

Co-creating a Mobile Health App including Physical Activity Recommendations for Older People living with Parkinson's or Dementia Disease: Pilot Study

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Abstract

Background: “Personalised Integrated Care Promoting Quality of Life for Older People” (PROCare4Life) was an EU funded project whose objective is to develop an integrated care Information and Communication Technology (ICT) based system to support the quality of life (QoL) of older people living with Parkinson's Disease (PD) or Dementia Disease (DD). One module focuses on Physical Activity Recommendations (PAR).

Methods: This article is about the development of PAR based upon the users' needs and requirements as well as on behavioural change theories. Older adults with DD or PD tested these PAR in a multi-centre trial on the 'usage feasibility' and 'technical feasibility' during 40 days within PROCare4Life Pilot 2. The usage feasibility was rated by patients via the Intermediate Evaluation Questions (IEQs), focusing on the content evaluation on the PAR sets via a five-point Likert scale. These IEQs were related to six sets of daily contents provided to the patients during the 40-day cycle. At the end of the study, the Final Evaluation Questions (FEQs), with the option 'Yes', 'No' or 'I don't know' appeared in the mobile app, to identify how the PAR sets could be adapted. Functional and operational performance of the technology was assessed to cover the technical feasibility.

Results: The first three PAR sets were rated by more than half of the participants as 'excellent' or 'good'. The final sets were rated from one quarter and more as 'excellent' or 'good'. Only 13.2% are willing to use the PAR further on, whereas 84.2% indicated the opposite. Results were used to improve the PROCare4Life system for Pilot 3.

Discussion: Feedback regarding the PAR sets was mainly positive. Due to the low digital literacy level of the sample group and technical issues, the result of the trial, showing that patients would not like to use PAR further, is understandable. These results are consistent with the recent findings and relevant to discussions on the right phase to involve large number of participants in the iterative testing of eHealth systems. The PROCare4Life consortium decided that the largest part of the participants should be involved for Pilot 3, when the technology is further developed, and data gathering is better understood.

Conclusions: The study concludes that PROCare4Life is a comprehensive initiative aiming to provide large-scale, accessible integrated care solutions for older adults with DD, PD, and with chronic conditions. The mobile health app's implementation, particularly the PAR, was positively perceived by users, but operational and technical issues need addressing to enhance the overall experience. The future design should focus on flexibility and personalisation to improve the app's effectiveness and user satisfaction.

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Original Manuscript

Co-creating a Mobile Health App including Physical Activity Recommendations for Older People living with Parkinson's or Dementia Disease: Pilot Study

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Abstract

Background: The project “Personalised Integrated Care Promoting Quality of Life for Older People” aimed to develop an integrated care system based on information and communication technology to support older people living with Parkinson’s disease or Dementia disease. One module focuses on physical activity (PA) recommendations.

Methods: This article describes the development of the PA recommendations based on the health action process approach (HAPA). A first pilot assessed the feasibility of the overall PROCare4Life system (previously reported). In a second pilot, users evaluated the content of the PA recommendations during 40 intervention days. In a third pilot users evaluated their satisfaction with a mobile health satisfaction questionnaire.

Results: The PA recommendations focused on different aspects of an adapted version of the HAPA model, while they simultaneously approached three activation factors: skills, knowledge and motivation. The content was generally well-received, with most users rating key sections as excellent or good, particularly "benefits and consequences of PA" (79%) and "five golden rules of PA" (83%). However, less than a third gave high ratings to "PA guidelines from the WHO" (25%) and "practical tips for PA" (29%). Regarding satisfaction, at least half of the 237 participants found it easy and good to use, with acceptable time spent and clear instructions. Compared to agreement or neutral evaluations, most disagreed with negative statements about it being time-consuming (47%) or boring (42%). While 41% recommended it and 44% felt it helped them understand lifestyle benefits, fewer agreed the recommender system helped them set personal goals (33%) or motivated change (37%).

Discussion: The report describes the development and evaluation of PA recommendations, based on the HAPA model and activation factors. Users found the recommendations understandable, engaging, and practical, though some aspects, such as motivation and goal setting, received criticism. Challenges in pilot 2, particularly related to setup difficulties, limited participation, leading to system modifications in pilot 3 that improved usability and data collection. The study involved a multidisciplinary team and followed an iterative design process, ensuring a comprehensive and user-focused approach.

Conclusions: It has been confirmed that co-creating and iteratively testing the contents on HAPA and approaching the activation factors contributed to increasing the acceptance of the PA. The intervention development has been based on the user needs and using comparable methodology across profiles of users and pilot phases. All in all, users were positive about the contents. The research team has identified that digital systems, that provide monitoring-functions of the mobile health app and Fitbit wristband are considered advantageous by participants in the co-creation process. Addressing the activation factors can be recommended for researchers and technical developers of other projects. Future adjustments to the design should focus on personalisation to encourage the adoption of a healthier lifestyle.

Trial registration number: 6342 from Casa di Cura del Policlinico.

Keywords: healthcare; physical activity; personalised recommendations, ICT, quality of life, codesign process

Introduction

Active and inactive lifestyles

The World Health Organisation has developed guidelines for different age groups on how much physical activity (PA) is needed for good health [1], whereby adults should get 150 minutes of moderate PA and/or 75 minutes of vigorous PA per week. Yet, on a validated PA questionnaire answered by over 2,000 older adults in the European Union (mean age of 74.9 years, SD=4.5), 42% were found to not meet these global PA recommendations. These findings mirror others indicating that most older adults have a physically inactive and sedentary lifestyle [2-4]. Further, older participants tend to meet the recommendations less often [5]. Notably, people's amount of PA decreased dramatically during the Covid-19 pandemic, when they faced isolation and social distancing. Specifically, home confinement reduced people's total weekly PA time and intensity and increased daily sitting time in a health-threatening direction [6], as these factors increase one's risk of mortality, obesity, sarcopenia, frailty, falls, functional impairments and neurodegenerative diseases [7,8]. By contrast, regular PA results in a lower risk of falls and mortality as well as an improved overall health status, including better Quality of Life (QoL) [7,9]. PA is known to reduce one's risk of DD [10], and in PD it is "a vital component to maintain balance, mobility and activities of daily living" [11]. In a web-based survey during May-August 2020, 75% (64/85) of participants with these conditions reported that receiving PA recommendations was desired, and 79% (57/72) of caregivers reported the same. Interviews with patients and workshops with healthcare professionals support these results [12].

Behaviour changes techniques

Strategies for changing people's behaviour to become healthier fall under the general umbrella of behaviour change techniques, which might often rely on four activation factors: *skills*, *knowledge* and *motivation*. Research shows that previous interventions which addressed these factors, could positively influence individuals' PA behaviour [13,14]. Notably, these factors can be addressed by different behaviour change techniques; for example, skills can be trained with instructions or demonstrations of a specific exercise [15], knowledge can be addressed by educating individuals on the benefits of sufficient PA and consequences of insufficient PA and by comparing their own PA behaviour with guidelines [16], and motivation can be targeted by activity monitoring, either by the user, another person or a technical device [16], and through personalised feedback [17]. All of these were incorporated into PROCare4Life mobile application and iteratively tested and co-created with older people living with Parkinson's or dementia. A recent review showed that integrating the above-mentioned activation factors result in most benefits when aiming at influencing PA behaviour. Further, addressing the three activation factors can be accomplished via using a variety of interfaces [18] and digital interactions, that have been incorporated into PROCare4Life mobile app. Thus, it can be expected according to previous literature that digital health systems incorporating PA recommendations can potentially benefit from incorporating the above-mentioned activation factors and using various modalities to do so. These expectations were tested through the co-creation process of the PROCare4Life mobile app, that includes PA recommendations. The PROCare4Life PA recommendations approached skills and knowledge via notifications and PDFs that were displayed in the users' smartphones, whereas the motivation was approached by personalised gamification of the smartwatch app, that could also be read through the mobile app. In addition, the PA recommendations were developed according to the health action process approach (HAPA). HAPA was used to guide the development of PROCare4Life PA training and adherence programmes from a psychological theory perspective to enhance the efficiency on PA behavioural changes among elder people living with Parkinson's or dementia (Alzheimer's and other) [19].

PROCare4Life and health recommender systems

In the European Union, the recent project “Personalised Integrated Care Promoting Quality of Life for Older People” (PROCare4Life) funded by Horizon 2020 (Grant agreement No. 875221, 2020-2023) developed an interactive care system based on digital technologies for people living with neurodegenerative diseases, their caregivers (mobile health app, smartwatch for both profiles), and healthcare professionals (web interface) [20]. Health recommender systems (HRS) [19] have become valuable digital tools [22-24], as they provide personalised suggestions and predictions to users by analysing vast amounts of data and employing advanced algorithms. HRS have shown significant potential to improve patients’ and caregivers’ healthy behaviours and quality of life [25-27]. The co-creation and iterative testing supported the development of the digital interactive care system through several pilot waves. PROCare4Life pilots were implemented at six real life sites including day care, home and rehabilitation scenarios, located in five different EU countries (Germany, Italy, Portugal, Romania and Spain). The cocreation methodology included several steps:

- (0) A user requirements study [12,28] in which PROCare4Life users shared their needs linked to receiving personalised PA recommendations.
- (1) Development of PROCare4Life digital system, including feasibility testing of the digital technologies.
- (2) Development and content evaluation of the PA recommendations, both by experts, researchers and representative of the target future users.
- (3) Iterative cycles of adaption of the different modules of PROCare4Life. Satisfaction evaluation of the PA recommendations for users.

The PA recommendations were included in the iterative testing from the start of pilot 2, when the technology was mature enough for testing. They were embedded in the mobile app to support users in creating and maintaining an active lifestyle. The focus of this article is to describe PROCare4Life co-creation and iterative testing-processes from the PA recommendations [31,32].

Research aim

The present article focuses on the co-creation process to support the development and iterative testing of the PROCare4Life PA recommendations and its key results. Based on the specific needs of older people living with Parkinson’s or dementia, and after assessing iteratively the users’ recommendations regarding the PA contents, changes were incorporated into the digital system to improve the personalisation to its end users. Overall user satisfaction assessment of the PA recommendations was also included as one of the research aims. The overall aim of PROCare4Life was to increase the quality of life of people living with DD or PD, their self-management and empowerment.

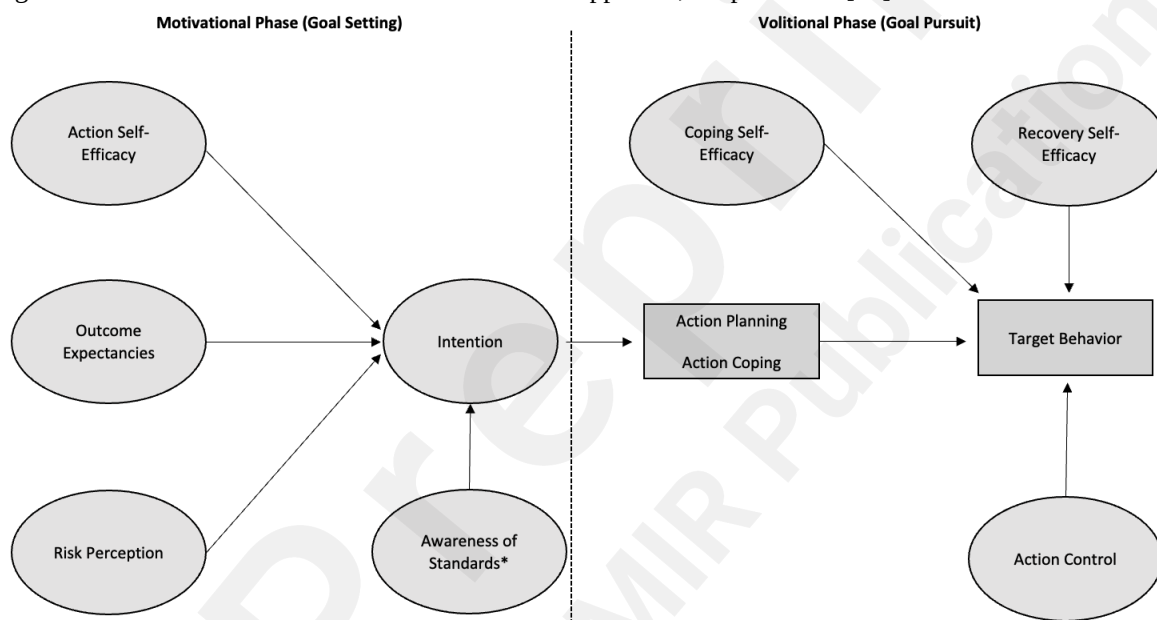
Methods

In this section the development of the PA recommendations, the functionalities of the PA recommendation system and methods for pilot 2 and pilot 3 are described.

Development

The HAPA model was used to develop the PA recommendations of the PROCare4Life digital interactive system. It includes an initial motivational phase for goal setting and a subsequent volitional phase focusing on how to implement behavioural changes to pursue the personalised goals. Between these two phases, individuals using the PROCare4Life system can create an intention to be active [31]. As older people living with Parkinson's or dementia, PROCare4Life users needed to have basic knowledge about the PA recommendations, including the adequate volume and intensity levels of activity for each person. Accordingly, the HAPA model was amended to include the construct *Awareness of Standards*, which was not originally present (Figure 1).

Figure 1: Visualisation of the Health Action Process Approach, adapted from [31]



Note. Awareness of Standards was added as HAPA construct for PROCare4Life PA recommendations.

Four HAPA constructs of the motivational phase and two constructs of the volitional phase were aligned with six performance objectives resulting in the PA recommendation contents with three underlying activation factors, as summarised in the Table 1 below. The contents were fused into six PA recommendation sets. The process to develop the PA recommendations contents.

Table 1: Development of the PA recommendation contents

HAPA constructs (Activation factor)		Performance objectives	PA recommendation contents	Final PA recommendation sets
Action (Skills)	Self-Efficacy	Awareness of ways to be active	Practical tips to be active	Set 1: Benefits of regular and consequences of insufficient physical activity
Outcome (Knowledge)	Expectancies	Awareness of benefits of regular physical activity	Benefits of regular physical activity	
Risk (Knowledge)	Perception	Awareness of consequences of insufficient physical activity	Consequences of insufficient physical activity	Set 2: Five golden rules of physical activity
Awareness of Standards (Knowledge)		Awareness of the physical activity guidelines	Five golden rules of physical activity, Rate of Perceived Exertion Scale, Physical activity guidelines from the World Health Organisation	Set 3: Perceived exertion scale Set 4: Physical activity guidelines from the WHO
Coping (Skills)	Self-Efficacy	Experience opportunities to be active	Links for more information and videos about physical activity	Set 5: Practical tips for physical activity
Action Control (Motivation)		To be aware of the own physical activity level	Monitoring of steps via the Fitbit wristband	Set 6: Links for more information and videos about physical activity

Examples for the different messages of each PA recommendation sets are the following:

- Set 1: Benefits of regular and consequences of insufficient PA, i.e.:
 - Regular physical activity improves your sleeping patterns.
 - Insufficient physical activity increases your risk for joint and back pain.
- Set 2: Five golden rules of physical activity, i.e.:
 - Reduce your sitting time with regular standing breaks every 30 minutes
 - Every minute of physical activity counts.
- Set 3: Perceived exertion scale: The Rate of Perceived Exertion Scale is a measure of subjective perceived exertion during physical activity with different ranges.
 - Varies from very light activity (1), light activity (2-3), moderate activity (4-5) to vigorous activity (5-6).
- Set 4: Physical activity guidelines from WHO, i.e.:
 - Perform three activity-forms per week: Aerobic, muscle strength and balance training.
 - Conduct aerobic exercises, for example walking, 150-300 minutes per week.
- Set 5: Practical tips for physical activity, i.e.:
 - Walking in the fresh air can be a mood booster, it improves your mind and body.
 - Conducting yard work, like pulling out weed, will make your arm muscles stronger. Practicing this regularly, carrying groceries can be easier.
- Set 6: Links for more information and videos about physical activity, i.e.:
 - Try this link out for further information to physical activity: Exercises for people with dementia disease.
 - Try this link out for further information to physical activity: Exercises for people with Parkinson's disease.

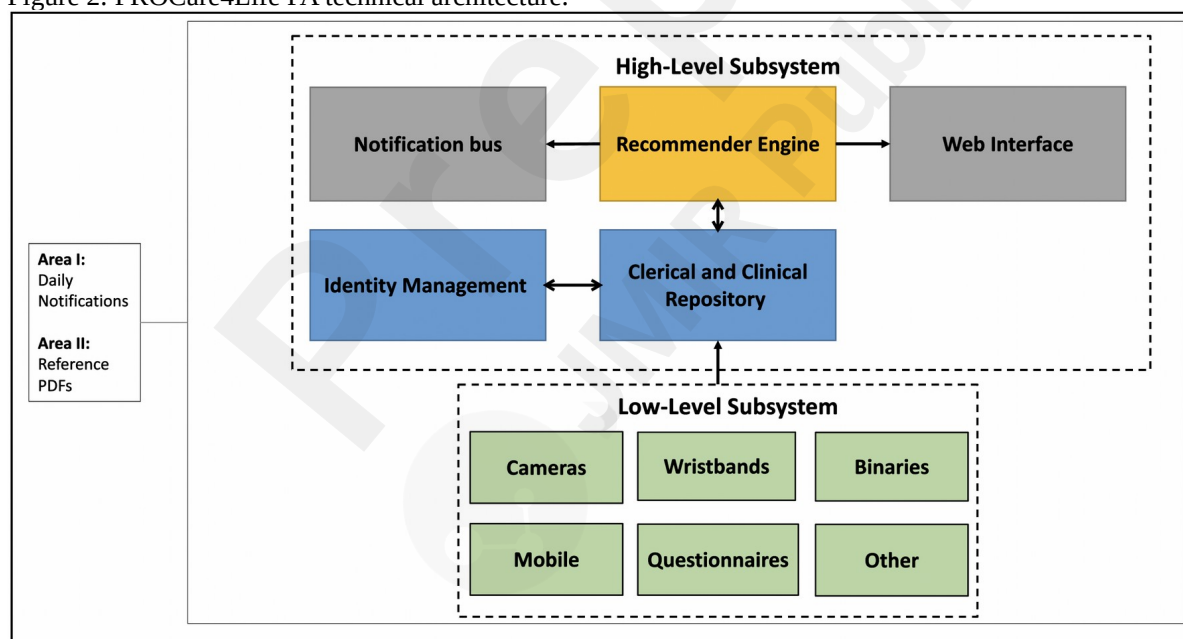
The goals of the PROCare4Life PA were reinforced by the technical architecture of the digital system, that is described in the following subsection.

Technical architecture

In terms of information collection, processing and delivery, the PROCare4Life PA technical architecture consists of two types of components which transfer the PA recommendations as notifications to users: the low-level subsystem (LLSS) and the high-level subsystem (HLSS).

The LLSS encompasses the set of devices, sensors and questionnaires, both active and passive, functions to acquire data from patients. It requires a smartwatch, a smartphone with the included mobile health app and questionnaires. Collected data is sent to the other subsystem. The HLSS, includes the recommender engine that extracts the necessary information to generate recommendations according to each user's profile. A notification bus sends and receives notifications involving the exchange of information and messages between the user-facing part and the systems logic based on the RabbitMQ [32] message broker. The recommender system operates on an automated daily routine, sending predefined notifications to patients, independent of their previous data. While this heuristic approach may diverge from traditional recommendation methods, it ensures consistent daily monitoring [33]. At the end of each cycle, a knowledge-based approach was employed to deliver customised routines and exercises tailored to each patient's primary disease group. The Identity Management provides a framework for creating, modifying and deleting users' data. In the Web interface, healthcare professionals can check historical notifications from patients and examine different patients' information. The purpose of the Clerical and clinical data repository is to store the different modalities of data that are related to users, including clinical and personal information (encrypted to comply with General Data Protection Regulation [GDPR] as well as some pre-processed sensorial summarised data that feeds the different dashboards and reports presented in the PROCare4Life user interface (Figure 2).

Figure 2: PROCare4Life PA technical architecture.



Ethics

Ethical

considerations

As the research included human subjects, the end-user pilot sites prepared within the consortium a first draft version of the ethical documentation. All relevant information on the ethics regarding the study were collected. Based on the local regulations of each end-user pilot site, the gathered information was integrated into the local documents: Ethical documentation for the ethics commission including the sections: description and procedures of the study,

voluntariness and anonymity, information about no compensation type for the participation, insurance coverage, scope of data collection and processing, legal basis, option for the withdrawal, contact data of the responsible contact persons. This information was fused into the ethics application and the connected general participant information and consent. In addition, a data handling agreement was established and signed by all parties.

Ethical approval

All pilot phases were ethically approved by the local ethical commissions of the six pilot sites of PROCare4Life: Wohlfahrtswerk für Baden-Württemberg (WBW), Asociación Parkinson Madrid (APM), Casa di Cura Policlinico (CCPP), Campus Neurologico Senior (CNS), Spitalul Universitar de Urgenta Bucuresti (UHB) and University of Medicine and Pharmacy (UMF), both located in Romania.

Participants

PROCare4Life second and third pilots were performed in accordance with the following inclusion and exclusion criteria:

- The inclusion criteria included individuals who had a clinical diagnosis of DD or PD, were 65 years or older, demonstrated a willingness to participate, had the ability to provide informed consent and were currently living at home, in a rehabilitation centre or in a day care centre.
- By contrast, candidates were excluded from participating in the study in cases of inability to learn and limitations impeding the ability to use the PROCare4Life system or key elements of its technical equipment, such as speech, vision, language, hearing or psychiatric impairments.

Participants were recruited from the social and health care centres involved in the study (CCPP, APM, CNS, UMF, UHB and WBW).

Study procedure

The study was conducted in three different scenarios: neurorehabilitation centre, day care centre and at participants homes. People living with DD or PD received periodically personalised PA recommendation (Multimedia appendix 1) over the 40 days that their participation lasted, via their PROCare4Life mobile app. Each day a different notification was sent. All these materials were additionally stored as PDFs (Multimedia Appendix 2) in the app pp allow participants to consult them later. Table 2 summarises the PA recommendation sets by the days of their appearance, gradually covering all the six sets.

Table 2: PROCare4Life PA recommendation sets and their appearance in the mobile health app

Sets	Topic	Days
1	Benefits of regular and consequences of insufficient physical activity	1-10
2	Five golden rules of physical activity	11-15
3	Perceived exertion scale	16-25
4	Physical activity guidelines from the WHO	26-30
5	Practical tips for physical activity	31-35
6	Links for more information and videos about physical activity	36-40

Note. PA= physical activity.

Pilot 2

The PA recommendations were evaluated by users through intermediate evaluation questions. They appeared in the PROCare4Life mobile app itself once each set of recommendations had been completed. Additionally, the system integrated reminders that prompted patients to respond to some

questions linked to each set of notifications. Users were requested to rate the information included in each PA set using a five-point Likert scale. They were requested to select one of five intuitive emojis, referring to “excellent”, “good”, “average” rated as positive, “poor” and “very poor” rated as negative.

Pilot 3

Over the pilot 3 implementation, participants were also invited to assess the PA recommendation system and contents after the 40-day participation, also via the PROCare4Life app-integrated mobile health satisfaction questionnaire [34]. On 12 items, they were able to select the options “agree”, “neutral” or “disagree” (Table 3).

Table 3: Mobile health satisfaction questionnaire displayed in the PROCare4Life app.

(a) What did you think about using the recommendation system in our PROCare4Life mobile app?	
Nr	Item
Q1	It was easy to use
Q2	It was good to use
Q3	The time spent using it was acceptable
Q4	The explanation on how to use it was sufficient
Q5	It was too time-consuming
Q6	It was boring to use
Q7	It was a disturbance
Q8	I can recommend it to others
(b) How did you experience the recommendation system in your PROCare4Life mobile app?	
Q9	It has motivated me to change my lifestyle habits
Q10	It has helped me to understand the benefits of improving my lifestyle habits
Q11	It has helped me to understand how I need to change my lifestyle habits
Q12	It has helped me set personal goals for my lifestyle habits in a way that I could not have done on my own

Statistical analysis

The following sociodemographic data was collected for pilot 2 and pilot 3 to support the data analysis, while guaranteeing the pseudo-anonymisation of the data: Patient ID; scenarios, birthdate; gender; diagnosis, pilot site. The analysis was performed using Microsoft Office (Excel, version 2.0). Descriptive statistical analysis was performed, identifying frequencies and percentages of responses. The evaluation results were crossed with the sociodemographic variables for comparison across diagnosis, age, pilot site, gender and scenarios.

Results

Pilot 2 – Content evaluation

Participants characteristics

A total of 167 participants were recruited, of which 55 were in the home scenario, 94 in the rehabilitation centre and 18 in the daycare centre. Out of the total number of participants, 43 (26%) evaluated the content of the PA recommendations. Most of them (63%, 27/43) were men. The mean age was 75 years (± 5.9). Patients came from Spain (67%, 29/43), Italy (16%, 7/43) and Portugal (16%, 7/43). Regarding living situations, 79% (34/43) were in a rehabilitation centre and 19% (7/43) at home. Continued problems with recruitment of patients for the daycare centres prevented the collection of significant enough information in that scenario. The most common diagnosis was PD (86%, 37/43).

Results related to the content evaluation

The results from the IEQs are presented in Table 6. The first PA recommendation set evaluations had a 100% completion rate by participants. As time went by and additional sets were delivered, the number of missing evaluations increased from zero to a maximum of 10 people. Therefore, the total number of evaluations, representing 100%, differs from set to set. The first sets were mostly rated as excellent or good: “Benefits and consequences of PA” (79.1%, $n= 34/43$), “five golden rules of PA” (83 %, $n= 34/41$), and “perceived exertion scale” (54%, $n= 22/41$). The same appeared by around one quarter of users for “PA guidelines from the WHO” (25%, $n= 9/36$), “practical tips for PA” (29%, $n=10/35$) and “content of links” (42%, $n=14/33$). All in all, it can be clearly stated that all sets were rated from most users as positive (minimum: average). Very few people ($n=5$) selected the option “poor” or “very poor”, in total among all (Table 4).

Table 4: Results from the intermediate evaluation questions

% (n)	IEQ1 PAR set 1 Benefits and consequenc es of PA	IEQ2 PAR set 2 Five golden rules of PA	IEQ3 PAR set 3 Perceived exertion scale	IEQ4 PAR set 4 PA guidelines from the WHO	IEQ5 PAR set 5 Practical tips for PA	IEQ6 PAR set 6 Content of the links
Excellent	37 (16)	39 (16)	10 (4)	0 (0)	9 (3)	6 (2)
Good	42 (18)	44 (18)	44 (18)	25 (9)	20 (7)	36 (12)
Average	16 (7)	17 (7)	44 (18)	75 (27)	71 (25)	52 (17)
Poor	0 (0)	0 (0)	2 (1)	0 (0)	0 (0)	6 (2)
Very poor	5 (2)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Not reported	n.A. (0)	n.A. (2)	n.A. (2)	n.A. (7)	n.A. (8)	n.A. (10)
Total	100 (43)	100 (41)	100 (41)	100 (36)	100 (35)	100 (33)

Note. PAR= physical activity recommendation.

Pilot 3 - Satisfaction evaluation

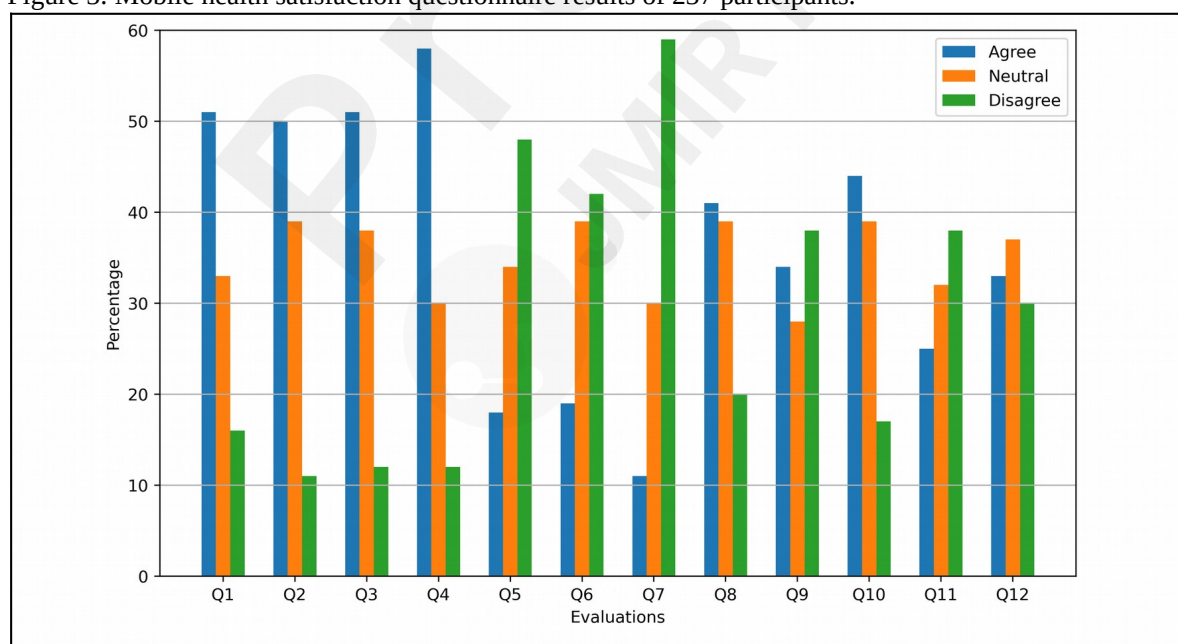
Participants characteristics

A total of 273 patients were recruited of which 132 were in the home setting, 102 in the rehabilitation centre, 39 were in the daycare centre. After excluding dropouts (n=36), 237 from 273 (87%) provided answers to the mobile satisfaction assessment questionnaire. Patients had a mean age of 72 years. Most came from Italy (n=82, 35%), followed by Spain (n=64, 27%), Romania (n=56, 24%), Germany (n=22, 9%) and Portugal (n=13, 5%). Regarding living situations, 120 (52%) people were located at home, 90 (38%) in the rehabilitation centre, 22 (9%) in the daycare centre and 5 (2%) did not reported.

Results related to the satisfaction evaluation

Results were positive in terms of satisfaction for many of the questions linked to the PROCare4Life PA recommendations, although some were not so positive. At least half of the 237 participants agreed to the sentences “Q1-it was easy to use” (51%, n=221), “Q2-it was good to use” (50%, n=119), “Q3-time spent using it was acceptable” (52%, n=123), “Q4-explanation on how to use it was sufficient” (57, n=135%). Compared to agreement and neutral evaluation, most people disagreed to negatively phrased worded statements, thus meaning a positive evaluation, namely “Q5-it was too time-consuming” (47%, n=111), (“Q6-it was boring to use” (42%, n=99) and “Q7-it was a disturbance” (58%, n=137). Most rated the following quotes positive: “Q8-I can recommend it to others” (41%, n= 97), “Q10 it has helped me to understand the benefits of improving my lifestyle habits” (44%, n=104). For the statement “Q12-it has helped me set personal goals for my lifestyle habits in a way that I could not have done on my own”, more people agreed (33%, n=78) as disagreed (30%, n=71). Mostly disagreement was expresses for “Q9-it has motivated me to change my lifestyle habits” (37%, n=88) and “Q11-it has helped me to understand how I need to change my lifestyle habits” (30%, n=71).“

Figure 3: Mobile health satisfaction questionnaire results of 237 participants.



Note. Q= Question.

Discussion

This report aimed to describe the development process of the PA recommendations according to the HAPA and activation factors, the content of the PA recommendations and users' satisfaction with the PA recommendation system.

All in all, the results of section 1 (Q1-Q8) of the mobile health satisfaction questionnaire clearly demonstrate that PROCare4Life PA recommendations were found to be easily understandable, interesting and usable, and users clearly understood the benefits of PA (Q10).

Developing the contents on the HAPA model and approaching all the activation factors in information and communication technology-based interventions supported the intervention development, as stated in previous research [35,36]:

(A) *Knowledge*: Via the seven statements within set 1 focusing on the positive influence of regular PA and on consequences of insufficient PA were delivered to patients' mobile phones. Often, older adults connect exercising directly with potential injuries and express their fear of falling [37]. After reading the first notifications, this incorrect statement can be resolved. Brawley and Latimer stated that pragmatic explanations and supporting messages are necessary to facilitate regular PA [38]. The five golden rules helped users to be regularly active, as adherence to the use of the app reflected. The rating of perceived exertion scale of set 3 introduced users to the possibility of measuring their subjective perceived exertion during PA and to categorise the intensity as very light, light, moderate or vigorous. Introducing users to the WHO's PA guidelines within set 4, aimed to make users aware of the PA standards. Each form of training was also matched with examples of activities to increase their knowledge.

(B) *Skills*: Statements of set 5 like introduced users to practical tips being active without specific PA equipment. Further, statements indicating the positive influences of PA on one's daily life within set 1 were sent to the users to perform the PA activities. The final five notifications of set 6 gave users access to links for more information and videos about PA based on the diagnosis and further explanations in the local language.

(C) *Motivation*: The Fitbit wristband supported the users to monitor their number of steps for keeping their motivation on a high level.

The PROCare4Life system chose to incorporate a mobile health app and Fitbit because PA recommendations may be better followed and lead to less sedentary lifestyles when they incorporate technology, due to the possibility to personalise the health values [39].

Interpreting the results of Q9-Q12 of the mobile health satisfaction questionnaire show that the recommendation system is criticised on how to motivate to change the lifestyle habits, to set personal goals and to facilitate these. The interpretation of these results is not completely clear for the research team. One possible conclusion was that the app failed to achieve its goal to improve the physical activity among participants and in changing their lifestyle habits. Other alternative explanation is that the participants were already motivated and understood how to change their lifestyle habits, and thus the reasons behind the negative assessment of these two questions might reflect an already positive starting point for the individuals sharing their disagreement. Further research might be needed in this respect. Features that could counter the criticism are a more personalised features that address the remaining constructs of the HAPA that are currently missing: By addressing the construct *Action Planning* of the HAPA, users could have the option to select a personal goal of steps based upon their measured average number of weekly steps, differentiated into maintenance (average base), low ambition (average base + 10%), medium ambition (average base + 20%) and high ambition (average base + 30%). Lee et al. (2015) proofed that technology-based goal setting helps people to advance the effectiveness of the number of steps [40].

By focusing on the construct *Action Coping* of the HAPA, the system could recommend specific

“exergames” via smart TV to the user, focusing on their measured average number of weekly steps, and on days with unsuitable weather for outdoor activity. Findings of Rhodes et al (2018) highlight the social aspects of exergaming. Exergames are capable to incorporate more than one user, to keep the motivation on a high level [41]. Addressing the construct *Recovery Self-Efficacy* of the HAPA, the system could send users an underachievement notification (e.g., “This week you did not achieve your personal step goal. You took 900 steps on average. Don’t worry, you can try it again or change your personal goal for steps”) [42]. Future interventions are encouraged to consider addressing the remains of the HAPA construct, facilitating more personalised PA interventions.

Limitations

The period in which pilot 2 of PROCare4Life was carried out was challenging due to Covid-19 and analysis of its outcomes highlighted some limitations of the system. Specifically, Pilot 2 suffered from installation and setup issues, including smartphone and the Fitbit. Difficulties with the initial setup prevented the patients from using the system at all, which also implied that PA recommendations were not used nor evaluated. Consequently, one-quarter of the participants were represented in the pilot 2 data.

To counteract changes performed in the solution deployment to reduce the complexity of the setup and improve the user experience. The main change was the elimination of the physical mini-PC, which was the data collection hub for pilot 1 and pilot 2, and at the same time, the main source of installation and operation issues. In pilot 3, most of the patients only had the wristband and the phone. Data collection figures increased significantly in Pilot 3. Additional changes were made to the PA recommendation components of the PROCare4Life solution, enabling more data collection points and potentially a more interactive experience for the patients.

This study reported on the theoretical background of BCT and on the technical development. The results are based on multinational participants, across various settings and health conditions. The multidisciplinary team, which included technical partners (for developing the back-end and front-end), academic partners (for creating research-related content), an educational network (for producing relevant materials), a security company (for guaranteeing data protection and privacy requirements) as well as clinical pilot sites (for testing the end product), followed an iterative design process for developing the interfaces as recommended by Zaman and colleagues [43].

Conclusions

The PA recommendations were implemented in a systematic way and addressing the activation factors *skills*, *knowledge* and *motivation* to focus on relevant behaviours change constructs. Based on users’ perceptions of system, the content was rated positively, and users were satisfied with the PA recommendations. Addressing the activation factors can be recommended for researchers and technical developers of other projects. The current implementation of the mobile health app uses daily static notifications and performs limited monitoring of patients’ activities. More features need to be implemented to personalise the recommender system to each individual user.

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Data Availability

The collected data is not publicly available, as we deleted all the data according to our project data agreement. Only technical partners stored this data during the process of analysis, but after that, it was removed. This study was conducted in 2021/2022. At that time, it was not as common as today to publish the data in publicly available repositories.

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Conflicts of Interest

The authors declare no conflict of interest.

Abbreviations

CCDR: Clerical and clinical data repository

DD: Dementia disease

GDPR: General data protection regulation

HAPA: Health action process approach

HLSS: High-level subsystem

HRS: Health recommender systems

ICT: Information and communication technology

JMIR: Journal of medical internet research

LLSS: Low-level subsystem

PA: Physical activity

PD: Parkinson's disease

QoL: Quality of life

RCT: Randomised controlled trial

RS: Recommender systems

Multimedia Appendix

Multimedia Appendix 1 [Physical activity recommendations daily messages]

Multimedia Appendix 2 [Physical activity recommendations in PDF files]

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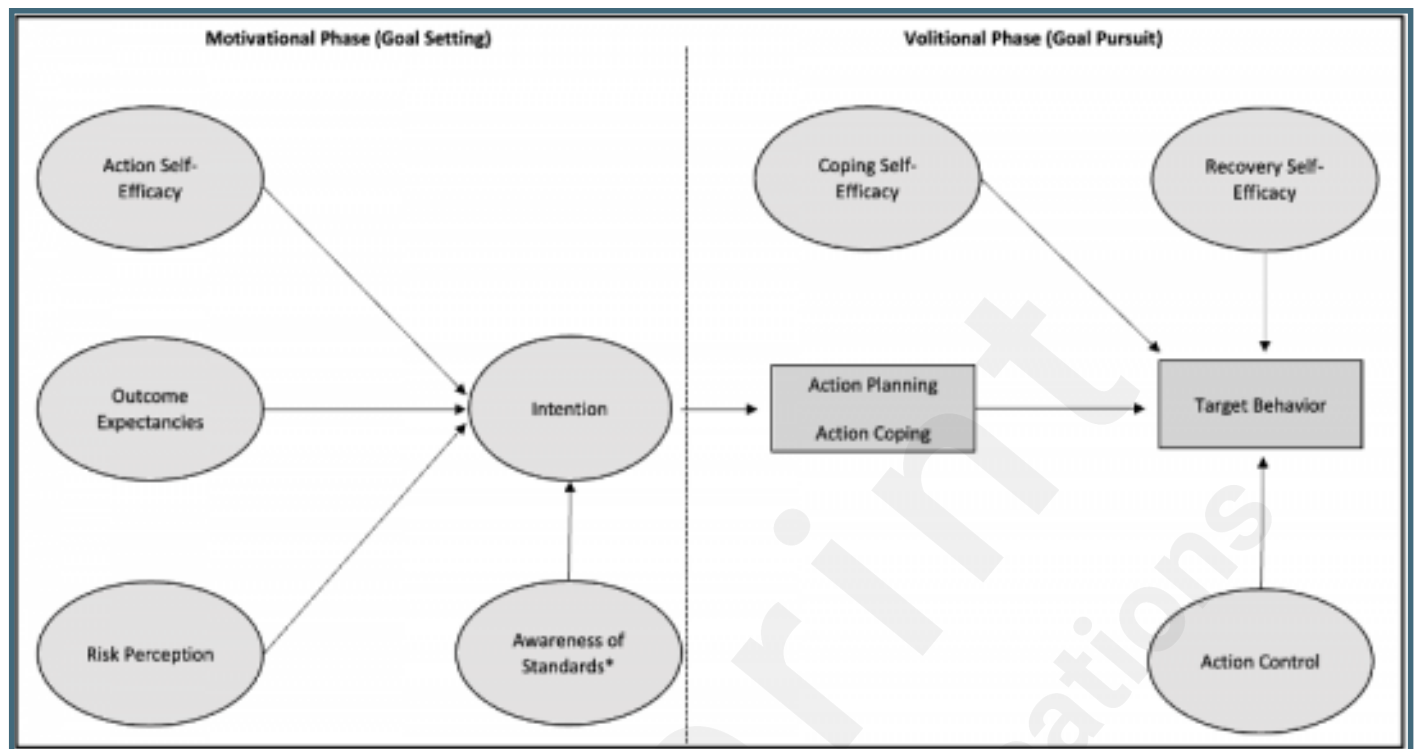
Supplementary Files

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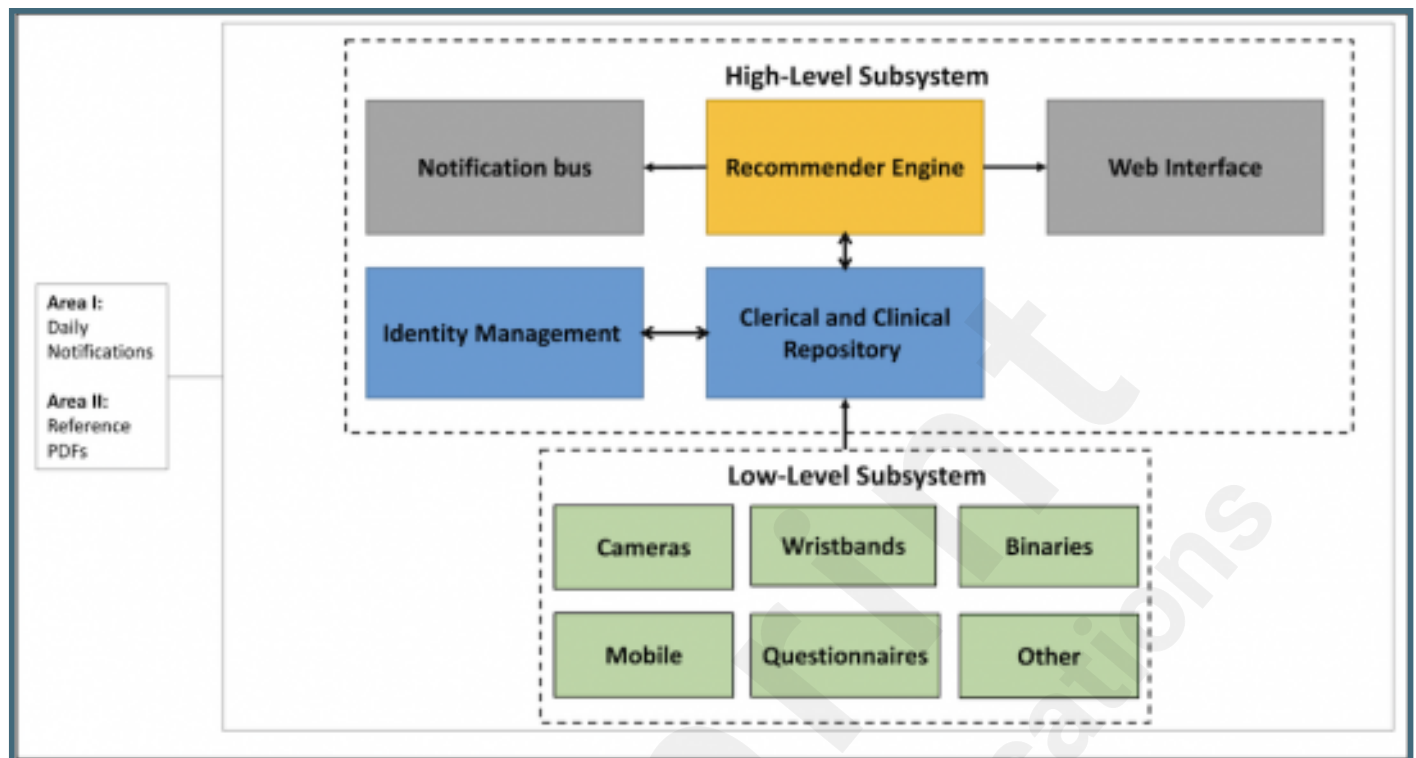
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Figures

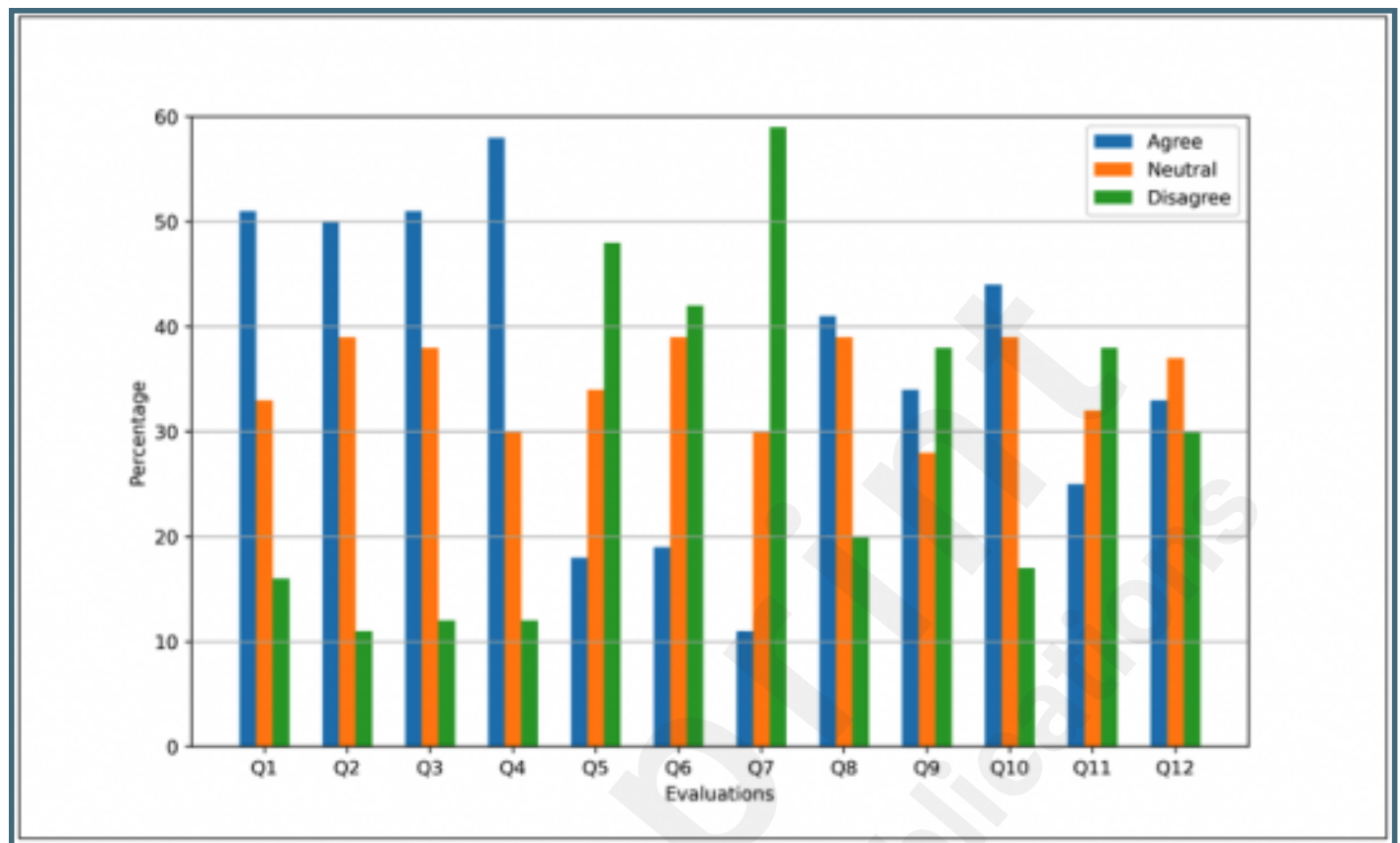
Visualisation of the HAPA.



ProCare4Life Technical Architecture.



Mobile health satisfaction questionnaire results.



Multimedia Appendixes

Physical Activity Recommendations daily messages.

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Physical Activity Recommendations in pdf files.

URL: <http://asset.jmir.pub/assets/5b0060eb67d0c5d73229411a7e55f62a.docx>

