

Exploring the Impact of a Gamified Exercise Platform to Support Healthy Ageing: Home-based Study with Older Adults

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Abstract—Active ageing is an increasingly important concept within society due to the ageing of the world population and search for enhanced quality of life. Technological resources such as serious games can be used as a means to promote healthier lifestyle and ageing, particularly in older adults.

This study intended to explore the effects of using a digital approach composed of serious games to support physical and cognitive exercise at home, to support healthy ageing.

Eleven older adults voluntarily participated in an eight-day home-based study. The aim of the study was to explore the feasibility of the digital approach in autonomous sessions at home, by measuring satisfaction and motivation, and assessing the impact of different gamification strategies.

The results showed that participants exercised autonomously on average on 5.5 out of the 8 days. Each session had an average duration of 35 minutes. Moreover, participants reported an average satisfaction of 80.0% throughout the sessions. Yet, the findings indicate that system usability should still be improved. Participants provided suggestions towards an easier user experience, pointing for example to the importance of personalized exercise plans. The findings suggest that gamification strategies focused on multi-joint and dynamic exercises were preferred over single limb and more monotonous exercises.

The current study highlights the potential of home-based digital solutions to support healthy ageing in older adults and provide suggestions for future endeavors in this area.

Index Terms—Active Ageing, Healthy Ageing, Serious Games, Physical Exercise, Cognitive Stimulation, Rehabilitation, Gamification, Home-based care

I. INTRODUCTION

Recently, the concept of active ageing has been used in different contexts, both in research areas or as a public policy instrument. This concept was initially adopted by the World Health Organization in 2002 with the intention of addressing

quality of life and fundamental pillars (health, participation, security and lifelong learning). Active aging can be described as "the process of optimizing opportunities for health, participation and security in order to enhance quality of life as people age" [1]. For which it is closely connected with the promotion of healthy ageing. Due to increasing ageing of the world population, active and healthy ageing is of great interest to all societies, both more or less developed [2], [3].

Different studies report the importance of supporting active ageing through physical and cognitive activity. Studies suggest physical and cognitive activity facilitate healthier ageing trajectories, with better quality of life and improved cognitive functioning [4]. Furthermore, these activities are reported to reduce the risk of cardiovascular incidents, fractures, breast and prostate cancer, disability in activities of daily living, recurrent falls, functional limitation and cognitive decline, dementia, Alzheimer's disease, and depression [5]–[7].

As the number of videogames users over 50 years old has grown, e.g. 27% in USA [8], [9], and 18% in Germany [10], Serious Games (SG) can be a good strategy to promote active ageing. These games integrate simulation and learning or training for purposes like education, health, rehabilitation, and alike [11], [12]. Properly designed serious games have the potential to teach multiple skills, including cognitive, motor, social and emotional skills, as illustrated in Figure 1, while keeping the user engaged, motivated, immersed, entertained and challenged through the gaming experience [14]. SG allow consolidation and even genesis of neural connections, and potentiate quicker learning processes [15], [16]. All these factors are important since they enable learning of important processes and have the potential to support health, without inducing any negative connotations related to the processes that are being trained [17]. In parallel, another important SG

characteristic is the potential to collect information on the activity of the user, to monitor important aspects regarding the processes while the game is being played.

Through data collection and analysis, it is also possible to create game components that can promote greater user engagement, e.g. immediate feedback to user actions or achievement systems [18]. Furthermore, a serious game created with customisable game elements allows the user to adapt and tailor the game to their needs and goals [19].

Several studies analyse the use of SG by older adults. Using different devices (e.g. personal computer (PC), Virtual Reality, console), these studies show that SG are beneficial in reducing pain and promoting health and well-being, supporting stability of the health care system [20], improving balance and mobility function, and increasing muscle strength and endurance [21]. Other studies also point to benefits in cognitive function and global memory, and depressive outcomes [22], attention restoration, ameliorate stress, and promoting cognitive rehabilitation [23]. Older adults can especially benefit from SG, as SG can provide emotional, psychological and social benefits [24].

To effectively extend usage of SG for the older population, for example in the comfort of their homes, it is necessary to use an user-friendly interface and minimize complexity and equipment for the monitoring elements.

This study explores the effects of using the Clynx Platform [17], [25], which is a gamified exercise platform aimed at supporting active and healthy aging. To this aim, a home study with older adults was performed. The main objectives were to explore the feasibility and usability of integrating the Clynx Platform into autonomous home-based sessions, the impact on healthy ageing, and which kind of gamification strategies were more successful in promoting activity.

The remainder of the work is organised as follows. Section II describes the technology, population, protocol and methodologies used in the study. Section III presents an analysis and discussion of the results collected, grouped into three types of analysis: the usability, satisfaction and motivation, and gamification strategies. Section IV provides a critical summary with the main considerations and conclusions of the work, and Section V outlines recommendations for future work in this line of research.

II. METHODOLOGY

A. Clynx Platform

The Clynx Platform, the technology used in the current study, enables digital sessions for physical exercise and cognitive stimulation, that take place in an engaging game-like environment. It aims at making physical and cognitive therapy an enjoyable experience, by combining body movement tracking with a gamified-based approach. This technology has been used in healthcare, particularly in physiotherapy applications [17], [25], and is intended to be extended to fit the needs of active and healthy ageing. Namely, it is expected to support the older adults by promoting autonomy in daily life

Cognition: Perception Attention Understanding structures and meanings Strategic thinking Problem solving Planning, management Memory	Motor control: Eye-hand/foot coordination Reaction time Rhythmic abilities Balance Flexibility, endurance, strength
Emotions & volition: Emotional control Stress control Endurance	Social competencies: Cooperation Mutual support Empathy Interaction and communication skills Moral judgements
Personal competencies: Self-observation Self-critics Self-efficacy Identity Emotional control	Media competency: Media knowledge Self-regulated use Active communication Media design

Fig. 1. Skills that can be acquired by playing video games [13] (p. 262).

activities, safe customised care, continuous lifelong learning, digital inclusion and emotional well-being.

Using this technology, each user has their exercise plan, composed of several exercises that are serious games. Each serious game promotes an exercise within a different gamified objective, scenario and environment. Moreover, it includes multiple gamification elements, such as a star system, a performance bar, repetition and time counter, voice and audio feedback. The platform also includes global gamification strategies such as avatar customization and virtual medals for activity achievements, which are all aimed to stimulate engagement, enjoyment and motivation.

During each session, the user logs in on their computer application and has access to their plan of exercises. One single off-the-body sensor, a 3D camera, is used for body tracking. This motion tracking is key to allow users to interact with the digital gamified environment throughout their session, to provide them with real-time feedback, and to determine relevant body movement information such as exercising and performance indicators. The portability of this digital solution enables it to be used at home.

The platform is designed to provide older adults with a digital experience that enables physical and cognitive stimulation intended at promoting healthy ageing in multiple ways: autonomy in activities of daily life; safety and integrated customised care; continuous lifelong learning and digital inclusion; and emotional well-being. All these converge to providing a holistic proposal to improve quality of life.

Considering the importance of testing new technologies in the native language of the participants, the Clynx Platform has been fully translated to the Dutch language. It has also been integrated with the platform RegiCare, which is a software solution that supports processes in healthcare and welfare.

A pre-validation study with nine older adults has been conducted in a living lab that simulates a home environment. The feedback that participants provided in the pre-validation was incorporated in the Clynx Platform to ensure the readiness

of the technology to be tested in this home-based study.

B. Sample Characterization

The study and experimental protocol involving human subjects described in this paper were approved by the Ethics Committee 'Computer & Information Science' at the University of Twente.

This work comprises data collected from 11 participants, who voluntarily participated (7 of which were female), with ages comprised within 55 and 84 years and an average of 67.82 ± 9.33 years old.

The inclusion criteria targeted older adults (55+ years old) that were willing to test a digital coaching system to support healthy ageing. Participants had to live in the Enschede area, in The Netherlands, and to be physically able to execute home exercises. Participants were also required to have a Wi-Fi connection, a Windows (8 or above) PC.

C. Home-based Study Protocol

The testing phase lasted a total of eight days.

Each participant was given access to the Clynx Platform and was aware that participation in the study was fully voluntary and no specific schedule should be followed, i.e. the participants were free to use the platform only on the days they wanted.

All participants had access to an exercise plan of 10 gamified exercises that included both physical and cognitive SG, as illustrated in Figure 2 and detailed in Table I. The exercise plan, in terms of exercises and their difficulty levels, was the same for every participant.

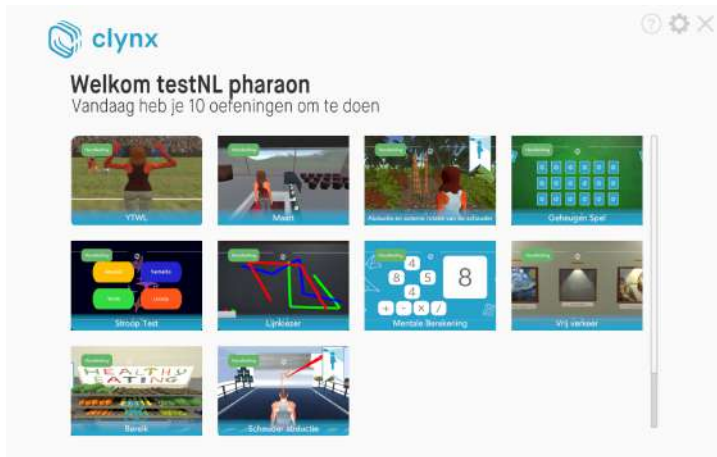


Fig. 2. Welcome screen with preview of exercises included in the plan.

During the 8-day period of the home-study, the procedure was as follows.

1) *Day 1*: Two researchers visited the participants at their home to onboard the participants on the study, where they received information on the protocol, the technology and the functioning of the study.

Firstly, the participants were given the opportunity to ask any questions they might had regarding the study, followed by the reading and signing of the Informed Consent form.

Then, the researchers proceeded in supporting the software installation on the PC of the participant, provided the participants with their credentials to login on the platform, and they jointly watched the onboarding tutorial and tried out the technology (c.f. Figure 3).

Finally, the participants were asked to autonomously answer to the questionnaire of day 1. It contained demographic questions (year of birth, gender and level of education), questions on modern technology use, questions on their level of physical activity (e.g. confidence and motivation to move), on their health (on a 0-100 scale), about quality of life (EQ-5D-3L [26] and EQ VAS [27] [28]), and about usability through the System Usability Scale (SUS) [29]. The participants reported their satisfaction on a 1-7 scale during the first activity session.



Fig. 3. Participant watching the tutorial of the application, on Day 1.

2) *Day 2-7*: Each participant was free to use or not use the Clynx Platform, and asked to fill the daily questionnaires. Participants were asked to fill in a daily questionnaire in which they were asked whether they used the platform, whether they succeeded in using it and to rate how much they agreed with the quote "In general, I am satisfied with the ease with which I could use the digital exercise coach" on a scale from 1-10. If participants performed a session on a given day, they were asked to report their satisfaction, on a 1-7 scale, during the activity session.

3) *Day 8*: On the last day of the study, the participants were asked to answer to the questionnaire of day 8 (which included similar questions to those posed on Day 1, except for demographics), were interviewed about their experience, where the participant could freely provide feedback, and received a reimbursement (VVV card of 30 euros) for their participation.

In addition to the data collected from the daily questionnaires, the activity of each session was collected directly from the technology. In particular, activity parameters such as login time, logout time, and a list of exercises performed during the session were collected automatically by the platform in each session, in order to compute the session duration, the number and type of exercises performed.

Figure 4 illustrates a participant performing a physical gamified exercise.

D. Analysis

This subsection outlines the methods used to analyse the results obtained from this home-based study.

The number of sessions was calculated by looking into the number of logins registered by each participant throughout the 8-day period. Moreover, only sessions that had more than 1 exercise done were considered, and only one session was considered per day, even if the participant had two logins registered on the same day.

The SUS data collected at the Day 1 and 8 was used to assess how participants rated the usability of the platform, for which the final score will be presented. Moreover, a set of questions was selected to gain further insight on the ease of which the application is used, the learning curve of using the application, and the overall feel of using it: "I think I need technical support to use a digital exercise coach like this"; "I felt confident while using the digital exercise coach".

The questions "Have you started exercising more in the past week?" and "How motivated are you to move", that participants provided a score on Day 1 and 8, will be analysed to assess motivation. The satisfaction feedback collected at the end of session will be analysed. To place the questionnaire data and usage data in perspective, the input that participants provided in the interview at the end of day 8 will be explored.

The session duration was calculated by subtracting the time the participant closed (logout time) the application with the time the participant opened it (login time). Outliers were removed from the analysis, i.e. sessions in which the participants did not exit the application shortly after completing the exercises were not considered.

The list of exercises done in each session was also computed though the analysis of the activity registered by the platform. It provides insight into the exercises activity, to evaluate how the gamified exercises and strategies impacted the overall experience of the participants.

Note: Throughout the analysis, all results that refer to data averages are presented along with their respective standard deviation.

III. RESULTS AND DISCUSSION

A. Usability of the digital exercise at home

The study included a total of 60 sessions amongst the 11 older adults, with an average of 5.5 ± 2.0 sessions per participant throughout the eight-day period. Moreover, when analysing the questions from the daily questionnaires, participants reported that, on average, they managed to exercise

TABLE I
GAMIFIED EXERCISES INCLUDED IN THE PLAN.

Exercise Name (ID)	Characteristics of the Gamified Exercise		
	Description & objective	Main Stimulus	Scenario
Shoulder Abduction (1)	The user is on a track in which several walls approach over time, each has a human silhouette that the participant must mimic.	Physical	Factory
Reach Training (2)	The participant must perform shoulder flexion (below and/or above 90°) to collect the items on the shelves.	Physical	Supermarket
Joint Free Movements (3)	The participant is in front of a blurry image. With a cloth in his hand, the participant must move his arm, according to free joint movements of the shoulder, as if they were cleaning a window.	Physical	Museum of Art
External Rotation and Abduction (4)	The participant must perform the rotation and external abduction movement of the shoulder, using his sword to cut bamboo clusters that come in the way.	Physical	Forest ¹
YTWL (5)	The participant acts as a goal-keeper, and aims to defend the balls that are shot, exploring different ways of moving and positioning the two arms.	Physical	Football Stadium ¹
March (6)	The participant marches while simulating the crushing of grapes to produce wine.	Physical	Vineyard ¹
Math Game (7)	It challenges the user to perform mental calculations. They must select from the four numbers and arithmetic operations that show up on the screen to accomplish a given final result.	Cognitive	Black Background
Memory Game (8)	The traditional memory game is important for concentration and memory. The player has to select individually and try to guess all the pairs of cards, with the fewest possible attempts.	Cognitive	Playing Table
Stroop Test (9)	Buttons of different colours appear on the screen, with a color written on it. The user must identify the button where the color and word do not match.	Cognitive	Blue Background
Pick the Line (10)	Several lines (random sizes and shapes) are shown on the screen. The user has to visualise and spatially manoeuvre them to identify which is the longest.	Cognitive	School Board

¹ Open-air environment.

86% of the times they wanted to. These results show that the participants were able to autonomously exercise in the majority of the days. Moreover, each session had an average duration of 35 ± 13.7 minutes.

From the SUS data collected, it is possible to calculate an average SUS score of 62.2 with a standard deviation of 14.4. From this result, it is possible to conclude that there is still room to improve the technology and its usability.



Fig. 4. Participant performing the "March" exercise, on Day 1.

Taking a closer look at the three questions under analysis, the results were the following (all items are on a scale from 1 to 5):

- "I found the digital exercise coach easy to use". For this question, the participants scored an average of 3.6 ± 1.1 and 3.4 ± 1.0 on day 1 and 8, respectively.
- "I think I need technical support to use a digital exercise coach like this". For this question, the participants scored an average of 1.9 ± 0.8 and 1.5 ± 0.5 on day 1 and 8, respectively. Note that for this question, a score of 1 is better than a score of 5.
- "I felt confident while using the digital exercise coach". For this question, the participants scored an average of 3.4 ± 1.3 and 3.9 ± 0.8 on day 1 and 8, respectively.

Lastly, regarding the easiness of using the technology, the participants reported a score of 6.8 ± 1.5 on a scale from 1 to 10 in the daily question "In general, I am satisfied with the ease with which I could use the digital exercise coach".

B. Satisfaction and Motivation

One of the goals of this study was to evaluate the ability of this tool to be used as a means to exercise more to promote a healthier lifestyle. Participants were asked at the end of the testing period whether they had been encouraged to exercise more or not. Five out of eleven participants answered positively to this item. when answering the question "Has the digital exercise coach encouraged you to exercise more?", suggesting that this tool has motivated them to exercise more.

Another important aspect was to assess the overall satisfaction of the participants.

The average satisfaction was 5.6 out of 7 (80%) with a standard deviation of 1.5.

It is also important to note that 91% of the participants reported a level of 4 or 5, on a scale of 1 to 5, regarding the question "How motivated are you to move", on Day 1. Thus, the starting motivation for most participants was already quite high, which might point to a slight bias in the population sample and to an increased difficulty in measuring the influence on motivation.

Regarding the self-assessed health status, the average level on day 1 was 80.9 ± 13.0 and 79.5 ± 16.0 on day 8. There is a large similarity in both results, which is probably due to the limited time in which the approach was tested, suggesting that eight days is a short period to analyse the impact that using this platform can have on the health of the participants.

C. Gamification Strategies

In order to explore the impact that using gamified exercises had on the experience of the participants, an individual analysis on each exercise was conducted. Since the exercises that participants could choose from were always the same for every participant and for every session, each participant had the option to do the ones they preferred the most. The average number of exercises performed by participants was 46.7 ± 27.1 exercises, amongst all sessions, with an average of 8.1 exercises per session. This indicates that the participants did on average 80% of the total exercises available, in each session. Figure 5 presents the distribution of the exercises performed.

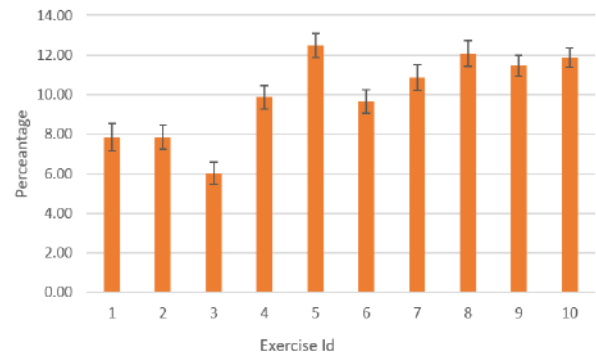


Fig. 5. Exercise distribution.

From Figure 5 it is possible to observe that the exercise distribution is mostly uniform, with the most used exercise being the YTWL (ID 5), with a usage of 12.47%. In order to understand why this exercise was the most used, it is necessary to look at the scenario and objective of the exercise and the movement performed. To complete this exercise, the participants had to lift both arms to form a shape and defend an incoming soccer ball. The fact that both arms were used was a key point for the participants, as it will be later discussed. Regarding the scenario/objective, compared to other exercises, this had a more compelling objective, which was to act as

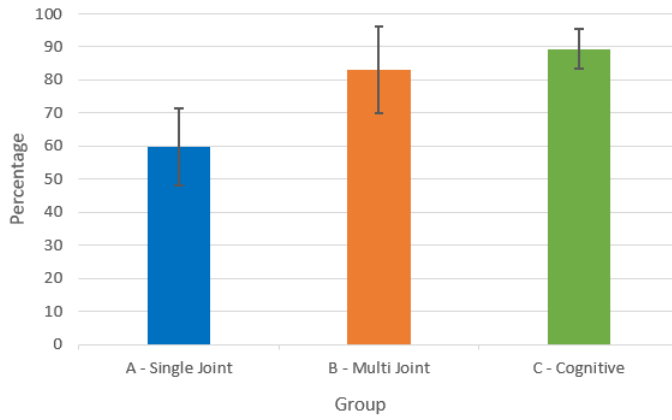


Fig. 6. Percentage of sessions that contained exercises from a given group.

a goalkeeper. Moreover, this exercise combined 4 different movements/shapes. These are probable reasons as to why this was the preferred exercise.

On the other hand, the exercise least used was the Joint Free Movements (ID 3) with a usage of 6.04%. Opposed to the previous exercise, this one only worked one arm at a time, and it was set in an indoor (museum) scenario. Moreover, this exercise had a key difference that only one other exercise had, which was that they both are in first-person. These might have contributed negatively to the experience of the participants regarding this exercise.

Moreover, one can notice that exercises with IDs 4, 5 and 6, identified in Table I as having a forest, a football stadium and a vineyard as scenario were the most used ones within the physical exercises. They performed better than the exercises with IDs 1, 2 and 3, all of which had indoor scenarios. Despite the participants interviews did not provide any insight on this topic, the use of simulated green environments has been previously associated with calming and relaxing benefits during exercise [20], [30], and the data collected seems to suggest a preference for the SG with green and outdoor environments, for which future work could explore this hypothesis.

It is possible to further explore how the participants responded to the exercises by grouping them. Group A - Single Joint (exercises with IDs 1-4) includes exercises that only work one limb at a time. Group B - Multi Joint (IDs 5-6), since these are multi-articular exercises that promote exercising with different limbs, and Group C - Cognitive (IDs 7-10) that represents the cognitive exercises. It is possible to observe the average use for every group in the Figure 6.

Figure 6 depicts the percentage of sessions that contained exercises from the corresponding group.

While Group B and Group C have very similar use activity, there is a clear difference from Group A to Group B, despite both promoting physical activity. It strengthens the hypothesis that participants preferred doing exercises that involved the whole body and not just a particular joint. One can infer that multi-articular exercises promote exercises that are naturally more dynamic and that this fact might influence their interac-

tivity to be used by the older adult. These conclusions were supported by the interview data. In fact, some participants reported "Repetitions for left and right should automatically change", which reinforces that exercises in Group A, for imposing repetitive movement with just one side of the body, lacked dynamism that is key in motivating older adults.

Group C showed a very high activity level. A possible reason could be related to the setup of these cognitive exercises. These exercises could be done while seated, making them more effortless exercises to choose and play. Moreover, the interview revealed that participants liked the switching between cognitive and physical exercise for variety. In that sense, some participants also provided suggestions to enable a more effortless experience, such as "I would prefer if calibration was required only once and not at beginning of every exercise" and "The 'skip tutorial' option should be default".

Although the results suggest some conclusions, one can also note the time limitation of this study. A longer testing period would enable stronger and better validated conclusions.

Moreover, the authors observed a limitation in that all participants followed the same exercise plan. Although all participants had the common goal of active ageing, every person has their own physical and cognitive characteristics. In addition, the study included older adults with a wide range of ages. Thus, some exercises revealed to be too easy for some participants and too complex for others. In fact, some participants reported "I would like to recommend difficulty increase to both physical and cognitive training".

Using the same exercise plan was necessary for the standardization of the study, but these results suggest that future implementation should include a higher level of customization and allow participants to evolve to higher difficulty levels.

IV. CONCLUSION

In this work we explored the impact of using the Clynx Platform to support healthy ageing, by promoting physical and cognitive autonomous exercise with serious games. The data was collected in a 8-day home-based study with older adults.

The analysis addressed the feasibility of the approach in autonomous home sessions, the impact in satisfaction and motivation to a healthy ageing, and the study on which kind of gamification and digital techniques were more successful.

The results showed good adherence by the older adults, who exercised autonomously on average on 5.5 out of the 8 days. Each session had an average duration of 35 minutes. Moreover, on average, participants needed little technical support and felt confident while using it.

Concerning satisfaction and motivation, the participants reported an average satisfaction of 80.0% throughout the exercise sessions. Yet, the overall SUS score was 62.2, indicating that usability can still be improved. Moreover, participants provided improvement suggestions towards an easier user experience, pointing for example to the importance of personalized exercise plans.

The sessions activity suggested that gamification strategies that focused on multi-joint and dynamic exercises were preferred over single limb and more monotonous exercises.

The current study highlights the potential of home-based digital solutions to support healthy ageing in older adults.

V. FUTURE WORK

Future work could consider tailoring digital approaches to support cognitive and physical exercises to the individual, providing for example a personalized workout plan or including SG that adapt their difficulty level to the performance of the user. Future studies could also explore long-term effects when using the Clynx Platform for a longer period of time in larger and diverse samples of older adults. Other potentially interesting endeavors are including a control group that performs traditional physical therapy exercises and to explore what gamification strategies are most suitable for what types of individuals.

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