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ACCEPTANCE AND USABILITY OF TECHNOLOGY-SUPPORTED INTERVENTIONS FOR MOTIVATING PATIENTS WITH COPD TO BE PHYSICALLY ACTIVE

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ABSTRACT

In chronic care, technology can play an important role to increase the quality and efficiency of healthcare. But to be successful, healthcare technology needs to be acceptable, usable, and easily integrated into daily life. As a consequence, end-users need to be actively involved in the design process. In the European IS-ACTIVE project, we developed technology-supported interventions that promote physical activity in patients with COPD, by using an ambulant activity coach and an interactive game. In this paper, we elaborate on the design, involving the end-users, to develop interventions that are highly usable and well accepted.

KEYWORDS

COPD, e-health, physical activity, usability, user acceptance, user-centred design, gaming

1. INTRODUCTION

Regular physical activity plays an essential role in chronic disease management, such as for Chronic Obstructive Pulmonary Disease (COPD), a respiratory disease characterized by the progressive development of airflow limitation that is not fully reversible (GOLD, 2013). Providing face-to-face care to stimulate patients in regaining activity levels is difficult as care professionals lack insight in the patient's activity behaviour in daily life. Besides, the adherence with exercise programmes is low (Hernandez et al., 2000), and they do not necessarily lead to improved daily activity behaviour (Cindy Ng et al., 2012). The growing pressure on healthcare resources and costs and the increase in the number of patients (Mannino & Buist, 2007), argues for the need to find inventive ways to care for these patients. Healthcare technology seeks to respond to these pressures by assisting healthcare professionals in delivering high-quality patient care, and empower patients in self-care and disease management. Although numerous ICT-based healthcare applications have been designed and investigated, very few are eventually implemented in daily healthcare (Esser & Goossens, 2009). User acceptance of the technology is an important barrier to successful implementation in healthcare (Broens et al., 2007), which emphasizes the need for involving users in the design process. In addition, the usability of an application seems to be a key aspect for success (Broens et al., 2007) and should be evaluated in designing healthcare technologies (Alexander & Staggers, 2009).

In this paper, two of the technology-supported interventions developed in the European IS-ACTIVE project (www.is-active.eu) are described and evaluated. These interventions aim to improve the physical activity of COPD patients from two perspectives: 1) daily monitoring and feedback using an ambulant activity coach and 2) supporting exercise using an interactive game. These interventions were developed from a user-centred perspective, in an iterative manner (see Fig. 1), where requirements were elicited from scenarios based on the PACT approach (People Activities Context Technology) (Huis in't Veld et al., 2010). Both user needs and the state of the art in physical activity interventions for chronic conditions (e.g. Consolvo et al., 2009; Dekker-van Weering et al., 2012) were used as input. Different stakeholders took part from the early stages of the design process, to meet the needs and wishes of the potential users, to improve usability, to increase the chance of user acceptance and consequently, adoption of the product being developed. The prototypes were first evaluated regarding technical feasibility. Subsequently, users need to work with the applications to obtain early user feedback. Therefore, this paper describes the small-scale evaluation of the technology-supported interventions. In future large-scale trials, the interventions – with a fixed design – will be investigated in terms of clinical and cost-effectiveness to work towards implementation in health care.

The aim of this study was to determine the acceptance and usability of the interventions and to gain knowledge for further improvement, e.g. to explore how patients would like to receive feedback. The paper describes (1) the activity coach, (2) the interactive game, (3) the methodology for the evaluation study, and subsequently (4) the results. Finally, the findings of the evaluation are integrated and discussed to move towards next steps for improving physical activity in patients with COPD.

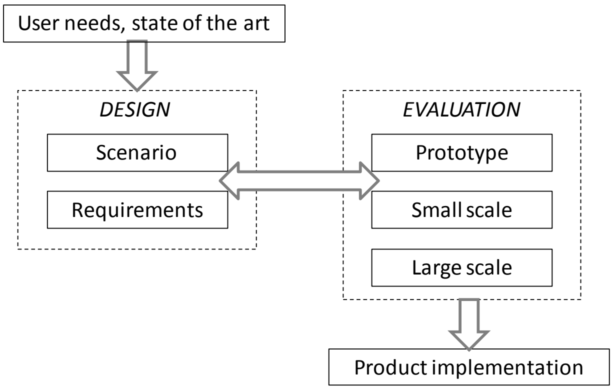

Figure 1. Methodology for the development of the technology-supported interventions

2. THE ACTIVITY COACH

The promotion of physical activity in daily life is one of the key treatment goals for patients with COPD (GOLD, 2013). Patients with COPD often restrict activities due to dyspnoea (during exertion), which leads to an inactive lifestyle and consequently a lack of fitness (Cooper, 2009).Previous studies showed reduced amounts of daily activity in patients with COPD compared to healthy controls, and a distinctive activity decrease in the early afternoon (Tabak et al., 2012). Besides, COPD patients were moderately aware of their daily activity and do not have the intention to change their present daily activity. According to behaviour change theories, like the transtheoretical model, patients need to be aware of their activity behaviour, otherwise treatment is unlikely to be effective (Prochaska & Diclemente, 1984). Telemonitoring can provide the possibility of measuring the activity behaviour in daily life in an objective manner and thus create awareness. Similar to the feedback from the professional, ambulant technology-provided feedback should create awareness about patient's own functioning, motivate and stimulate patients to positively change their activity behaviour, and eventually improve patient's functioning (Hermens & Vollenbroek-Hutten, 2008). In technology-supported interventions, the feedback can be intensified and provided in real-time, within the daily environment of the patient.

The activity coach aims to coach and motivate patients with COPD to obtain and maintain a physically active healthy lifestyle. The treatment goal is twofold: to increase activity levels and to distribute the activity level more equally over the day. The activity coach consists of a smartphone (HTC Desire S) and a sensor node with an on-board 3D-accelerometer (Promove-3D, Inertia Technology B.V., Enschede, the Netherlands) that measures the daily activity, referred to as the IMA value (Bouten, 1995). Both the accelerometer and the smartphone are worn on the subject's hip, measuring the 3D bodily movement to estimate energy expenditure (Bouten, 1995). The sensor connects with the smartphone using Bluetooth. The smartphone shows the measured activity cumulatively in a graph, together with the cumulative activity the patients should aim for: the reference activity line (Fig.2). Patients are asked to try to approach the reference line as closely as possible during the day. In addition, the patients receive textbased motivational cues on the smartphone. These messages are based on the difference between the measured activity and the reference line at the moment the message is generated. There are three types of motivational cues: Encouraging (>10% deviation below reference line), discouraging (>10% deviation above reference line) and neutral messages (≤10% deviation with reference line). Besides, the user can answer questions on the smartphone about self-perceived activity performance and dyspnoea and fatigue levels.

Figure 2. shows from left to right: (1) the main screen with a graph of daily activity, (2) a motivational cue, (3) a multiple choice question and (4) a Visual Analogue Scale (VAS) question. The top bar in each of the device screenshots shows a list of icons from the application that gives an indication of the application's current status, from left to right: sound on/off, wireless sensor connection, wireless sensor battery status, smartphone battery status.

3. INTERACTIVE GAME

All patients with COPD benefit from exercise training programmes and from regular physical activity (GOLD, 2013) yet adherence with home exercising is low (Hernandez et al., 2000). Gaming technologies are believed to provide a variation or addition to the regular therapy, which can have a positive effect on motivation (Lange et al., 2009) without additional burden on neither formal, nor informal health care. Furthermore, games can increase the treatment intensity as players would like to beat their high score. However, very few of the available games today specifically target the elderly population (Nap et al., 2009) or aim at exercise for patients with a (chronic) condition (Taylor et al., 2011).

The Orange Submarine game aims to support and motivate patients with COPD to exercise. In this game, a submarine moves at a constant speed across an underwater landscape with hills at regular intervals. Air bubbles appear in a sinusoidal arrangement. This pattern can be adapted to the exercise the patient has to perform. The goal of the game is to catch as many air bubbles as possible, by directing the submarine through them. During the game, real-time feedback is given about the score, pulse rate, and oxygen saturation for motivation and controlled exercising (Fig.3). Thresholds for heart rate and saturation could be entered before game play and when the patient crosses these thresholds, the game stops and displays a warning message. This warning message urges the patient to take a break.

A sensor node with an on-board 3D-accelerometer (ProMove-3D, Inertia Technology, Enschede, the Netherlands) is used to control the orange submarine in the game. By moving the sensor node up or down, the orange submarine moves in the corresponding direction. The node transmits the sensor data at 250 kbps through a 2.4 GHz wireless radio to a gateway,

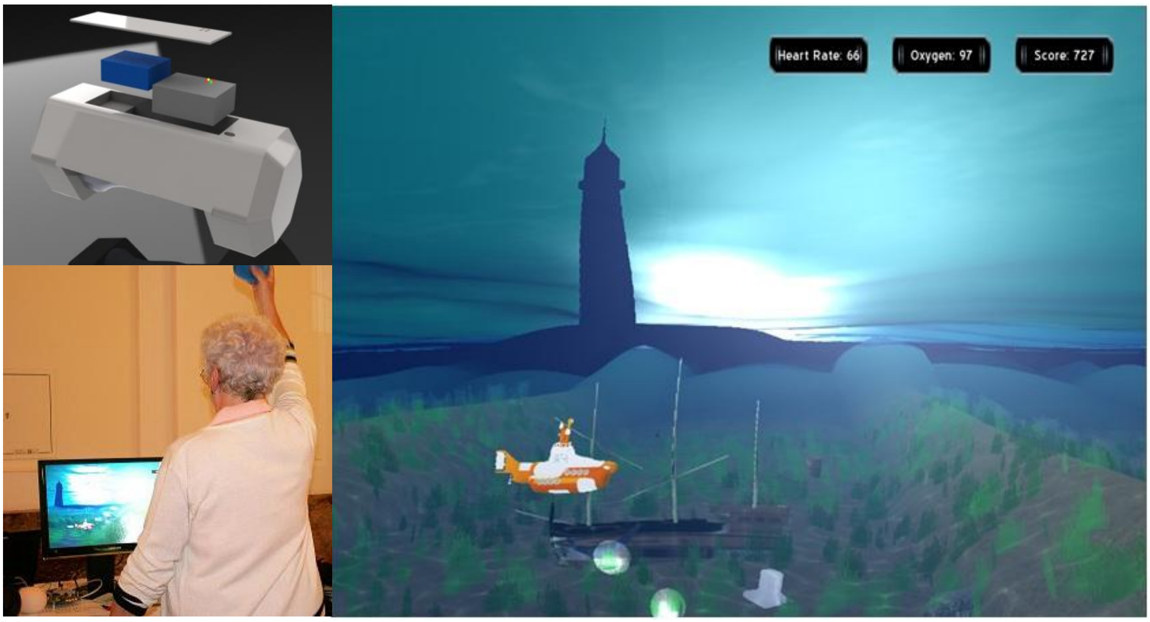

Figure 3. Right: screenshot of the orange submarine game, top left: the dumbbell (exploded view, showing the accelerometer and pulseoximeter integrated), bottom left: person playing the game

which in turn is connected through USB 2.0 to a computer. The oxygen saturation and the heart rate are measured with a Nonin WristOx$_2$ 3150 sensor, which is connected to the computer through a secure wireless Bluetooth 2.0 connection. For upper extremities exercising, a special dumbbell is used where the sensor node and the pulseoximeter are integrated in one single device (see Fig.3). For lower extremities exercises the sensor node is attached to the hip and the saturation is measured using a separate finger clip sensor.

4. METHODS

The purpose of the small-scale evaluation studies was to gain early user feedback. Patients with a clinical diagnosis of stable COPD, age above 40 years, and ability to read and speak the local language, were recruited from physiotherapy practices and (rehabilitation) hospitals in the Netherlands, Norway and Romania. All participants gave their informed consent prior to participation.

The test with the activity coach was performed in a lab-setting and was designed to simulate daily use of the activity coach application and to simulate daily activities while using the application. At measurement start, the researcher tells a scenario to the patient to describe the patient why and how the activity coach can be used in daily life:

"You are diagnosed with COPD and you regularly exercise with your physiotherapist. You often feel short of breath, which causes you to be less active. This influences your daily routines and activities, and weakens your physical condition. A vicious circle develops that greatly affects your quality of life. To prevent physical deconditioning, an active lifestyle is very important. To do so, you follow physiotherapy and home exercises, which are intensive for you, but also demanding for your physiotherapist. Therefore, the physiotherapist gave you a new device, so you can be treated at home, using technology. This is the activity coach. The activity coach consists of an activity sensor and a smartphone. The activity sensor measures your daily activities during the day. The sensor can be attached to your belt and the smartphone can be put in your pocket or purse. You wear the activity coach during the day, at home and outdoors. The smartphone shows your activity in a graph. You receive messages with advice about how you can change your activity, in order to keep an active lifestyle and promoting a more uniform spread of activities during the day. You use the activity coach at least 4 days per week. You keep following your regular physiotherapy sessions, and you can discuss your progress with the physiotherapist. The idea is that, when you follow the advice of the activity coach, your physical condition will improve."

Subsequently, the patient uses the application while performing a number of daily life tasks, such as standing up from a chair and walking.

For testing the orange submarine game, an easy-to-perform exercise was chosen for the lower extremities: squatting. This exercise is suited for use in a home-based environment and is often part of the regular treatment. Beforehand, a short demonstration was given of the orange submarine game to familiarize the patients with the game. Patients first performed a measurement at rest to obtain a mean baseline score for pulse rate and saturation. A notebook was positioned in front of the patients and they were asked to stand next to or in front of a chair. If able, the patients were asked to play the game a total of three times.

In both evaluations, patients were asked to fill out the following questionnaires afterwards:

- The System Usability Scale (SUS) was selected to obtain a general and high-level view on usability The SUS is a simple scale with 10 statements covering a variety of aspects of system usability, such as the need for support, training, and complexity (Brooke, 1996).
- The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is a technology acceptance model that aims to explain user intentions to use an information system and subsequent usage behaviour. As this was a first user evaluation study, the technology aspects of the UTAUT model were assessed (i.e. performance expectancy and effort expectancy) and in addition, intention to use. Example statements include: *"Using the system will improve my physical condition*" and "*I believe the system is easy to use*". The questionnaire consisted of statements with a 5-point (activity coach) or 7-point (game) Likert scale ranging from "strongly agree" to "strongly disagree". The percentage of respondents that provided a positive (score coach: 4/5, score game: 6/7), negative (score: 1/2) and neutral answer (score coach: 3, score game: 3/4/5) were evaluated for each question.

- Additional questions were asked to obtain feedback about the game and activity coach using statements on a 7-point Likert scale. Example statements include: "*The meaning of the graph is not clear to me*" or "*I find it difficult to follow the air bubbles on the screen*".

5. RESULTS

In total, 39 patients with COPD participated in the evaluation of the technology-supported interventions. Twenty-one patients contributed in the evaluation of the activity coach: 7 males and 14 females, with a mean age of 63.5±9.6 years. Eighteen patients with COPD participated in the evaluation of the game: 5 males and 13 females, with a mean age of 58.6±7.1 years.

The average SUS score was 75.6 (range: 27.5-97.5) for the activity coach. Lowest scores were found for the learnability aspects: patients need some time learning how to operate the application, and expect they need help using it. The mean SUS score for the game was 85.0 (range: 50-100) with the lowest scores found for the question on the integration of various functions within the game.

Fig. 4 shows the results of the UTAUT questionnaire for performance expectancy, effort expectancy and intention to use. Performance expectancy relates to the degree that a patient believes the use of the technology intervention would improve health outcome. 60% responded positively for the coach and 44% for the game. For the latter, the majority of patients answered "somewhat agree" to the different questions, so they are not convinced that the game can improve their performance. For both interventions the questionnaire showed that patients believe the system is useful but they do not all believe that their complaints will actually improve (game: 5.2 out of 7, coach: 3.2 out of 5). Effort expectancy relates to the degree of ease that a patient associates with the use of the technology-supported intervention. 76% responded positively for the coach and 67% for the game i.e. patients do not think it will require a lot of effort to use the interventions. Patients generally believed the game is easy to use and that interaction is clear in most cases. Lastly, 65% of the patients have the intention to use the activity coach or game in the future. This was also specifically asked in a multiple choice question: "How long would you like to use the activity coach in the future?" 45% of the patients indicate 'always', 15% 'one year', 5% '3 months', 15%, '1 month', 15% '1-2 weeks', and 5% 'never'.

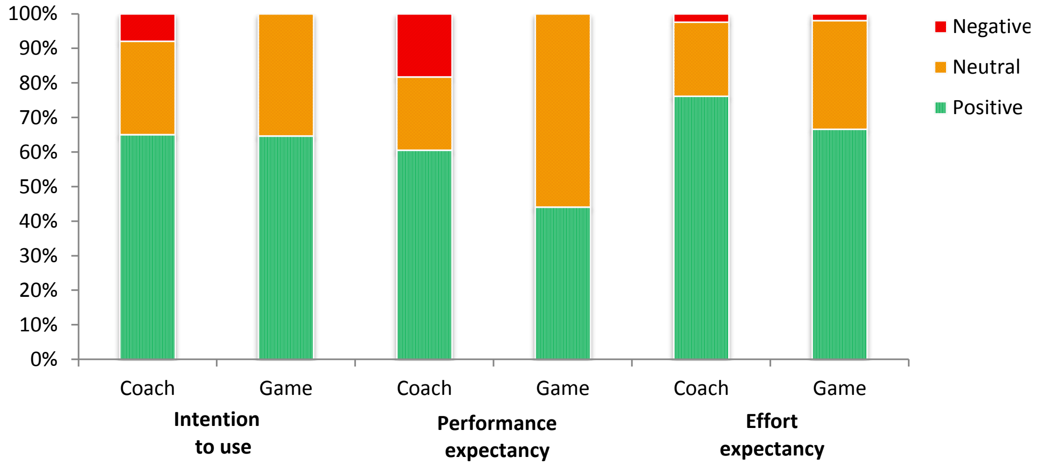

Figure 4. Results from the UTAUT questionnaires for performance expectancy, effort expectancy and intention to use, for both the activity coach evaluation (n=21) and the interactive game evaluation (n=17)

The additional questions showed where the effort was expected by. Regarding the activity coach, patients scored lowest (score: 3.3) for that the smartphone was not light-weight enough. Also specific questions were asked for both feedback modalities of the activity coach: the activity graph and motivational cues. For the activity graph the mean score was 5.4, which includes a lower score on the question that the meaning of the graph was not always clear (score: 4.7), while the colours used were most highly appreciated (score: 6.3). The motivational cues questions had a mean score of 5.5; the cues were considered readable and motivating. The majority of all patients preferred both graphs and messages as feedback modality and preferred to receive their feedback whenever needed. Also, the patients in Romania considered the application useful for getting more information regarding heart rate and oxygen saturation in daily life to increase their confidence being active. Regarding the game, the additional questions showed that patients found it difficult to follow the bubble pattern of the game (score 3.3). Patients would like to get better in the game (score 5.9) and believe they are able to play the game at home by themselves (score: 6.3)

6. DISCUSSION

6.1 Lessons Learned

This study aimed to investigate the usability and acceptance of two technology-supported interventions that aim to improve physical activity in patients with COPD.

The small-scale evaluation showed a SUS score of 75.6 for the activity coach and of 85.0 for the game, which means that the technology-supported interventions have a good to excellent usability (Bangor et al., 2009). This is an important finding, as previous research showed that for example ease of use is an important factor of adherence to telecare systems (Wade et al., 2012). The scores were well above the average of 68 found in literature (Brooke, 1996). For example, an exergame for physical rehabilitation of chronic pain patients had a usability score of 79 (Jansen-Kosterink et al., 2013). In that study, patients with chronic pain had to play a game as part of their rehabilitation treatment. In our study the game was tested in a lab setting. Although lower scores were given for the integration of functions within the game, usability scored high, which could mean that the patients see past the flaws in this version of the game and recognize the potential for future use. This is also shown in the response to the squatting exercise which was well-received, despite the fact that most patients were unable to follow the bubbles with the submarine properly by squatting. In a next phase, we should evaluate the actual user experience as part of regular treatment.

Patients regard the interventions as useful, believe their use does not require lots of effort, but remain a bit more doubting whether it could increase their performance, especially in relation to their complaints. Both interventions are indeed primarily aimed to improve activity behaviour, but we expect that its use will consequently lead to improved symptoms and quality of life. Symptoms cause patients to avoid activities, inactivity limits physical exertion capabilities, this decreases physical condition, and consequently, symptoms worsen and a negative circle ensues (Cooper, 2009). In this phase, it is unclear whether the daily coaching can improve daily activity behaviour and whether the gaming exercise is a valuable addition to COPD treatment. This should be a research aim of future investigations.

Literature also shows that performance expectancy can be influenced by worries concerning the quality of feedback, the possibility of fellow patient’s contact and the feeling of alienation (Cranen et al., 2011). Therefore, when providing the activity coach or game to the patient in the future, the patient should be well informed about why he/she should use the application, how the feedback works and how it can improve the health status. This is also confirmed by literature; education is important for introducing new applications (Broens et al., 2007). Patients can be provided a manual, or can receive a short training within the smartphone or game to familiarize (e.g. Nguyen et al., 2013). Professionals are also important to help patients understand the nature of the disease, the potential benefits of treatment, and to encourage development of self-management skills (Bourbeau & Barlett, 2008). As such their attitude towards the technology-supported interventions can greatly influence the perception and adherence of the patients.

Patients generally showed a positive intention to use the interventions in the future. The majority of the patients would like to use the activity coach for more than a year or always. Moreover, the patients found the exercise of the game easy to perform, they expect to be able to play the game in their home-environments and they would like to get better at the exercise. In a recent study of Wardini et al. (2013) a virtual game system (Nintendo Wii) was used within a 3- to 4-week inpatient pulmonary rehabilitation programme. The patients with COPD enjoyed the programme and would recommend it to others. As such we would expect that the orange submarine game – which is dedicated to the target group - could be a motivational tool for performing physical activity for patients with COPD either at home or in a care setting.

The strength of this study is that it provides a very early insight in the usability and acceptance of newly designed technology-supported interventions aimed to improve daily activity, so we can easily integrate the feedback in the upcoming iterations. In addition, the evaluations were performed with the future target group of the interventions, which is not always common practice (van den Berg., 2012). A limitation of this study is that, although based on the same framework, the UTAUT and evaluation questionnaires differed for the coach and the game, and that these questionnaires were not validated. Another limitation of the current study is that the evaluation tests were not performed as part of the daily lives of the patients. For the activity coach, some activities were resembled in the lab and for the game we tested only one exercise. Future evaluations should incorporate more exercises including for the upper extremity, and gain insight in the use and experience in the daily environment and regular healthcare. For these upcoming studies, the other UTAUT constructs, i.e. facilitating conditions and social influence, should be investigated too, in order to obtain a complete picture of the acceptance and subsequently, usage behaviour. This would preferably be combined with qualitative data, such as the number of hours the activity coach was worn to obtain adherence.

6.2 Next Steps

The evaluation provided us with concrete points for improvement. For the activity coach this has already resulted in a number of development steps. First of all, the feedback (i.e. the graph and motivational cues) has been optimized. The cues were provided at fixed time intervals (time based), but patients pointed out that the cues should be given when necessary. This affirmed our work on developing an intelligent coach that is tailored to the individual user in terms of its timing and content. This coach is able to learn to predict the optimum timing by analysing previously given cues and learning when a patient is likely to respond well to a given message by relating relevant context factors to patient compliance and content (op den Akker et al., 2011). We expect that the tailored feedback will increase user acceptance of the activity coach, and that this will also increase the motivational aspect. The latter remains a challenging factor in this – mainly elderly – patient group; how can we ensure that people will keep using the activity coach? Therefore, we are investigating motivational terms, e.g. the possibility to add weekly messages that display the progress of the patient.

Based upon the requests of especially the Romanian users, it was decided to integrate oxygen saturation measurement (Nonin Medical) with the activity coach. The pulseoximeter values are transmitted to the smartphone along with the information from the activity sensor, and the patient can see these values on the screen of the smartphone, besides the activity graph. The saturation values are presented in coloured, traffic light boxes, indicating the saturation level and its potential risk. This enables the user to gain insight into the health status, and enables a safe training environment in daily life. This is expected to give the user more self-confidence and impulse to become more physically active, following the feedback from the smartphone.

Training and learning how to use the device were important aspects that resulted from the small-scale evaluation. We therefore made a clear, short manual for the patients, which describes the different aspects of the application and its use. To enable different kinds of future uses of the activity coach, three versions are available. These are containing the activity graph, and in addition: 1) motivational cues with self-adapting content and timing, 2) time-related motivational cues or 3) or pulseoximeter values. In the future, the weight of the smartphone could be addressed by providing the activity coach as an app on the patient's own phone.

For the game a number of adjustments should be made before it can be evaluated in regular care. First, the controls of the game should be improved to move the submarine up and down by squatting with the sensor attached to the hip, for example by incorporating the gyroscope and magnetometer information. Second, the current version only consisted of one level and one (squatting) exercise. Although previous research showed that one simple exercise provided by a smartphone and telephone follow-up can effectively improve activity and have good adherence (Liu et al., 2008), an increase of the number of levels and exercises would be desirable. With these adjustments incorporated, the game can be applied in healthcare and the effectiveness can be investigated. The current study can therefore be used as a stepping stone towards 1) further development of the orange submarine game, introducing compatibility with different physiotherapeutic exercises and testing in the patient's home environment, and 2) evaluation of a training effect when using a physiotherapeutic exercise in combination with the orange submarine game.

Besides, little is known what motivates elderly users such as COPD patients to engage in (ambulant) gaming and what games elderly would like to play (Nap et al., 2009). Therefore, we started to investigate preferred motivation strategies and effective gamification feedback strategies in elderly (patient) groups by combining a user-centred design approach with experimental work based on theoretical models related to player motivation strategies and behavioural change. With this knowledge, combined with the further development of the game, gaming can be better tailored towards the treatment goals of the individual patient and might effectively improve daily activity in the future.

6.3 Towards Implementation in COPD Care

Before the activity coach can be implemented in COPD care, more insight is needed in the (long-term) use and acceptance, in the real-life care setting. Therefore, we are now heading towards small to medium field trials with the activity coach following the same methodology as the small-scale study, by evaluation of the usability (SUS) and usage behaviour (UTAUT and quantitative data) in field trials. In Romania, a longitudinal study has been executed in which the activity coach with the pulseoximeter addition was used for one month in daily life. In the Netherlands, the tailored activity coach with self-adapted timing is used for 3 months in a longitudinal study, to investigate the changes in COPD activity behaviour on a long term. Besides, in the Netherlands a randomized controlled trial has been executed where the time-based activity coach is part of a telehealth programme. These studies are the last phase before the interventions are investigated in terms of clinical and cost-effectiveness to eventually work towards final application in health care.

We envision several options of applying the activity coach in the future. First of all, as a standalone application that supports mild, stable COPD patients in keeping an active lifestyle without supervision, who do not follow physiotherapy sessions on a regular basis, but want to work on their activity behaviour. For this, strong motivational strategies are needed to support long-term use and obtain sustainable changes in daily activity. Second, as an application for mild to severe COPD patients, in addition to – or as partial replacement of – physiotherapy sessions, e.g. in a rehabilitation clinic. Using the activity coach in daily life provides insight in the activity behaviour of the patient, and by showing the activity on a webportal both patient and physiotherapist can monitor the progress. Third, as a part of a self-management programme for (very) severe COPD patients, in which patients not only work on self-management of their activity behaviour, but also on self-management of their exacerbations. Another possibility is to use the activity coach in exacerbation treatment, to prevent activity level decline during the exacerbation, and consequently have better health outcomes after exacerbation. Or lastly, as a post-treatment after completion of a rehabilitation programme to maintain the built physical capacities and prevent a relapse into an inactive lifestyle.

The game supports specific exercises of patients with COPD and can provide a fun and motivating manner to promote exercise, at home or in the healthcare clinic. The use of the game in healthcare could provide valuable information on treatment adherence, or can monitor the patient's progress. In this way, the professional can better align treatment to the individual patient and the patients can exercise in a fun way with higher intensity. The game is not ready for application in healthcare; further developments and research are needed.

7. CONCLUSIONS

In this study, technology-supported interventions that aim to promote daily activity have been developed by means of a user-centred design approach. The activity coach aims to improve activity behaviour of patients with COPD by applying real-time feedback based on measured activity levels, while the interactive game aims to motivate exercising by means of a game. This small-scale evaluation study showed good usability and acceptance of these interventions in the target group.

For the activity coach both the continuous feedback (by an activity graph) and motivational cues were preferred as feedback modality, and patients would like to receive the motivational cues whenever needed. We are now heading towards small to medium field trials with the activity coach. The game was positively received by the patients and could provide a new fun way for performing exercises, either at home or as part of the regular treatment. The game is not ready for implementation, but prospects are promising as the patients found the game usable and intent to use the game if available in the future.

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