perform the remaining activities (e.g., 6–13). Thus, we analysed the ratio of completed sessions at once in three situations of (i) completed at once when exercising individually and in joint sessions, (ii) completed at once individually and, (iii) completed at once in joint sessions.

From the 669 recorded sessions for the 20 participants of the *social group*, the ratios are as: (i) completed individual + joint = 40.75%, (ii) completed individual = 34%, (iii) completed joint = 42.42%. For the 451 recorded sessions for the 17 participants of the *control group* the ratios are (i) completed individual + joint = 39.46%, (ii) completed individual = 34.92%, (iii) completed joint = 50.51%. Although the completion ratio for joint sessions is higher in both *social* and *control* groups, this is mostly caused by the fact that longer sessions increase the chance of meeting with the other trainees, and in any case the difference is not significant.

(c) Success rate of invitations to join a training session

Participants in the *social group* were given the possibility to send invitations to the other trainees, by asking them to join to the classroom with them. Out of 20 participants of the *Social group*, 11 participants had sent at least 1 invitation. We account for 129 invitations received, and the percentage of invitations that caused trainees to join within 2 min of notice is 50.59%, indicating that a considerable number of received invitations caused the participants to start training immediately.

DISCUSSION

The use of Gymcentral as technological support for home-based training has been effective in keeping independent-living older adults motivated during the training program. We discuss our results addressing each of our initial hypotheses:

H1. Gymcentral increases the participation of independent-living older adults to home-based training

The results indicate that the *Social group* had a significantly higher persistence rate ($M = 85.4\%$, $SD = 16.1\%$) compared to the persistence rate of the *control group* ($M = 65.1\%$, $SD = 24.6\%$), $t(34) = 2.98$, $p = .005$. This confirms our hypothesis that Gymcentral increases the participation of older adults to home-based training programs, compared to a simpler version of the same application without social and persuasion features. In terms of completeness of training sessions, the level for both groups has been very high, with no statistical difference between both, suggesting that users tend to finish their sessions once they have started.

Furthermore, we have observed that trainees have not only complied with the minimum requirements of the coach in terms of sessions per week (2 sessions), but performed even more. These results are encouraging as they suggest that the effects of the application are not limited to compliance but promote real engagement.

H2. Social presence increases joint participation of independent-living older adults in training sessions

We have seen a significant difference between the *social group*, where social presence was in place in the form of virtual avatars, with respect to the meetings by chance in the *control group* ($t(35) = 6.14$, $p < .001$). The difference remains significant and large even when we correct, in a conservative way, for the slightly larger number of participants in the *social group* ($t(32) = 3.90$, $p < .001$). This result suggests that the social presence motivated participants to join the training sessions at the same time, thus confirming our hypothesis. A limitation of the analysis is that the level of participation of the *social group* was higher, as a result of the persuasion strategies that were in place, and this factor could not be isolated for this particular analysis.

As users could pause training sessions and complete them at multiple times, we explored if users tended to complete sessions at once, or spend more time training, while in presence of others. We have not seen any significant difference in both, which is in line with our previous finding that once users start, they tend to complete their training sessions, whether in a social or individual condition. In addition, the success rate of our invitation feature was encouraging, motivating further study into the effects of normative influence in co-presence.

CONCLUSION

In this paper we have introduced a virtual fitness environment to promote home-based physical training to independent-living older adults. The application, namely Gymcentral, incorporates individual and social persuasion strategies, featuring social facilitation tools to motivate long-term adherence and co-presence in training sessions. We have investigated the effectiveness of our design and its influence in an intervention study, with promising results.

The design of the virtual gym, including the persuasion and social features, has been very successful in keeping older adults motivated during the training program. Older adults in the intervention group have not only shown a level of compliance with the training program significantly higher with respect to the *control group*, but also a superior level of engagement seen in trainees performing more training sessions than those initially prescribed. We suspect the difference is mainly due to the social features, but given the limitations in the study setting we are not able to confirm this.

We have also seen that older adults prefer to train with others. It has been observed in the higher level of co-presence in the *social group* compared to the meetings by chance in the *control group*. This result is encouraging, as it motivates further research into using home-based training programs as an opportunity to stay physically and socially active, especially for those whom for various reasons are bound to stay at home.

Even more importantly, the overall perception of the application has been very positive. Indeed, the association of older adults who participated in the study has formally requested to continue using the service, and new training programs are currently under development. Moreover, similar studies are currently being replicated in Russia and the Netherlands to analyse the effects of cultural differences, and of different training programs.

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Competing Interests

Iman Khaghani Far, Francisco Ibarra, Stefano Tranquillini, Marcos Baez, Fabio Casati are researchers at the University of Trento and are also associated with Gymcentral; however, they do not receive compensation from GymCentral nor did Gymcentral have any role in their research or publications. Nicola Doppio is an employee of Trento Rise.

Author Contributions

- Iman Khaghani Far, Francisco Ibarra and Marcos Baez conceived and designed the experiments, performed the experiments, analyzed the data, wrote the paper, prepared figures and/or tables, performed the computation work, reviewed drafts of the paper.
- Michela Ferron conceived and designed the experiments, performed the experiments, analyzed the data, wrote the paper, prepared figures and/or tables, reviewed drafts of the paper.

- Stefano Tranquillini conceived and designed the experiments, performed the experiments, analyzed the data, prepared figures and/or tables, performed the computation work, reviewed drafts of the paper.
- Fabio Casati conceived and designed the experiments, analyzed the data, wrote the paper, performed the computation work, reviewed drafts of the paper.
- Nicola Doppio conceived and designed the experiments, performed the experiments, analyzed the data.

Ethics

The following information was supplied relating to ethical approvals (i.e., approving body and any reference numbers):

The study received ethical approval from the CREATE-NET Ethics Committee on ICT Research Involving Human Beings (Application N. 2014-001).

Data Availability

The following information was supplied regarding data availability:

All raw data is contained in Data S1.

Supplemental Information

Supplemental information for this article can be found online at http://dx.doi.org/10.7717/peerj-cs.30#supplemental-information.

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