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Development and Evaluation of a Blended Home-Based Exercise Intervention for Older Adults

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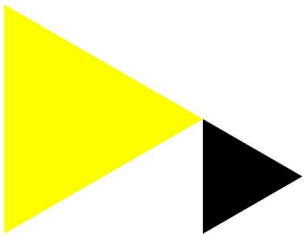

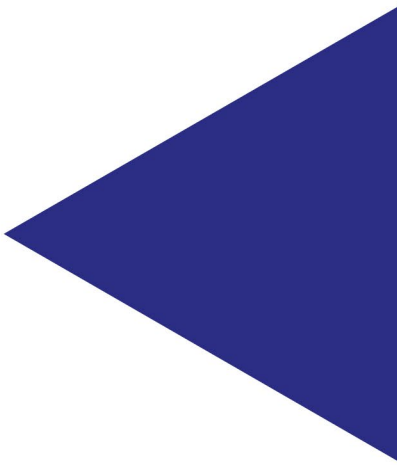

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Creating Tomorrow

Development and Evaluation of a Blended Home-Based Exercise Intervention for Older Adults

Sumit Mehra

Development and Evaluation of a Blended Home-Based Exercise Intervention for Older Adults

Sumit Mehra

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Development and Evaluation of a Blended Home-Based Exercise Intervention for Older Adults

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1

General Introduction

Many countries are facing an aging population. Currently, 20% of the Dutch population is 65 years old and above, similar to other European countries [1]. The United Nations expects that in 2050, over 35% of the European population and 25% of Asian and Latin American populations will consist of older adults [2]. To cope with the aging of the population, an appeal is being made on the resilience of older adults to age in place, that is, "the ability of older people to live in their own home and community safely, independently and comfortably" [3]. However, this poses a challenge. Aging is associated with a declining ability to carry out daily tasks, such as general housecleaning, running errands or personal hygiene [4–6]. Fortunately, an active lifestyle and physical activity can delay or diminish the decline that is associated with aging, thereby increasing the ability of older adults to live independently at home [7–9].

To foster physical activity in older adults, local community centers across the world offer exercise classes for senior citizens. In the Netherlands, for instance, approximately 300,000 older adults participate weekly in the nationwide program More Exercise for Seniors ('*Meer Bewegen voor Ouderen*' in Dutch, or in short MBvO) [10]. In small groups, older adults exercise together under the supervision of a qualified trainer. A previous study, however, could not find any benefits in terms of health-related quality of life or functional status for the older adults who were participating in the weekly MBvO exercise classes [11]. Exercising once a week in programs such as MBvO is not enough to have an effect on fitness or physical health [12–14]. To attain health benefits, the frequency, intensity and duration of physical activity should meet the global recommendations of the World Health Organization (WHO) [15]. That is, older adults should follow these recommendations:

a) At least 150 minutes of moderate-intensity aerobic physical activity should be done throughout the week, in bouts of at least 10 minutes duration.
b) Muscle-strengthening activities involving major muscle groups should be performed on 2 or more days a week.
c) Older adults with poor mobility should perform physical activity to enhance balance and prevent falls on 3 or more days per week.

To meet those guidelines, older adults could participate in group-based exercise classes several times per week. However, this is not always possible. Older adults are limited in energy, time and money, which are needed to commute to a community center [16,17]. Additionally, community centers often have practical or economic limitations in hiring an instructor or securing a location that is needed for group-

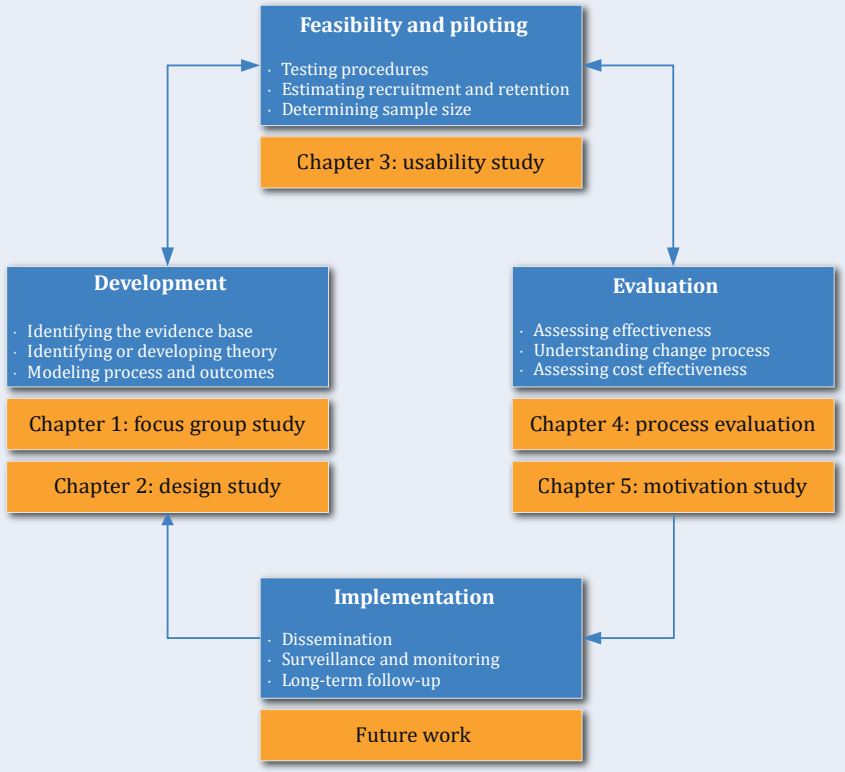
based activities.

An alternative approach is to combine a group-based exercise program with home-based exercises [18]. This allows older adults to continue exercising besides the weekly group-based classes. In the comfort of their homes, older adults can perform additional exercises at their convenience. Furthermore, home-based exercises can be extensively tailored to individual needs [19]. Guidance of a personalized exercise program, however, remains crucial. In recent years, technology has been used to deliver physical activity and exercise interventions for various populations [20–23]. Although it is possible to rely on technology to fully automate guidance, eHealth and mHealth interventions that incorporate human guidance and feedback are associated with increased efficacy [24–26]. Nevertheless, such blended use of technology has not often been utilized to specifically support older adults in their exercise behavior. Furthermore, to our knowledge, only one study has examined the use of blended technology in conjunction with a group-based exercise program. In a pioneering pilot study by Lee et al [27], older adults in Korea were provided with an iPad that supported them in performing home-based exercises, which was combined with a supervised group-based exercise program. Unfortunately, the researchers did not find any effects of the combined intervention on participants' physical function or perceived health status. There were, however, several limitations of the pilot study. The study involved only 26 older women. Participants were not randomly assigned to the control group, and the duration of the intervention was limited to 8 weeks. Furthermore, neither the content nor the underlying design choices of the iPad application were properly described, making it hard to draw any clear conclusions from it. To advance knowledge of the scientific community, Michie et al [28] have called on researchers to make theoretical assumptions more explicit and to increase transparency by describing design choices in detail. The hiatus in a well-described blended mHealth exercise intervention for older adults has led to the following central research question of this thesis:

> *How can mHealth be employed, in a blended manner, to support older adults in performing home-based exercises, as a supplement to a group-based community exercise program?*

To address this research question, as part of the VITAMIN project at the Amsterdam University of Applied Sciences (AUAS), an intervention was developed and evaluated according to the Medical Research Council (MRC) framework [29,30.] See Figure 1 for how the structure of this PhD thesis mirrors the MRC framework.

Figure 1. MRC Framework for Complex Interventions Mirrored By the Thesis Structure



The framework prescribes that the first activity to develop an intervention is to gain a thorough understanding of the target audience. In Chapter 2, therefore, the following research questions will be addressed: (a) *What motives do older adults have to participate in a group-based exercise program?* (b) *What are their attitudes and expectations toward performing additional exercises at home?* (c) *What are their attitudes and expectations for supporting technology to facilitate home-based exercises?* To answer those research questions, eight focus groups were held with older adults who were participating in a supervised group-based exercise program of the earlier described MBvO. The interviews were analyzed according to the self-determination theory, relating the motives and attitudes to the basic psychological needs of competence, autonomy and relatedness.

The next key activity the MRC framework prescribes is identifying relevant theories. In Chapter 3, therefore, the following research question will be addressed: *How can theoretical principles and scientific evidence on behavior change be translated into features of a tablet-supported intervention to increase the physical activity levels of older adults?* Many physical activity interventions either lack sound theoretical underpinnings or claim to be based on a specific theory but do not clarify how this has actually been done. In Chapter 3, the use of blended technology and behavior change through self-regulation are identified as a solid theoretical basis, and subsequently, it details how this has been incorporated into the design of a tablet application.

After developing an intervention, MRC recommends piloting the intervention meticulously before evaluating its efficacy. This is often neglected, leading to the evaluation of suboptimal and ineffective interventions. Usability plays a key role in the success of eHealth or mHealth interventions. In Chapter 4, therefore, the following research question will be addressed: *Can first-time users operate the app that was designed to support older adults in performing home-based exercises?* To answer this question, older adults were asked in a laboratory setting to complete a series of standardized tasks on a tablet while verbalizing their ongoing thoughts. Their performance was tracked, and after completing the tasks, a post-use interview was held to gauge their experience.

The next stage in the MRC framework is to evaluate the intervention in practical use. The effectiveness should ideally be assessed with a randomized clinical trial (RCT)[1]. However, the framework prescribes not only to evaluate the effectiveness with a RCT but also to gain an understanding of the underlying change process. By omitting such a process evaluation, the results of an RCT cannot properly be explained. Therefore, a process evaluation of the developed intervention is presented in Chapter 5. The research questions that will be addressed are as follows: *(a) Was the tablet usable in a real-world setting for an extensive period of time, and (b) How does the tablet, in conjunction with a personal coach, support older adults in performing home-based exercises?* The questions were answered by administering a validated usability questionnaire and by in-depth follow-up interviews with participants who had used the tablet for over six months. The interviews were analyzed according to the various phases of self-regulation, i.e., the theoretical basis of the intervention.

1 Please note, assessing the effectiveness in terms of health outcomes falls outside the scope of this thesis. Van den Helder et al have reported the protocol and results of a randomized controlled trial elsewhere [31,32].

To further a deeper understanding of the underlying change processes, a secondary analysis of the interviews was also conducted from the perspective of the self-determination theory. Chapter 6 addresses the research question: *How does the blended intervention influence participants' exercise motivation, specifically their basic psychological need for competence, autonomy and relatedness?*

Chapter 7 addresses the actual exercise behavior participants exhibited. It describes how often the participants performed exercises during the 6-month intervention period and attempts to quantify the contribution the tablet made to this effort. Specifically, the research question that will be addressed in this chapter is as follows: *To what extent does engagement with the tablet predict exercise adherence and physical activity?* This question is answered in a post hoc study by conducting statistical analysis on clinical trial data that was logged with the tablet. Finally, in Chapter 8, the overall conclusions that can be drawn from this thesis, lessons learned and future directions are discussed.

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2

Attitudes of Older Adults in a Group-Based Exercise Program Toward a Blended Intervention; A Focus-Group Study

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Abstract

Ageing is associated with a decline in daily functioning and mobility. A physically active life and physical exercise can minimize the decline of daily functioning and improve the physical-, psychological- and social functioning of older adults. Despite several advantages of group-based exercise programs, older adults participating in such interventions often do not meet the frequency, intensity or duration of exercises needed to gain health benefits. An exercise program that combines the advantages of group-based exercises led by an instructor with tailored home-based exercises can increase the effectiveness. Technology can assist in delivering a personalized program. The aim of the study was to determine the susceptibility of older adults currently participating in a nationwide group-based exercise program to such a blended exercise program. Eight focus-groups were held with adults of 55 years of age or older. Two researchers coded independently the remarks of the 30 participants that were included in the analysis according to the three key concepts of the Self Determination Theory: autonomy, competence, and relatedness. The results show that maintaining self-reliance and keeping in touch with others were the main motives to participate in the weekly group-based exercises. Participants recognized benefits of doing additional home-based exercises, but had concerns regarding guidance, safety, and motivation. Furthermore, some participants strongly rejected the idea to use technology to support them in doing exercises at home, but the majority was open to it. Insights are discussed how these findings can help design novel interventions that can increase the wellbeing of older adults and preserve an independent living.

Introduction

The number of older adults in Europe will rise in the coming years [1]. Ageing is associated with a decline in daily functioning and mobility [2,3]. A physically active life and physical exercise can minimize the decline of daily functioning [4]. Older adults with a sedentary lifestyle are at higher risk of health related problems, becoming dependent and facing a lower quality of live [5,6]. Studies have shown that older adults benefit from regular exercise that increases muscle strength, balance, endurance, and flexibility [7,8]. Physical exercise improves physical-, psychological- and social functioning and preserves an independent living [3,4,7,8].

To execute physical exercises correctly and persistently, however, knowledge, skills and tenacity is needed [9]. It has been argued that the Self-Determination Theory (SDT) is useful for understanding the initiation and maintenance of physical exercise behavior and is successful in predicting the adherence to exercise programs [10–12]. SDT poses that intrinsic or internalized extrinsic motivation is determined by the extent that three basic psychological needs are met [13]. Firstly, the need for autonomy. People need to feel in control of their behavior and goals they strive. Exercise programs should match the personal goals of an individual. Secondly, the need for competence. People need to gain mastery of relevant tasks and skills to achieve those goals. Guidance in executing exercises properly plays a key role. Thirdly, the need for relatedness. People need to feel connected to other people and have a sense of belonging. Exercising with peers can motivate to persevere. The beneficial role of supervision and peers is reflected by the higher adherence to supervised group-based programs then to programs where individuals are expected to exercise in solitude without supervision [5,14].

Although older adults can benefit from the supervision of an instructor and the company of peers, there are several disadvantages too. First of all, it is not always feasible. Employing an instructor and renting a location that can accommodate a group of participants can be costly. Secondly, in a group-based exercise program there is less opportunity to tailor to the individual needs of participants. Thirdly, participants need energy, time, and money to commute to the location. This is especially true for older adults that have, in general, more financial and physical limitations than others do. Because of those barriers the exercise frequency of supervised group-based programs is often too limited to attain health benefits [9,15].

However, a combined intervention can compound the benefits of a supervised group-based exercise program with the benefits of an individual exercise program to achieve the required intensity, frequency and duration of exercises [5]. The American College of Sports Medicine recommends exercising three to five times a week 30–60 min with moderate intensity [16]. Furthermore, technology, such as a computer, tablet, or smartphone can provide support for home-based exercises and tailor the program to the individual needs [17–19].

To explore the attitudes of the older adults toward such a blended exercise program a qualitative study was carried out as part of the VITAMIN and MOTO-B project that intent to develop an intervention to increase the vitality and functional ability of older adults (≥55 years of age) in the Netherlands. The aim of the study was to determine the susceptibility of older adults currently participating in a nationwide group-based exercise program to a personal tailored home-based exercise program supported by technology. The research questions were:

(a) What motives do older adults have to participate in a group-based exercise program?
(b) What are their attitudes and expectations toward doing additional exercises at home?
(c) What are their attitudes and expectations of supporting technology to facilitate home-based exercises?

To address the research questions focus-groups were held. In line with the SDT the results were analyzed in order to identify the motives, attitudes and expectations of older adults toward of blended exercise programs. The insights of this study will help the design of novel interventions that increase the health benefits of older adults and contribute to an independent living.

Materials and Methods

Design

Focus-group interviews are an effective means to understand what people feel or think about various issues [20], including health related believes [21], and were therefore used in this study to infer the attitudes of older adults toward a blended exercise program. As prescribed by the methodology of focus-group interviews [20], the recruitment of focus-group was ended when the saturation point was reached

and no new information was presented.

Participants

Participants were recruited by convenience sampling from a community-based program known as More Exercise for Seniors (in Dutch *Meer Bewegen voor Ouderen*, abbreviated as MBvO). In this nationwide program 300,000 older adults of 55 years and older across the Netherlands participate in a weekly group-based exercise class under supervision of a certified trainer. An e-mail with information about the study and the goal of the focus-group was send to a number of trainers asking permission to pay a visit. During the visit the study was verbally explained to the older adults and were asked to sign-up for the focus-group that was to be held at a later date. Also flyers were given with additional information. Participants had to be 55 years or older and live independently in order to participate in the study.

The recruitment of focus-group was ended when saturation point was believed to be reached based on a preliminary analysis of the results. In total 15 trainers were contacted and eight focus-groups were held, including two pilots, with in total 48 older adults.

Materials

An interview guide was developed according to the instruction manual for focus-group of the Dutch quality institute for healthcare [22]. The interview guide was reviewed by a panel of experts with a diverse background, ranging from human movement to ICT. Two pilot focus-groups were conducted to test and refine the guide. The resulting interview guide is presented in Table 1.

Procedure

The focus-groups took place at the locations where the weekly MBvO-class were held and at average consisted of six participants. During the focus-group a semi-structured interview and brainstorming session was held, guided by a moderator and an assistant that took notes. Prior to the focus-group the participants provided demographic information and signed an informed consent to agree to an audio-recording of the interview. The focus-group started with an introduction, informing participants that questions would be asked regarding their opinions about an additional home-based exercise program. It was emphasized that there were no right or wrong answers and that all opinions were equally valued by the moderator. During the focus-group the moderator asked questions, in line with the interview guide (see Table 1), and gave some examples when no responses were contributed.

The focus-groups lasted approximately 1 h. The Medical Ethics Committee of the VU University Medical Center Amsterdam approved the study.

Table 1. Interview guide.
Introduction
(1) What is your name and what is your mean reason to participate in MBvO?
(2) What do you think about MBvO?
Transition
(3) What are your activities besideMBvO?
(4) Which activities do you like?
(5) Which activities are the most important for you?
(6) What are the activities that are more difficult when you are older?
(7) What is the reason that activities are more difficult now?
(8) What motivates you to do activities and exercises?
(9) What are the barriers to do activities and exercises?
Core
(10) What is your opinion about an additional home-based exercise program?
(11) Do you want to do more activities or exercises? What do you like to do?
(12) Are you already doing exercises at home?
(13) What kind of exercises do you like to do?
(14) What do you think about exercising at home?
(15) Do you think you would do exercises at home?
(16) What are your requirements for a home-based exercise program?
(17) What motivates to participate in a home-based exercise program?
(18). What do you think you need to do exercises at home?
(19) What do you think about technology to support a home-based exercise program?
(20) Would technology help you to do activities and exercises?
(21) What are your requirements for technology?
(22) What do you think about different technologies?
(examples: video's,music,virtualcontact,wearables)
End
(23) What is your most important recommendation to develop an additional home-based exercise program?

Data Analysis

After each focus-group the moderator and assistant evaluated and discussed the most notable statements and common themes. The results of each focus-group were compared with other groups in order to find common patterns related to the research question. On basis of this preliminary analysis the researchers assessed if

new information was obtained or saturation was reached. Afterward the assistant transcribed the audiotapes anonymously and the transcripts were analyzed with software for qualitative data analysis (MAXQDA). The transcripts were analyzed using a sequential coding strategy. Three types of coding are used consecutively: open, axial, and selective coding [23]. The initial codes (themes) were created by studying the segmented information and the assistant's notes (open coding). Then the open codes were subcategorized to provide more details of each category and to indicate connections between different categories (axial coding). At the end the core categories were identified and matched with the three elements of the SDT; autonomy, relatedness, and competence (selective coding). All data was independently coded for themes by two researchers. When they differed in classifying participant's remarks, a discussion was held in order to reach consensus. If they failed to do so, a third researcher decided which theme was most appropriate.

Results

Participants

Due to technical problems, the recording of one focus-group was lost and could not be analyzed. Furthermore, participants of the two pilot-groups were excluded from data-analysis. Data from the remaining 30 participants was included in the analysis and reported below.

The mean age was 74 years (SD = 9, range 58–88). The mean length of participation in the weekly MBvO-classes was nine years (SD = 9, range 3 months – 28 years). All participants were female (N = 30). The level of completed education the participants received varied, ranging from no schooling or elementary school (N = 3), lower vocational schooling, or lower secondary schooling (N = 12), intermediate vocational schooling or intermediate/higher secondary schooling (N = 13) to higher vocational schooling or university (N = 2).

Motives do Older Adults to Participate in a Group-Based Exercise Program

Autonomy

Staying physically fit and being self-reliant was identified as a major reason for the participants to join the weekly MBvO classes. They indicated they considered themselves to lead an active lifestyle, doing household chores (washing windows,

gardening, vacuuming, cooking, e.g.) and various leisure time activities (tennis, swimming, dancing, fitness, e.g.). Examples of typical remarks were: "…being on the move is for me reason number 1; I believe it is very important for staying healthy," "…living independently is for me the main reason. It is crucial" or "…to be able to take a stroll on a nice day. To the forest or along the sea. Imagine that you can't do that!"

Nevertheless, they believed doing additional exercises would contribute to their ability to remain mobile and live independently for a longer time. Some participants stated specific complaints as the reason for joining the exercise program (arthritis, e.g.). A few participants expressed clearly a fear of becoming dependent on others, as illustrated by the following remarks: "…the mere thought of being dependent on neighbors, friends, or whosoever. I wouldn't want that," "…I want to remain mobile, to buy groceries, cook and not have to rely on others," and "…I am scared to death of becoming dependent on others. That is the worst thing that could happen to me."

Competence

The majority of the participants stressed that they felt that expert guidance was crucial. The instructor that led the MBvO classes indicated the importance of each exercise and how it can be carried out safely. They clearly valued the supervision of the instructor, as illustrated by the following remarks: "I believe what plays a part is the guidance. Someone who tells you what you should do" or "…[the instructor]… how you should do it and what you are able and aren't able to do."

Relatedness

Besides staying physically fit, as mentioned before, social relations and 'having fun' were identified as other major reasons for the participants to join the weekly MBvO classes. Unanimously participants referred to this social aspect. They indicated they had good rapport with the group, felt that the presence of their peers motivated them to exercise and enjoyed each other's company. In some cases participants even formed close friendships since they exercised across the years together. Typical remarks made by the participants were "for me it's all about the social atmosphere" and "I wouldn't want to miss out on being in touch with the others."

Attitudes and Expectations Toward Doing Additional Exercises at Home

Autonomy

Participants felt that a home-based exercise program could have several benefits. First of all, it could be tailored to their individual needs, allowing such a program to match their personal goals. Secondly, they indicated doing exercises at a moment that suits them, would also be a benefit compared to a group-based exercise program. Thirdly, participants were positive about the possibility of an exercise program that could be followed at different difficulty levels and was self-paced.

Typical remarks that illustrate the opportunities they identified were: "… a program with different difficulty levels, that allows you to take it each time further," "…something like the television program The Netherlands on the Move (in Dutch *Nederland in Beweging*), but with the opportunity to adjust it to your pace" and "I belief having a choice is important and the pace, I should be able to decide for myself."

Competence

Besides recognizing benefits of a home-based exercise program, the participants also expressed concerns if they would carry out exercises at home without guidance. Firstly, the felt the need for background information about the exercises. They indicated they would want to know which exercise contributes to which goals and if the exercise will improve strength, flexibility, balance, or endurance. They believed this information would motivate them to do the exercises. Secondly, the participants felt the need for instructions how to perform the exercises properly, thereby minimizing the chance of injuries. Some participants indicated that safety was an important concern. Thirdly, some participants mentioned that they need structure. To exercise at a specific day or time would help them to maintain their exercise routine. Fourthly, participants expressed the need for variation in a home-based exercise program as they valued this in the weekly MBvO classes. Fifthly, numerous participants indicated they considered themselves to have a busy life and felt that daily physical exercises should not take up more than 15 min a day.

Typical remarks that illustrate the competence related opinions: "I want to know which joints will benefit from a specific exercise," "then it becomes enjoyable, because you know what the benefits are" and "I believe you should build up a routine, like it's Monday so let's get started!" and "I hava a lot of activities… such an

exercise program should be 15 min at the most."

Relatedness

The participants recognized the benefits of doing exercises at home in addition to the weekly group-based exercises, but expressed concerns if they would be able to motivate themselves to do so, as illustrated by the following remark: "…if I would get a list of exercises I should do at home, I would manage for 2 days, but that's about it." They felt the social support of the weekly classes were crucial. The participants expected to miss the peer pressure and the social control if they would do exercise at home. Some typical remarks were: "…I don't think I would enjoy going about on my own" or "…I don't believe that people that are active, will exercise at home without any guidance." Some participants referred to the fact they had similar experiences with exercises that were prescribed by physiotherapists. Initially they would adhere to it, but in time their motivation drops and fail to maintain their home-based exercises.

A few participants raised, however, the idea of doing exercises with a spouse or with friends in order to mobilize social support in absence of a group led by an instructor, as illustrated by the remarks "… I might exercise with my husband" and "… if on Sundays I could go walking with a group instead."

Attitudes and Expectations of Supporting Technology to Facilitate Home-Based Exercises

Autonomy and Competence

When participants were asked if they believed technology like computers, tablets or smartphones could assist them in doing exercises at home, the opinions varied greatly. A few participants rejected the notion strongly, stating "…it doesn't interest me," "I think it's awful" and "I oppose it. My children try to impose it, but I won't have it!" Several participants indicated the fear of not being competent. They voiced a lack of confidence, even shame. Typical remarks were "…as an elderly, you don't understand computers really and feel a bit dumb," "… I don't have any brains, so I never have learned it" and "…I feel embarrassed to ask my children for help."

On the other hand, the majority of the participants were receptive to the idea of technology assisting them in home-based exercises and some were even enthusiastic. Typical remarks were "I have the feeling 1 day it's bound to happen [using computers], I am the only family member who doesn't have one," "…I wouldn't mind giving it a

try," "... I'm actually curious about it," "I have never learned to type, but I have an iPad, that's very easy" and "that would be fun!"

When the participants were asked how technology could support them in doing exercises at home, the responses ware limited. First thing that came to mind were videos of photos how exercise should be performed. Some participants, however, expressed concerns that exercises recommended by a computer or tablet would not know their physical limitations to the same extent as the instructor does, illustrated by the following remark: "...has been operated on her hip and then she says [the instructor], bending forward is ok, bending backward is ok, but don't bend sideways.... She gives all those kind of instructions."

Relatedness

If technology could not only support the participants in performing exercises, but also foster the social relationships they grew fond of in the weekly face-to-face classes, the participants held mixed opinions about. Some participants indicated they had no need for additional contact outside the weekly classes, while others stated they had already ample means if they wanted to reach out ("we can also pick-up the phone"). A few participants, however, came up with the notion to use video calls (Skype, FaceTime, e.g.) to form a virtual group and do exercises simultaneously at home. Finally, one participant welcomed video calls as a means to combat loneliness and stay in touch with others: "I have been thinking about it. I don't only want to have enough exercise, but also to get by. You lose family, I don't have kids, friends pass away, so you are left on your own. To be in touch with someone who lives on the other side of the county would be very nice..."

Discussion

As outlined in the introduction, ageing is associated with a decline in mobility and daily functioning that is needed for independent living. Physical activity and physical exercise can prevent or limit the decline and improve the overall wellbeing of older adults. An intervention, in line with ACSM recommendations, that combines group-based exercises led by an instructor with home-based exercises will help to achieve the needed intensity, frequency and duration of exercises in a functional context. The aim of this study was to determine the susceptibility older adults currently participating in a nationwide group-based exercise program to such a blended exercise program. The results of this study bear insights which should be taken into

account when designing novel exercise programs.

Firstly, the motives of older adults to participate in an exercise program seem to be twofold. Older adults strive to remain self-reliant. Exercises that contribute to their autonomy can count on their support, on condition that they receive proper guidance in which the benefits of each exercise is stressed and instructions are provided how exercises are to be performed correctly. Self-efficacy, outcome expectation and perceived benefits play a key role in the adherence to exercise programs [24]. On the other hand forming social relationships amongst peers and being in touch with others seems to be another clear motive of older adults to join an exercise program. The need for relatedness should be taken into account when designing interventions promoting physical activity or physical exercise.

Secondly, older adults recognize a number of benefits of additional home-based exercises. It allows them to a greater extent to tailor the exercises to their personal goals and needs in the level of difficulty, speed and timing, compared to group-based exercises. However, as also noted by Picorelli et al. [14], older adults have concerns missing the guidance they receive in instructor led group-based exercises. A home-based exercise program should have detailed instructions how exercises are to be performed correctly and safely. Furthermore, due to a perceived lack of time, also noted by others [25,26], the exercise program should be concise.

Finally, the role technology could play in supporting older adults to perform exercises at home is indistinct. Some older adults oppose the notion of using supporting technology for an exercise program in whatsoever form. However, this does not apply to all older adults. The majority does seem to be either enthusiastic or open to it, albeit they have no clear view or expectations about it.

The insights of this study should be interpreted with caution, however. Firstly, the choice to explore motives, attitudes and expectations with focus-groups relies on introspection and self-report. This implies that the participants in this study were able to consciously reflect on those aspects and accurately report them. As with all introspection techniques, this may not have been the case [27,28]. The authors believe this played especially a role with questions regarding the use of technology. Most of the participants did not seem to have any experience with ICT. The answers they gave were largely based on general views they held about it. Although this should not be disregarded, future research could extend the findings by presenting older adults detailed scenario's with use cases or working prototypes in order to

further investigate this matter.

Secondly, the focus-groups were led by either a psychologist with an ICT background or a human movement scientist. It was believed that the broad academic background of these researchers reflected the diverse key issues that play a role. In moderating the focus-groups the differences in academic background may, however, also have led to minor differences in which topics were elaborated upon. Yet the impact of those differences were minimized by the fact that the results of each focus-group were reviewed and analyzed by both researchers, safeguarding the comparability.

Finally, one should be careful in generalizing the results of this study to older adults by and large. In line with the aim of the study, attitudes toward a blended exercise program were explored amongst older adults currently participating in a nationwide group-based exercise program. It is reasonable to assume that these attitudes may differ from older adults that are not engaging in such activities. Furthermore, all the participants in this study were women and varied strongly in age and schooling. Although these characteristics of the sample are indicative of the targeted population of this study in which women are in the vast majority, is does raise questions how gender, age and education level influences the attitudes toward exercise and supporting technology amongst other populations of older adults. Reviews indicate that, in general, education has a positive correlation and age a negative correlation with exercise behavior [29,30]. Those reviews also conclude that the majority of studies show that men are physically more active than women. In contrast, Mesters et al. [31] reported in a recent study that for older adults in the Netherlands the opposite appears to be true; older women attain more physical activity than older men. The authors stipulate this may be the result of the type of activities Dutch men prefer, but cannot keep up at late age (i.e., outdoor sports). Women might also be more susceptible to the social support provided by the group-based program. Concerning differential attitudes toward supporting technology, a review by Or and Karsh [32] shows that the majority of studies found a positive relation between education and acceptance of health information technology, but no effect of gender. The effects of age were found to be inconclusive. Some studies report a negative relation, while other studies report a positive relation or no relation at all between age and the acceptance of supporting health technology [32]. Future research could expand upon the findings of the present study and clarify remaining issues by investigating different populations. By taking the attitudes of specific older adult populations into account, novel interventions can be designed that contribute to a healthy and independent living.

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3

Translating Behavior Change Principles Into a Blended Exercise Intervention for Older Adults: Design Study

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Abstract

Background: Physical activity (PA) can prevent or delay age-related impairments and prolong the ability of older adults to live independently. Community-based programs typically offer classes where older adults can exercise only once a week under the guidance of an instructor. The health benefits of such programs vary. Exercise frequency and the duration of the program play a key role in realizing effectiveness. An auxiliary home-based exercise program can provide older adults the opportunity to exercise more regularly over a prolonged period of time in the convenience of their own homes. Furthermore, mobile electronic devices can be used to motivate and remotely guide older adults to exercise in a safe manner. Such a blended intervention, where technology is combined with personal guidance, needs to incorporate behavior change principles to ensure effectiveness.

Objective: The aim of this study was to identify theory-based components of a blended intervention that supports older adults to exercise at home.

Methods: The Medical Research Council framework was used to develop the blended intervention. Insights from focus group, expert panels, and literature were combined into leading design considerations.

Results: A client-server system had been developed that combined a tablet app with a database in the cloud and a Web-based dashboard that can be used by a personal coach to remotely monitor and guide older adults. The app contains several components that facilitate behavior change—an interactive module for goal setting, the ability to draw up a personal training schedule from a library containing over 50 exercise videos, progress monitoring, and possibilities to receive remote feedback and guidance of a personal coach.

Conclusions: An evidence-based blended intervention was designed to promote PA among older adults. The underlying design choices were underpinned by behavior change techniques that are rooted in self-regulation. Key components of the tablet-supported intervention were a tailored program that accommodates individual needs, demonstrations of functional exercises, monitoring, and remote feedback. The blended approach combines the convenience of a home-based exercise program for older adults with the strengths of mobile health and personal guidance.

Introduction

Background

Physical activity (PA) is vital to a healthy life. A sedentary lifestyle is associated with numerous health-related problems such as obesity, diabetes, cardiovascular diseases, various forms of cancer, and depression [1,2]. Furthermore, for older adults, PA can prevent or delay the onset of functional impairments and prolong the ability to live independently [3]. Due to these well-acknowledged health benefits, community-based PA programs have spawned across the world [4,5].

A prototypical example of such a program that has been running for over 35 years in The Netherlands is “More Exercise for Seniors,” abbreviated as MBvO in Dutch. Weekly, 300,000 older adults exercise in a group under the guidance of an instructor. A study evaluating the effects of this specific program, however, concluded that exercising once a week is not sufficient [6]. Studies show a higher frequency and a longer exercise duration is needed to capitalize on the health benefits of PA. At least 5 days a week 30 min of moderate-intensity PA is recommended [7,8], and additional weekly strength and balance exercises prevent the decline of muscle mass and flexibility of older adults [9,10].

This raises the question of how older adults can be stimulated to achieve the recommended levels of PA. First, convenience plays a role. Exercising in a community center several times a week is difficult to achieve due to the cost, time, and effort needed to travel [11]. To attain the recommended intensity, a home-based exercise program could prove a useful addition to a community-based program—in the convenience of their home, older adults can continue the exercises they have learnt during the weekly community classes.

Second, older adults need support in following an exercise program. In community classes, an instructor chooses which exercises are suited for the participants, provides instructions how they can be performed safely, and motivates the older adults to persevere. However, technology is increasingly being used for these functions. The potential to reach a large population and low costs are reasons for its emerging popularity. Various reviews indicate that technology-supported interventions can increase the effectiveness of exercise programs [12-17]. Most of the reported studies used websites to deliver the intervention. More recently, mobile health (mHealth), the use of mobile devices to deliver health solutions, however, has become popular

[18]. In particular, for older adults, the use of tablets seems promising. Studies show that due to its large touchscreen, older adults are able to operate tablets better than personal computers [19,20] or smartphones [21]. The usability of tablets may be the reason for its increasing popularity in the United States [22] and The Netherlands [23,24] and its use in mHealth interventions for older adults [25].

Nevertheless, there are also limitations in the scope of mHealth. Automated feedback and guidance (ie, avatar coach) do not correspond well with the subtlety and social support that a person can provide [26]. A blended intervention, where personal guidance by a coach is matched with the possibilities technology can deliver, can be an effective approach. The blended intervention might be a useful extension of traditional community-based PA programs. It can increase the exercise frequency of such programs while relying on an existing infrastructure, such as the availability of instructors and the social support of peers.

Objective

As part of the VITAMIN (VITal Amsterdam elderly IN the city) and MOTO-B (MOtivating Technology for Older adults' Behavior) projects that aim to increase the vitality of older adults, we conceived a tablet-supported intervention to increase PA in older adults that currently participate in a community-based program by combining the convenience of a home-based program, the potential of mHealth, and the strengths of personal guidance. To develop an effective intervention, the following research question was addressed: How can theoretical principles and scientific evidence on behavior change be translated into features of a tablet-supported intervention to increase the PA levels of older adults?

The effectiveness of the intervention will be determined with a randomized control trial (RCT) that is currently ongoing. The procedure of the RCT is detailed in a protocol study [27]. In this study, we describe the design process that led to the blended intervention. The study meets the plea to transparently report how behavioral change interventions are developed [28]. In typical effect studies, either no theoretical underpinnings are provided or are loosely mentioned without giving a detailed report about how they have led to specific design and implementation choices. By sharing the process that led to the design, we attempt to contribute to this field.

Methods

To develop the blended exercise program, insights were drawn from scientific literature as well as from practice-based expertise. On the basis of the Medical Research Council (MRC) framework [29], the following steps were undertaken:

- Step 1: Identify attitudes of older adults
- Step 2: Identify scientific evidence and formulate design considerations
- Step 3: Identify requirements of the blended intervention
- Step 4: Design functional components
- Step 5: Implement components of the blended intervention.

After developing the intervention, the MRC framework recommends testing the intervention procedures and assessing the effectiveness in a controlled manner. These validation measures are discussed in the last section of the paper in light of follow-up studies.

Step 1: Identify Attitudes of Older Adults

Before developing the blended intervention, 8 focus groups were held with 48 older adults currently participating in the weekly MBvO community-based exercise classes. The aim was to explore the need for a blended intervention by investigating the attitudes of older adults toward an additional home-based exercise program and the possibility of supporting technology. The results show that participants recognized the benefits of doing home-based exercises. They had, however, also concerns regarding guidance, safety, and adherence to a home-based exercise program. The majority were open toward technology that could support them on those aspects, though some of them lacked the confidence to operate technical devices (see [30] for more details about the focus group study). Those insights fed into further development of the blended intervention.

Step 2: Identify Scientific Evidence and Formulate Design Considerations

To identify relevant literature, the ACM, IEEE, Google Scholar, PsycINFO, and PubMed databases were consulted. A combination of the following search terms was used—("older adults" OR seniors OR elder*), ("physical activity" OR exercise), (app OR internet OR web OR "mobile phone" OR smartphone OR tablet OR mHealth OR eHealth OR technology), and ("behavior change" OR adoption OR prevalence

OR use OR attitude OR acceptance OR intent*). Forward and backward references were screened, and the recommender feature of Mendeley Reference Manager was used to identify additional sources. Studies that were assessed to be relevant, where precedence was given to reviews and meta-analysis, were selectively discussed with supervisors and peers from varying disciplines.

On the basis of the scientific evidence, 3 design considerations were formulated that address the issues identified in step 1.

Design Consideration 1: Functional Exercises

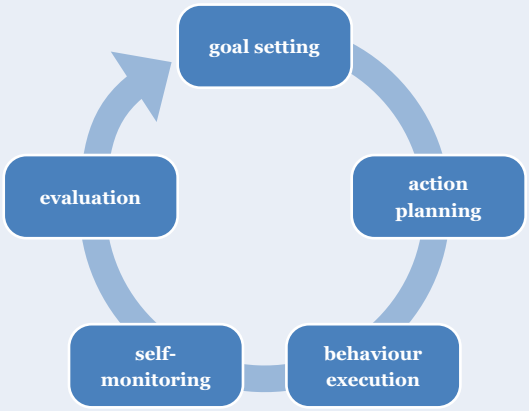
As people age, they lose muscle strength, flexibility, balance, and endurance. The decline across these 4 domains decreases their ability to perform activities of daily living (ADL); for instance, getting up from a chair, carrying groceries, or opening a jar [8]. A functional training program has shown to be more effective to counter this decline than general PA (ie, walking) or resistance training (ie, exercises with dumbbells) [31,32]. Functional training consists of exercises across the varying domains and is specifically designed to improve the performance of ADL. A functional exercise not only targets a daily task but also mimics its pattern. For instance, a functional exercise aiming to improve the mobility of older adults may contain exercises of walking up and down the stairs several times. Due to this close proximity to everyday life, older adults can integrate it autonomously into their daily routine. Furthermore, due to the resemblance, older adults recognize the relevance of the exercises more easily, which in turn improves the adherence to the training [33].

Design Consideration 2: Behavior Change

To regularly perform exercises at home, older adults have to develop new habits. The needed behavior change is hard to achieve, as indicated by the large part of the population that does not meet the recommended levels of PA and the low adherence rate to PA programs that seek to increase this [34,35]. Insights from the behavioral sciences can improve the effectiveness of these interventions. Notably, Michie et al [36] developed a taxonomy of 91 behavior change techniques (BCTs) that were synthesized from a wide body of evidence and afterwards refined to the CALO-RE taxonomy [37]. Techniques that are associated with the self-regulation of behavior appear particularly effective: goal-setting and self-monitoring [38] In addition, techniques that increase self-efficacy, such as action planning and demonstrating behavior, are also shown to be effective [39]. When these techniques are combined with an evaluation phase in an iterative manner, it corresponds with the widely

adopted control theory [40]. See Figure 1 for a schematic representation of the behavior change process adopted in this paper.

Figure 1. Behavior Change Through Self-Regulation.



Design Consideration 3: Blended Technology

Although the effectiveness of eHealth and mHealth to increase PA has been debated [41], 2 common success factors emerge from the literature.

First of all, feedback and guidance play a key role in enriching the various phases of the control theory. Several reviews underline the effectiveness of combining home-based exercise programs for older adults with (remote) guidance [39,41-44]. Geraedts et al [44] identified numerous studies that show higher adherence for home-based exercise intervention programs that included remote feedback. For instance, King et al [45] found the adherence rate of the home-based exercise program initially to be higher than the center-based program, but in a follow-up study [46], they reported a strong drop in adherence levels when the phone calls were ceased according to protocol after 1 year. Geraedts et al plead that PA interventions for older adults should utilize technology to support remote feedback and personal guidance.

The second success factor identified was tailoring. Krebs et al [14] concluded from a meta-analysis of various health behavior change studies, of which 25 targeted PA, that interventions with computer-tailored exercise programs were more effective than the control groups, with effect sizes varying from small to moderate. On average,

43% of participants in the eHealth groups adhered to the PA recommendations compared with 34% in the control groups. Furthermore, iterative tailoring was associated with a larger effect size than tailoring that was only done on the basis of baseline measurements, and this effect was stronger for longitudinal outcomes.

The importance of these 2 factors is also reflected by practice-based findings. The previously described focus group study (step 1) indicated that prospective participants believed additional home exercises would be a useful addition to the group-based classes, but also had worries about the motivation and adherence to such a program [30]. They value the personal guidance and feedback that the instructor provides during the weekly group-based classes. The majority of the participants were open to the idea of using supporting technology in doing exercises at home, though there were concerns if they were able to operate it.

Step 3: Identify Requirements of the Blended Intervention

By consulting experts from health sciences (requirement 1 and 3) and behavior science (requirement 2 and 4), leading requirements were formulated.

Requirement 1: Comprehensiveness

Following design consideration 1, the app should contain functional exercises that vary across domains and difficulty level that can be performed safely in a home setting. The exercises should target the strength, endurance, flexibility, and balance of older adults.

Requirement 2: Effectiveness

Following design consideration 2, the app should facilitate behavior change by supporting self-regulation.

Requirement 3: Adaptability

Following design consideration 3, the user should be able to create and customize a personal training schedule according to individual needs. Users should be able to increase or decrease the complexity as well as the physical load of the exercise.

Requirement 4: Remote Guidance

Following design consideration 3, the app should facilitate remote guidance by a personal coach to motivate and counsel users.

The identified requirements were discussed with practitioners who were involved

with the community-based exercise programs for older adults. They confirmed the relevance of the requirements.

Results

After identifying the needs, design considerations, and requirements (step 1 to 3), consultation of behavioral scientist, computer scientist, and designers resulted in the design and implementation of the blended intervention (steps 4 and 5).

Step 4: Design Functional Components

By consulting a physical therapist and behavioral scientist, the 4 requirements that were formulated were translated into the components described below.

Comprehensiveness: Exercise Library

Users can browse through a library of 17 functional exercises. For each exercise, 3 variations are available that differ in complexity, amounting to a total of 51 exercise variations. Each exercise variation contains a video demonstration with a voice-over for verbal instructions, a factsheet with written instructions, and background information. The instructions stress how the exercises can be performed safely.

Effectiveness and Adaptability: Goal Setting

When using the app for the first time, older adults start out by filling in an interactive series of questions. First, they select the activities they value from a set of predefined ADLs. They then prioritize the selected ADLs by ranking these into a top 5 list. Finally, in the last step, the app recommends a number of exercises that match their goals. The user has the possibility to either add those exercises to their personalized exercise program or to ignore the suggestions. Moreover, users can commit to personal goals that they formulate themselves (free-choice alternatives).

Effectiveness and Adaptability: Action Planning

The exercise can subsequently be added to the personal training schedule of the user. When adding the exercises, users select the variation and the day they would like to perform the exercise. Optionally, they can set a reminder for a specific time to be alerted.

Effectiveness and Adaptability: Behavior Execution

Before performing the exercises as scheduled by the action planning app, users have

the opportunity to watch a video in which an older adult demonstrates the exercise along with a voice-over explaining various aspects. Furthermore, before execution, they can alter the physical load with 3 parameters—the duration of the exercise (30, 60, or 90 seconds), the number of repetitions (1, 2, or 3), and the intensity level (1, 2, or 3). During execution of the exercise, users are supported by a countdown timer that keeps track of the duration and repetitions.

Effectiveness and Adaptability: Self-Monitoring

After an exercise is performed, users are asked to rate the exercise with a visual analogue scale (slider) on 3 aspects: (1) the complexity of performing the exercise, (2) the effort it took, and (3) the likeability of the exercise. After rating the exercise, it is marked as completed. With checkmarks and progress bars, users can view their progress at a glance.

Remote Guidance: Videoconference

Users can make a video call to a personal coach. This coach has remote access to the personal schedule, the exercise parameters, and the ratings of the user. In dialogue with their personal coach, users can reflect on their progress by comparing their goals with their performance. If needed, they can adjust either their goals or the training schedule.

By employing creative brainstorming techniques (eg, scenarios, personas, wire-frames) during sessions with physical therapists, behavior scientists, and interaction designers, BCT defined by CALO-RE (Coventry, Aberdeen & London–Refined taxonomy) [37] were translated into envisioned functions of the tablet app. See Table 1 for the mapping.

Step 5: Implement Components of the Blended Intervention

Functional Exercises

The exercises were developed by a team of human movement scientists and physiotherapists. During the development of the program, active involvement of the older adults, PA trainers, and health professionals was arranged to guarantee that all exercises were understandable, feasible, and could be performed safely. Exercises were first piloted under supervised conditions in the group exercise setting, then under supervision at the older adults' homes, and finally by the older adults without direct supervision. During this process, the exercises and instructions were fine-tuned to achieve optimal functioning.

Table 1. Mapping Between Behavior Change Techniques and Functions of the Tablet App.

BCTs[a] as defined by CALO-RE[b]	Function of the tablet app
Identifying barriers or problem resolution	Videoconference with personal coach (intake)
Goal setting	Prioritize activities of daily living (ADL) and formulating SMART (Specific, Measurable, Attainable, Realistic and Timely) goals
Setting graded tasks	Three variations of each exercise; before 3 execution parameters can be altered
Action planning	Tailored daily and weekly schedules
Prompt practice	Reminders or alarm
Instruction on how to perform the behavior	Voice-over instructions during video, written instructions in the specification sheet of each exercise, and countdown timer during exercises
Demonstrate behavior	Video depicting an older adult demonstrating how the exercise should be performed
Self-monitoring	Marking exercises as done; rating exercises on effort, complexity, and likeability
Provide feedback on performance	Videoconference with personal coach
Review of behavioral goals	Video conference with personal coach; modification of weekly schedule
Review of outcome goals	Video conference with personal coach; modification of SMART goals
Informing when and where to perform the behavior	Videoconference with personal coach
Environmental restructuring	Videoconference with personal coach
Training to use prompts	Videoconference with personal coach
Motivational interviewing	Videoconference with personal coach
Generalization of target behavior	Videoconference with personal coach
Facilitate social comparison	Weekly face-to-face classes
Plan social support	Weekly face-to-face classes

[a]BCT: behavior change techniques.
[b]CALO-RE: Coventry, Aberdeen & London–Refined taxonomy.

Envisioned Use Case During Randomized Controlled Trial

In line with the MRC framework, the blended intervention will be tested with an RCT. During this study, older adults are screened for eligibility, and a research coordinator assigns a personal coach to a user. The coach hands out the tablet to the user, along with a short written instruction on how to operate the device. Moreover, a short demonstration is given, and the user can try out the app himself. Then, the user starts by setting goals and drawing up a personal training schedule, assisted by the coach. After this, the user can perform the exercises independently

at home. All activity on the tablet is sent to the server (goals, training schedule, and exercise ratings), which can be remotely monitored by the coach. At agreed times, the user seeks guidance of the personal coach by starting a video call within the app. User and coach reflect on the progress, and if needed, the user modifies his goals or training schedule afterward. This process can be done iteratively to support the self-regulation cycle. See Figure 2 for an overview of the use case.

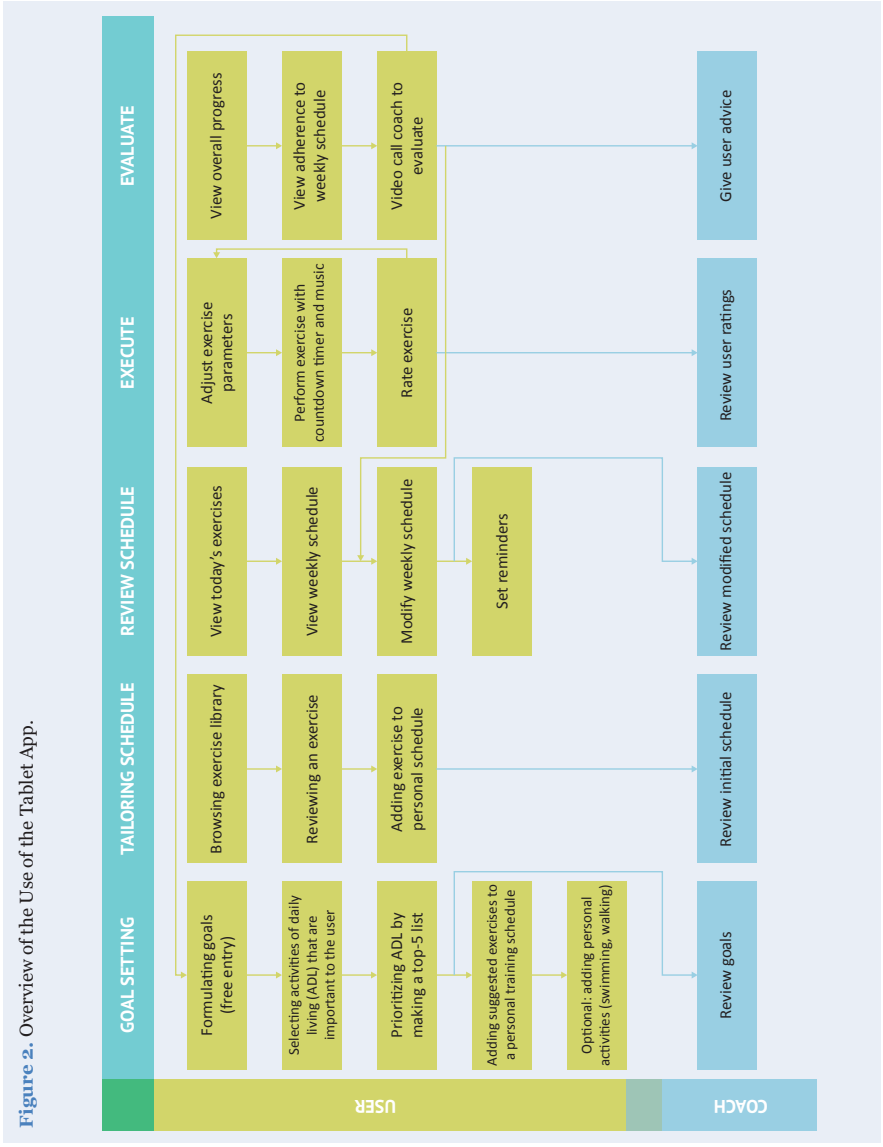
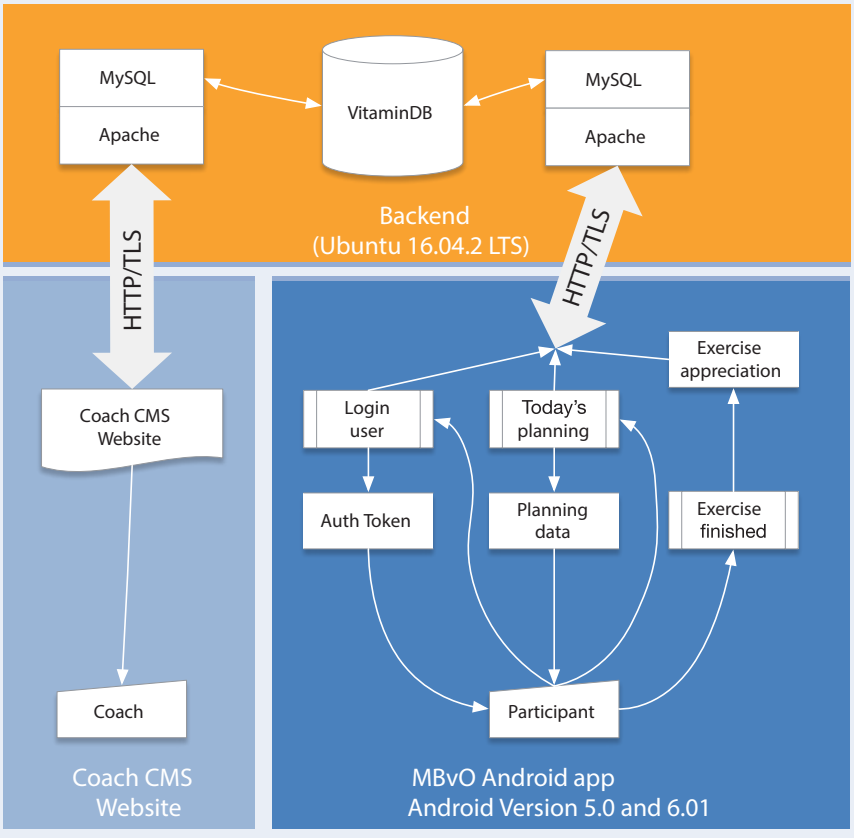


Figure 2. Overview of the Use of the Tablet App.

Software Architecture

The functional components described in the previous step were implemented in a client-server system consisting of an app that was optimized for a 10-inch Android tablet, a back-end for data storage and communication, and a Web-based dashboard to establish communications with the human coaches. See Figure 3 for an overview. On the tablet, users can set goals, view video demonstrations, create and modify personal training schedules, and rate exercises. The goals, training schedule, and exercises ratings of the user are securely sent to the back-end server and stored in a database. Personal coaches assigned to the users can login on a secured website and view the goals, training schedule, and exercise ratings of the user.

Figure 3. Information Technology Architecture. MySQL: Open-Source Relational Database Management System; APACHE: Open-Source Web Server; VITAMIN DB: Database Containing All Relevant Data; CMS: Content Management Software; MBvO: More Exercise for Seniors; Android: Operating System for Tablet Computers; Ubuntu: Operating System for the Server; HTTP/TLS: Encrypted Network Traffic.



User Interface

To ensure the usability for older adults with no prior experience with mobile devices, simplicity was the guiding principle. Information was layered in various tabs, a metaphor based on an agenda or a Rolodex that older adults are familiar with was used. Furthermore, the visual design was also kept simple. The interface was kept clean with a limited number of elements. Exercises were represented by pictograms that could be viewed at a glance. Large font sizes and contrasting colors were used to ensure readability. To validate the interface, a small-scale usability test was done with 3 prospective users. Various minor modifications were made to improve the usability. See Figures 4-11 for an impression of the resulting user interface.

Figure 4. Exercise Library.

Figure 5. Selecting Exercise Variation.

Figure 6. Personal Training Schedule.

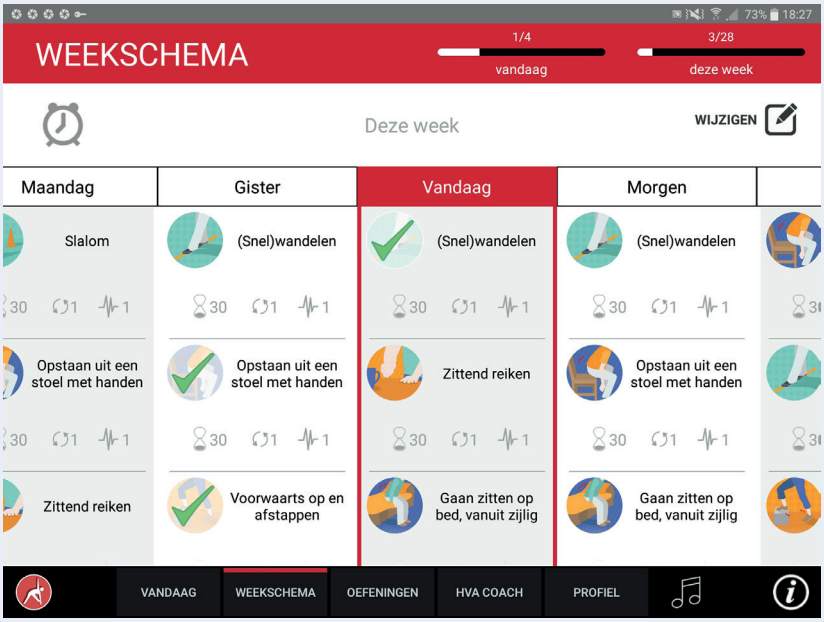


Figure 7. Today's Program.

Figure 8. Modifying Execution Parameters.

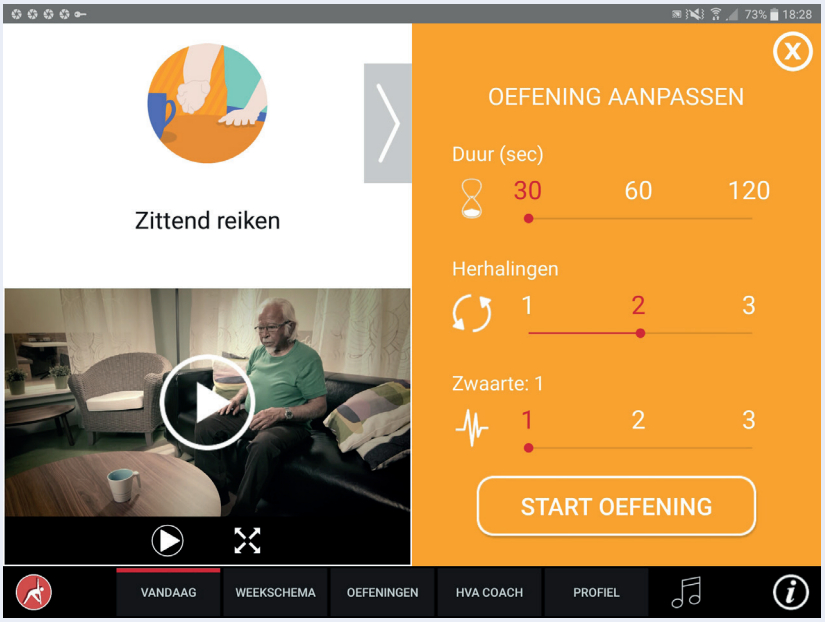


Figure 9. Countdown Timer During Executing.

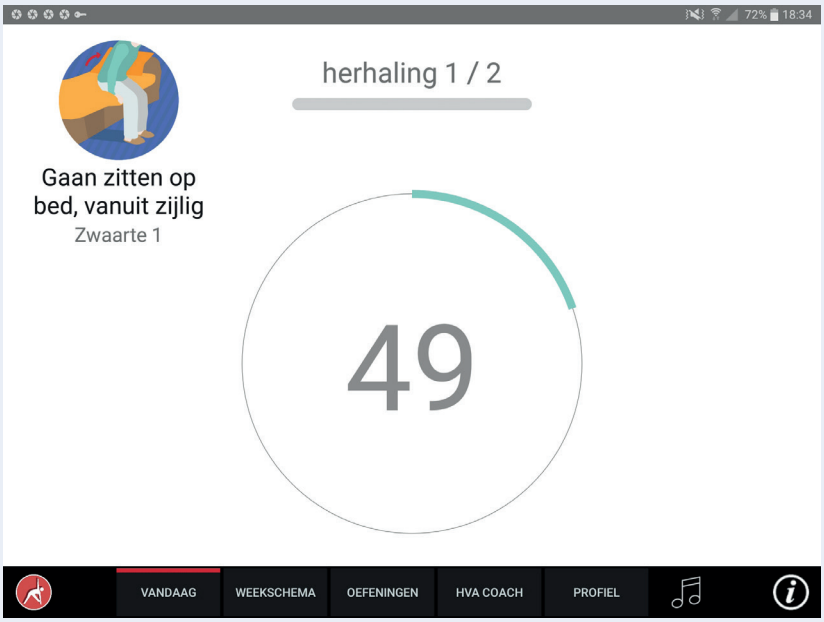


Figure 10. Rating An Exercise.

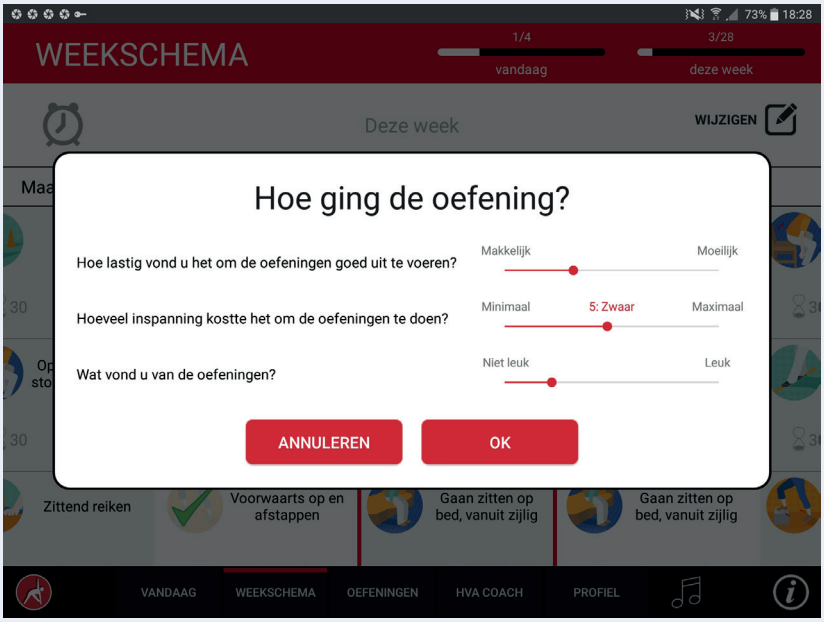
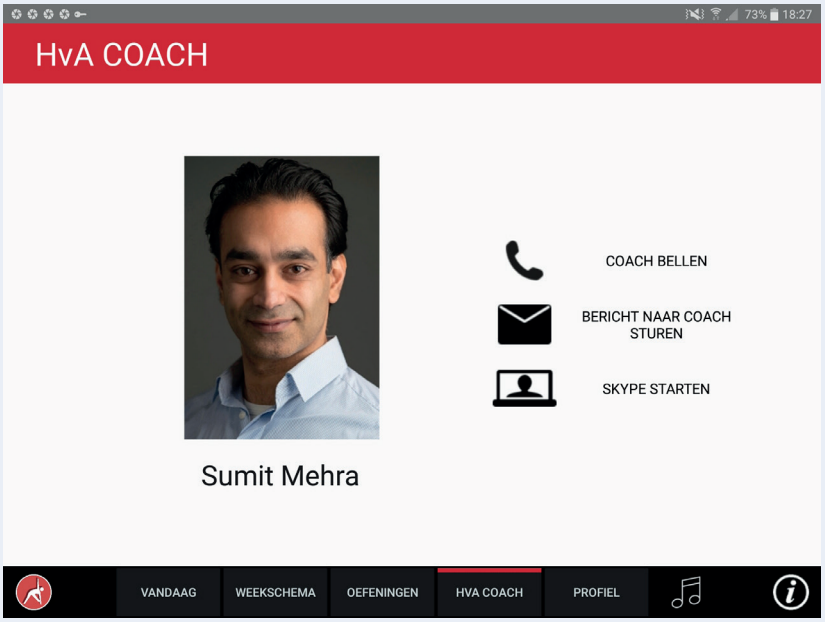


Figure 11. Initiating Video Call To Coach.



Discussion

Principal Findings

By following the MRC framework, a novel intervention has been developed to perform functional exercises at home. It is designed for older adults currently participating in weekly community classes to increase the frequency, duration, and intensity of exercises in a safe and convenient manner in a familiar setting. With a tablet, a customized training schedule can be compiled that matches the personal goals of the user. Furthermore, for motivation and advice, the tablet facilitates remote guidance by a personal coach. Moreover, older adults not participating in community exercise programs can use the tablet autonomously, albeit without the auxiliary guidance of a personal coach. All the components of the blended intervention have been carefully selected and are based on the behavior change theory.

Contribution and Related Work

There is a wide body of evidence that health interventions that support self-regulation in the general adult population are effective. For older adults, however, there are mixed results. French et al [47] found, in a systematic review, that interventions containing goal-setting and self-monitoring were remarkably associated with lower levels of PA in older adults. They suggest this may be caused by a decline in executive functioning associated with aging. Self-regulation requires cognitive effort. In the systematic review of Devereux-Fitzgerald et al [48], however, it is argued that supporting self-regulation is also important for interventions targeting older adults, but specific characteristics of this population have to be taken into account. Older adults value maintaining social relations with others and rather focus on short-term health benefits instead of long-term benefits. The blended intervention reported here takes those aspects into account by extending community-based PA programs, where social relations already exist [30]. Furthermore, the intervention facilitates personal guidance of a coach. Finally, the goals revolve around activities of daily living that are recognizable for older adults, instead of general (long-term) health benefits. Examples are joining their spouse for gardening or being able to go for a walk with their grandchildren. Furthermore, one could argue that providing tools such as a tablet help older adults overcome their declining ability to self-regulate behavior. Daily and weekly schedules and reminders, for instance, lower the cognitive effort needed for action planning.

The reviews mentioned earlier [47,48] describe general PA interventions for older adults. Only a few review studies specifically focus on the role technology can play to promote PA in older adults [25,41,49]. eHealth interventions that explicitly take social aspects into account are rare. Notable early work of Silveira et al [50] describes a pioneering study in which a tablet not only supported self-regulation but also social support. Older adults could, for instance, monitor progress of other participants and could send each other motivational messages. Nevertheless, the study failed to demonstrate a beneficial effect of facilitating social support. The question remains, however, if merely facilitating online communication between peers who are not acquainted with each other is sufficient to capture the richness of social interactions. In contrast to the work of Silveira, the blended intervention described in this study is designed to extend existing community-based programs that rely on weekly face-to-face classes. Therefore, the proposed intervention can rely on social relations that are already in place.

As noted by Khaghani-Far et al [26], the present computer-generated support, mostly in the form of a virtual coach, is not capable of replacing the emotional support provided by a human coach. The contribution of our work is the demonstration of how PA in older adults can be stimulated by a blended approach. To our knowledge, only 1 prior study had combined the benefits of a face-to-face exercise program to the possibilities of mHealth. Lee et al [51] provided older adults with a tablet which they used for doing home-based exercises 3 times a week during a period of 8 weeks, in conjunction with weekly group-based exercises. Although participants showed an increase in motivation, no difference in physical functioning was observed. As suggested by the authors, a reason for this absence might be the limited number of participants in the trial (N=26) and the short duration of the study.

Limitations

The ability for older adults to draw up a personal training schedule is a key element of the design. Users can choose from a library containing approximately 50 different functional exercises. Furthermore, the duration, number of repetitions, and the intensity level of each exercise can be manipulated, amounting to roughly 500 unique exercise variations. Despite the ability to personalize the exercise program in great detail, there are still limitations to the tailoring. Older adults with specific limitations will not be able to perform some exercises in the manner demonstrated in the app or they may prefer outdoor activities above the home-based functional exercises (ie, taking a walk, riding a bike, gardening, etc). The variation in individual preferences is virtually unlimited. To accommodate this, the app was designed with the ability to add user-defined activities to the personal training schedule. The app allows the user to plan, monitor, and evaluate those exercises but does not contain instructions or video demonstration. The support for user-defined exercises is therefore somewhat limited.

Another key element of the design is the ability to receive remote feedback from a coach. As pointed out, the support by a human is more rich and effective than computer-generated feedback. There is, however, also a drawback. To be effective, feedback needs to be timely. Automated feedback can be near instant. In contrast, depending on the availability of the coach, older adults will have to wait some time to receive personal feedback.

A final limitation is the need for validation. The work presented here is ongoing. In line with the MRC framework, the developed intervention has to be validated rigorously by feasibility and effectiveness studies. First, older adults were involved

during the development of the intervention—initially by conducting focus groups to explore their attitudes toward a blended intervention and afterwards to pilot the exercises and tablet use. Due to practicalities, however, the exercises and tablet use were evaluated separately. Older adults that participated in the evaluation of the tablet focused on the usability of the app; they did not actually perform the exercises. In contrast, the older adults that evaluated the exercises did so without the support of a tablet. Thus, how users perform exercises at home supported with a tablet still needs to be addressed with a more extensive usability study.

Second, the effectiveness of the theoretically underpinned intervention has yet to be empirically determined. During the next phase of the study, an RCT will cast light on to which extent the intervention leads to increased adherence and health benefits in the long run. This will extend the findings of Lee et al [51] by testing the blended intervention among a sufficiently large number of older adults (N=240) for a 12-month period. In addition, the RCT will investigate how the effects of the exercise program can be reinforced by dietary intake [27].

Conclusions

In summary, an evidence-based blended intervention was designed to promote PA amongst older adults. The underlying design choices are underpinned by behavior change techniques that are rooted in self-regulation. Key components of the tablet-supported intervention are a tailored program that accommodates individual needs, demonstrations of functional exercises, (self-)monitoring, and remote feedback. The blended approach combines the convenience of a home-based exercise program for older adults with the strengths of mHealth and personal guidance.

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4

Supporting Older Adults in Exercising With a Tablet: A Usability Study

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Abstract

Background: For older adults, physical activity is vital for maintaining their health and ability to live independently. Home-based programs can help them achieve the recommended exercise frequency. An application for a tablet computer was developed to support older adults in following a personal training program. It featured goal setting, tailoring, progress tracking, and remote feedback.

Objective: In line with the Medical Research Council Framework, which prescribes thorough testing before evaluating the efficacy with a randomized controlled trial, the aim of this study was to assess the usability of a tablet-based app that was designed to support older adults in doing exercises at home.

Methods: A total of 15 older adults, age ranging from 69 to 99 years old, participated in a usability study that utilized a mixed-methods approach. In a laboratory setting, novice users were asked to complete a series of tasks while verbalizing their ongoing thoughts. The tasks ranged from looking up information about exercises and executing them to tailoring a weekly exercise schedule. Performance errors and time-on-task were calculated as proxies of effective and efficient usage. Overall satisfaction was assessed with a posttest interview. All responses were analyzed independently by 2 researchers.

Results: The participants spent 13-85 seconds time-on-task. Moreover, 79% (11/14)-100% (14/14) participants completed the basic tasks with either no help or after having received 1 hint. For expert tasks, they needed a few more hints. During the posttest interview, the participants made 3 times more positive remarks about the app than negative remarks.

Conclusions: The app that was developed to support older adults in doing exercises at home is usable by the target audience. First-time users were able to perform basic tasks in an effective and efficient manner. In general, they were satisfied with the app. Tasks that were associated with behavior execution and evaluation were performed with ease. Complex tasks such as tailoring a personal training schedule needed more effort. Learning effects, usefulness, and long-term satisfaction will be investigated through longitudinal follow-up studies.

Introduction

Physical Activity Interventions for Older Adults

Physical activity is vital for a healthy life. A sedentary lifestyle is associated with numerous health-related problems such as obesity, diabetes, cardiovascular diseases, various forms of cancer, and depression [1,2]. Furthermore, for older adults, physical activity can prevent or delay the onset of functional impairments and prolong the ability to live independently [3]. Provided by these well-acknowledged health benefits, community-based physical activity programs have spawned across the world [4,5]. A prototypical example of such a program that has been running for over 35 years in the Netherlands is "More Exercise for Seniors" ("*Meer Bewegen voor Ouderen*," abbreviated as MBvO in Dutch). Weekly, 400,000 older adults exercise in a group under the guidance of an instructor. Despite the popularity of this program, however, its effects on physical health appear to be insufficient [6]. In particular, studies show a need for higher frequency and longer exercise duration to capitalize on the health benefits of physical activity [7,8].

To achieve the recommended frequency and duration, a home-based exercise program could prove a useful addition to a community-based program such as MBvO. With the convenience of their home, older adults can continue the exercises they have learned during the weekly community classes. A focus-group study showed that the MBvO participants believed additional home exercises would be useful but also had worries about the safety, self-efficacy, and adherence to such an intervention [9].

Technology Use

Mobile health (mHealth), that is, the use of mobile devices and wireless technology for medical and health practices [10], is increasingly being used to attain health goals, for instance, increasing physical activity, weight loss, stress reduction, or chronic disease management like diabetes. In 2017, over 325,000 health apps were available for the general public through the various app stores [11]. Health professionals, policy makers, and researchers recognize the opportunity to reach a large audience through developing technology-enhanced interventions for various target populations and health outcomes. Increasing physical activity in older adults is one of such intended health outcomes [12-16]. In contrast to popular belief that older adults are not inclined to use technology, the ownership of tablet computers among older adults is growing rapidly [17-19]. The popularity of tablets

stems possibly from its usability. Studies show that older adults are able to operate tablets better than personal computers [20,21] or smartphones owing to their large touchscreen [22]. It is not surprising that recent health interventions for older adults choose tablets as the primary mode of delivery [23-27].

Development of a Tablet-Based Intervention

To increase the physical activity in older adults and capitalize on the potential of mHealth, a technology-enhanced intervention was developed as part of the Motivating Technology for Older Adults' Behavior (MOTO-B) and VITal Amsterdam elderly IN the city (VITAMIN) projects. The aim of these projects was to develop an mHealth intervention that can be used in conjunction with existing community-based exercise programs. By supporting older adults to perform exercises at home as well, it helps them to achieve the recommended exercise duration and frequency [7,8].

To develop the intervention, the Medical Research Council (MRC) framework was used [28,29]. This framework describes the process of developing, pilot-testing, assessing the effectiveness, and implementing complex health interventions. As part of the development stage, focus groups were conducted with prospective users, and relevant literature was identified, which led to 3 design considerations [9,30]. First, physical activity should be supported by functional exercises that can be executed safely within a home environment. Second, to facilitate behavior change, the intervention should support self-regulation. Third, a blended approach allows the convenience of a home-based exercise program and the ability to tailor the intervention to individual needs to be combined with the effectiveness of rich feedback and social support.

These design considerations were implemented in a tablet-based app called VITAMIN that delivered a home-based exercise program in conjunction with coaching. Key components were goal setting, the ability to tailor the program to individual needs, video demonstration of functional exercises, rating of exercises, and progress tracking and feedback of a personal coach that could remotely monitor performance. See Mehra et al. [30] for a detailed account of how behavior change principles were translated into the blended intervention.

Prior to evaluating the efficacy of the intervention in terms of health outcomes, the feasibility should be assessed. This stage is often overlooked, leading to efficacy studies of interventions that have not matured yet and problems that could have

been prevented with sufficient pilot testing [29]. Usability issues are one of the key factors that determine the success of mHealth interventions [31,32]. Usability is defined as the extent that devices can be operated by users to achieve the specified goals with effectiveness, efficiency, and satisfaction in a specified context of use [33]. In line with the feasibility stage of the MRC framework, this study sets out to investigate the usability of the tablet-supported intervention. The aim was to assess whether first-time users could operate the VITAMIN app that was designed to support older adults in doing home-based exercises. First-time users are older adults that have no prior experience of using the app.

Methods

Study Design

Zapata et al [32] conducted a systematic review on how the usability of mHealth apps is being evaluated. The majority of the studies use either interviews or questionnaires to investigate usability. These methods rely on self-report of prospective users after having used the device. These methods are suitable to gauge user satisfaction but in lesser degree effectiveness and efficiency. In contrast, other studies investigate the usability by observing users as they try to complete prescribed tasks on the device. This method is a reliable estimate of effectiveness and efficiency but not user satisfaction. Combining various methods to evaluate usability is therefore the recommended approach, although only a few studies do so [32].

This study used mixed methods to investigate the usability of the VITAMIN app. To evaluate effectiveness and efficiency, user performance was recorded and assessed as they executed tasks in a laboratory setting. Satisfaction was evaluated by asking the participants to “think aloud” during the execution of tasks. This is a common technique used in usability studies where users are requested to verbalize their ongoing thoughts as they execute a task [34]. After performing the tasks, participants were interviewed about their overall impression of the app.

Participants

A total of 15 older adults, 4 men and 11 women, were recruited from local community centers that offer weekly exercise programs. Inclusion criteria were that the participants be at least 55 years old, living independently at home, and taking part in the weekly exercise classes offered by the community center. Exclusion criteria were mental or physical health conditions that could prevent them of operating a

tablet, such as the presence of tremors or cataract. Both the inclusion and exclusion criteria match those of a future randomized controlled trial (NTR5888) and the intended implementation of the intervention as an addition to existing community-based exercise programs [35].

Materials

Tablet Application

The app was designed for a 10-inch Android tablet. The main functions of the VITAMIN app were delineated by 5 distinct tabs in the home screen: (1) Exercises, (2) Profile, (3) Weekly Schedule, (4) Today, and (5) Video Calling. Exercises is a library that contained 16 functional exercises, designed by human movement scientists, that were devised to be executed in a home setting with ordinary household objects as aids. Each exercise consisted of 3 versions that varied in difficulty. For each variation, a custom-made video with a voiceover was shot (48 in total) that depicted how the exercise could be executed safely (modeling). The video was accompanied by a factsheet that contained background information about the exercise (Figures 1 and 2). *Profile* is the possibility to formulate personal goals and a step-by-step wizard that helped users to set up a weekly schedule with suitable exercises (goal setting & tailoring). *Weekly Schedule* is an overview with icons depicting which exercises were planned for each day of the week (Figure 3). Users could checkmark exercises that had been performed and see, in a glance, what still had to be done (progress tracking). *Today* is a reel of exercises that were planned for that day. To aid the execution, a countdown timer depicted the remaining seconds. Prior to the execution, the user could customize each exercise using 3 parameters: the duration of the exercise, the amount of repetitions of the exercise, and the difficulty level (Figures 4-6). After the completion of each exercise, the user could rate the exercise using 3 scales on difficulty, effort, and fun (Figure 7). *Video Calling* is the option to video call an appointed coach that could motivate and assist the user from distance (motivational interviewing). This coach could also remotely monitor the weekly schedule and the user ratings of each exercise (Figure 8).

The typical use of the app would be exploring the available exercises (1) and setting personal goals (2) during the initial use. The Weekly Schedule (3) and Today (4) tabs are used on a daily basis to assist users in performing their scheduled exercises. Finally, the Video Calling (5) tab is to be used when users want to evaluate and discuss their progress with their personal coach.

Figure 1. Exercise Library.

Figure 2. Selecting An Exercise Variation.

Figure 3. Personal Training Schedule.

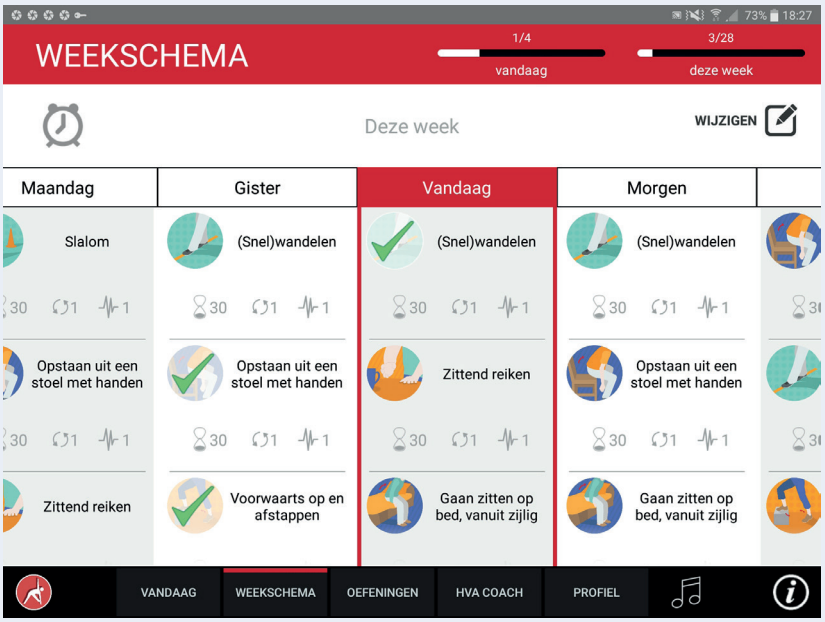


Figure 4. Today's Program.

Figure 5. Modifying Execution Parameters.

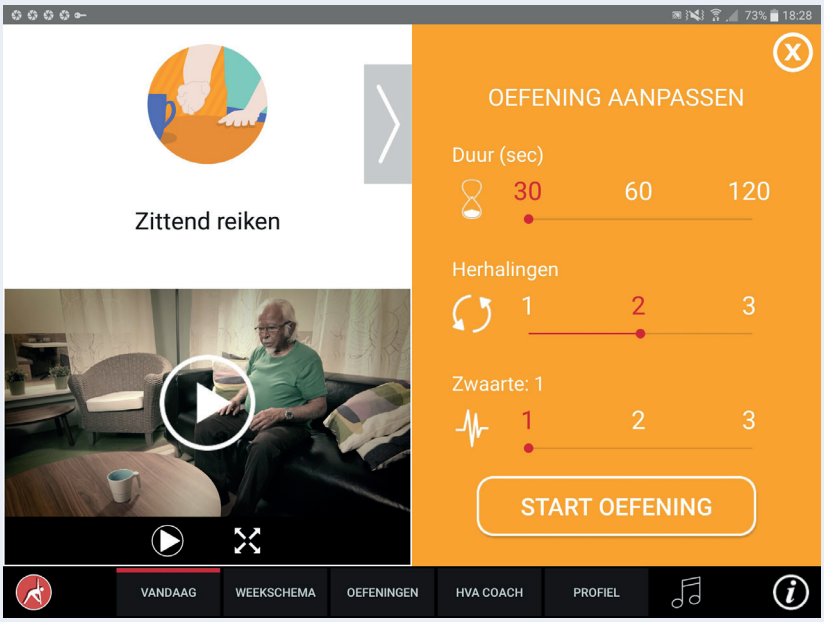


Figure 6. Countdown Timer During Executing.

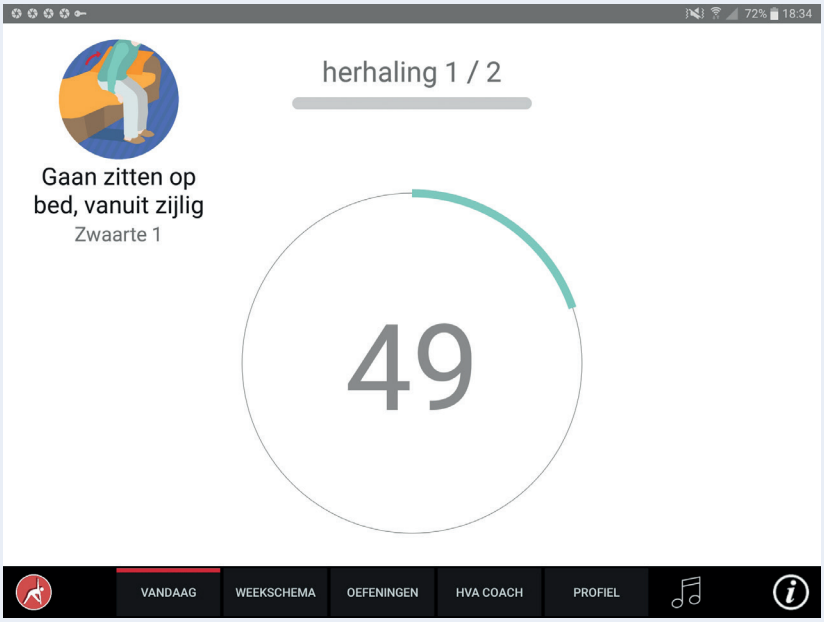


Figure 7. Rating An Exercise.

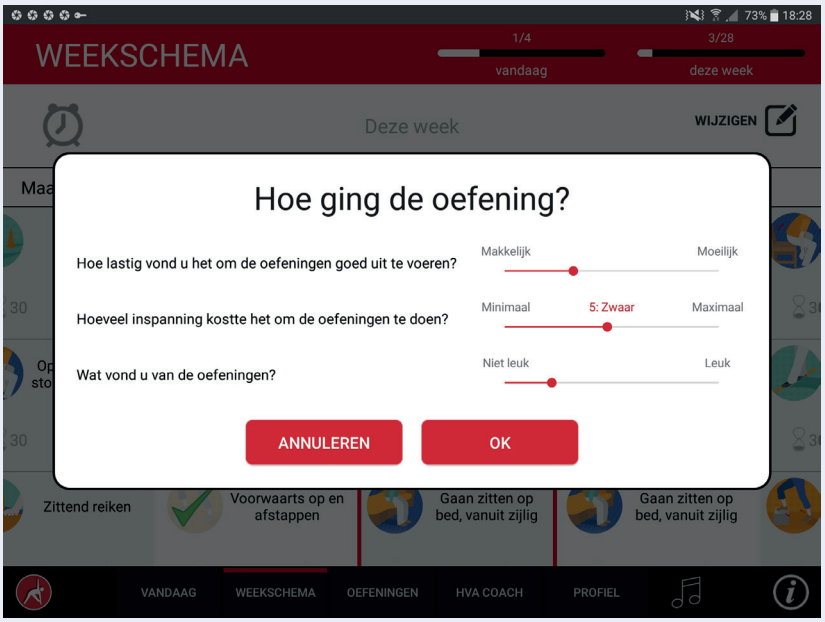
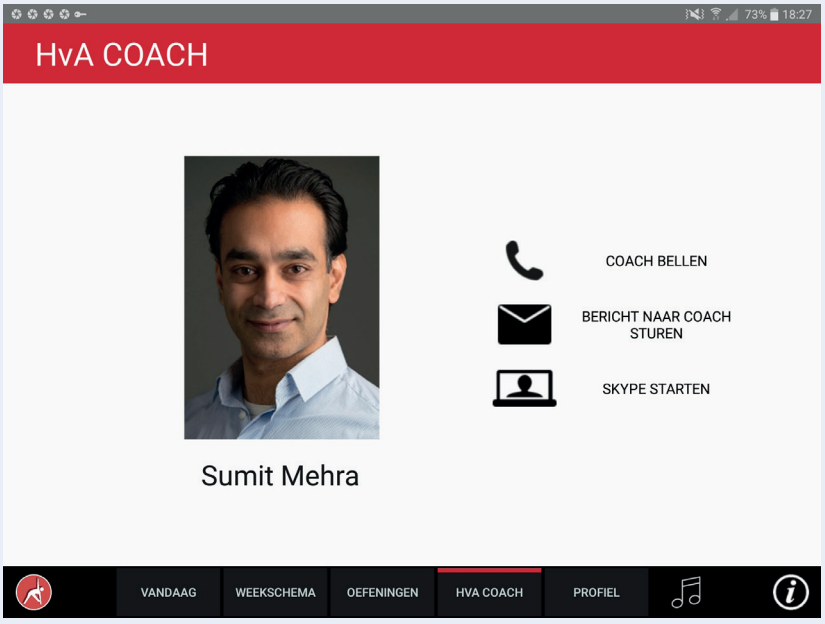


Figure 8. Initiating Video Call To Coach.



Textbox 1. Description of the Tasks That Were Performed By the Participants.

Today

- Today1: Execute the exercises that are scheduled for today. Adjust the duration to 10 seconds and set the repetition to 1.
- Today2: After completing an exercise, rate the difficulty, effort and fun using three scales.
- Today3: Find and watch the instructional video of exercise X.
- Today4 (expert): During the execution of an exercise, pause the countdown timer.

Weekly Schedule

- Schedule1: Look up which exercises are planned for Friday.
- Schedule2: Add an exercise to your weekly schedule that will increase your capacity to pick up objects from the floor.
- Schedule3: In the weekly schedule, remove exercises so that the maximum exercises for that day is three.
- Schedule4: Set an alarm so that you will get a daily reminder at 12.00.
- Schedule5 (expert): Yesterday you forgot to mark your exercises as completed. Do this in retroaction.

Exercises

- Exercise1: Look up information about exercise X.
- Exercise2 (expert): Study the different variations of exercise X.

Video Calling

- Video1: Make a video call to your coach.

Usability Tasks

In order to test typical scenarios for novice users that have no to little experience using the app, a series of basic tasks were defined. The tasks were grouped around the 4 tabs: Exercise, Today, Weekly Schedule, and Video Calling described above. The Profile tab could not be tested because it was still in development at the time. The basic tasks were designed with the novice user in mind. Three additional "expert tasks" were added to the testing procedure as a "back-up option" in case participants completed the basic tasks early. The expert tasks were defined as tasks that would be indicative for advanced users that have been using the app for an extended period of time (see Textbox 1 for a description for the basic and expert tasks that were tested).

Procedure

Participants were received in the usability lab of the university by an experimenter and an assistant. After signing an informed consent document and receiving a short verbal introduction, they were seated behind a desk. The participants were instructed to think aloud as they performed each task. If needed, they were encouraged to do so by asking "what do you see?" or "what are you trying to achieve?" during the experiment. If participants were stuck during the execution of a task, they were given a verbal hint by the experimenter after 30 seconds, for instance "the button you are looking for can be found in the top left-hand corner." In this manner, the

participant could continue with the rest of the task.

After practicing the procedure with a trial run, they were asked to perform the tasks as described in Textbox 1. The order of the tasks was fixed in principle, but some tasks were skipped if the experimenter felt this was appropriate. Occasionally, some participants deviated from the goal and explored the functions of the app. In some cases, this situation made certain future tasks irrelevant. For instance, if a participant already deliberately removed exercises from the weekly schedule during the task Schedule2, performing Schedule3 was skipped for that specific participant. Furthermore, the expert tasks were given only to the participants whose pace was high and when the experimenter believed that the participant would be able to complete all the tasks within the allocated time.

After completing the tasks, the tablet was put aside and the participants were shortly interviewed about their general impression of the app. The sessions lasted 45 minutes in total and were video recorded. Furthermore, the user's interaction with the tablet was recorded by screen capture software.

Data Analysis

All recordings were transcribed and coded using software for qualitative analysis (MaxQDA). Two researchers independently coded 4 metrics of the aggregated dataset:

1. Time-on-task: the average time the participants spent on executing a task.
2. Hints: the average number of hints that were given during the execution of a task.
3. Success rate: the proportion of participants that completed the task successfully without any hints, completed the task successfully with hints, and could not complete the task.

   Errors: the average amount of errors that were made by participants during the execution of a task. A distinction was made between the following: strategy errors: not knowing how to approach the task (eg, not knowing how to add exercises to the weekly schedule); interaction errors: not knowing how to execute the strategy (eg, unable to find the play button); and operating errors: being unable to operate the device (eg, swiping).

Furthermore, the remarks of the participants during the execution of a task (think-aloud protocol) and posttest interview were classified as either positive, neutral,

negative, or a suggestion for improvement.

After both coders annotated the data independently, they compared the results. Differences were resolved via discussion. If no consensus was achieved, the first author settled the rare dispute.

Results

Participant Characteristics

The ages of the 15 participants varied from 69 to 99 years old with an average of 77 years (SD 8.5). The majority indicated they had no prior experience operating a tablet.

Time-on-Task, Success Rate, and Satisfaction of Basic Tasks

The results of 1 participant were excluded from the study because she turned out to be insufficient in Dutch to understand the assigned tasks, and her responses could not be coded reliably. The remaining participants spent 13-85 seconds time-on-task for the basic tasks that were indicative for novice users. Depending on the task, 79% (11-14)-100% (14/14) of the participants completed the tasks successfully with either no help or after having received 1 hint.

Despite the fact that the tasks could be completed successfully by the majority of the participants, their performance varied greatly across different tasks. Executing an exercise (Today1), watching an instructional video (Today3), and video calling a coach (Video1) were conducted relatively easy, as demonstrated by the high success rate without any help. In contrast, adding an exercise to the weekly schedule (Schedule2) appeared to be a more difficult task, indicated by the relatively high failure rate (see Table 1 for the average time-on-task, amounts of hints given, and success rate for the basic tasks). The type of errors that were made ranged from strategy and interaction errors to operating errors (Table 2).

Table 1. Number of Participants Who Performed the Task (N), Average Time-on-Task, Number of Hints Given and Success- and Failure Rates for Basic Tasks.

Basic task	Participants, n	Time-on-task (s)	Hints	Success without hints, n (%)	Success with hints, n (%)	Failure, n (%)
Today1	14	78	1.0	10 (71)	3 (21)	1 (7)
Today2	14	59	0.9	6 (43)	8 (57)	0 (0)
Today3	12	20	0.8	7 (58)	4 (33)	1 (8)
Schedule1	12	33	0.8	5 (42)	5 (42)	2 (17)
Schedule2	14	85	0.9	2 (14)	9 (64)	3 (21)
Schedule3	11	60	0.9	0 (0)	10 (91)	1 (9)
Schedule4	13	85	1.1	6 (46)	6 (46)	1 (8)
Exercise1	13	19	0.8	6 (46)	6 (46)	1 (8)
Video1	11	13	1.1	6 (55)	5 (45)	0 (0)

Table 2. Number of Participants Who Performed the Task (N), and the Average Number of Errors Made for Basic Tasks.

Basic task	Participants, n	Strategy errors	Interaction errors	Operation errors
Today1	14	0.8	0.2	0.4
Today2	14	0.2	0.0	0.5
Today3	12	0.0	0.2	0.2
Schedule1	12	0.4	0.1	0.0
Schedule2	14	0.5	0.5	0.7
Schedule3	11	0.5	0.5	0.4
Schedule4	13	0.4	0.4	0.1
Exercise1	13	0.8	0.0	0.2
Video1	11	0.1	0.0	0.0

In addition to task performance, the satisfaction per task was assessed with the think-aloud protocol. The majority of the basic tasks elicited more positive remarks than negative remarks during the execution (see Table 3 for the type of remarks per task). Participants were most positive about performing the daily exercises from the Today tab (Today1). This task elicited 3 times more positive remarks than negative remarks. Examples are “I think this is great. A short break. A[n] interval,” “…yes, very easy,” and “…this is very convenient” or “it is quite orderly.” In contrast, the participants were not enthusiastic about looking up information in the Exercise library (Exercise1). During this task, participants could read background information about an exercise. This task elicited 2 times more negative remarks than positive remarks. Examples are “I think this is a lot of text” or “…this is not of much use.” The

suggestions made by the participants were "...look, you call it domain. I would use a different term for this" or "I think the text should be shorter." Also, for watching an instructional video (Today3), participants had several suggestions about enlarging the video to full screen, for example, "enlarging with two fingers would be useful" or "a different symbol for enlarging the video would perhaps be better."

Table 3. The Number of Participants Who Performed the Task (N) and the Total Number of Remarks Evaluated As Either Positive, Negative, Neutral, Or A Suggestion for Basic Tasks.

Basic task	Participants, n	Positive	Negative	Neutral	Suggestions
Today1	14	18	6	2	1
Today2	14	3	1	3	0
Today3	12	8	4	0	5
Schedule1	12	1	2	1	0
Schedule2	14	3	1	1	1
Schedule3	11	3	1	0	3
Schedule4	13	9	9	0	7
Exercise1	13	4	8	1	8
Video1	11	3	2	0	2

Time-on-Task, Success Rate, and Satisfaction of Expert Tasks

Besides the basic tasks, a few participants also completed the expert tasks. The time-on-task varied from 14 to 58 seconds. The success rate varied from 75% to 100%. As could be expected, more hints were needed to complete the tasks successfully compared with the basic tasks described earlier. Marking an exercise retroactively as completed, which required the participant to tap and hold down for a certain amount of time, proved to be an especially difficult task. This task had the highest time-on-task, failure rate, and errors. The verbal remarks of the participants indicated that they appreciated the possibility of retroactively marking exercises as complete but found its operation difficult (see Tables 4 and 5 for details of the expert task performance; see Table 6 for the type of remarks per task).

Table 4. Number of Participants Who Performed the Task (N), Average Time-on-Task, Number of Hints Given, and Success and Failure Rates for Expert Tasks.

Expert task	Participants, n	Time-on-task (s)	Hints	Success without hints, n (%)	Success with hints, n (%)	Failure, n (%)
Today4	4	14	3.5	2 (50)	1 (25)	1 (25)
Schedule5	8	58	1.5	1 (13)	5 (63)	2 (25)
Exercise2	4	18	3.5	1 (25)	3 (75)	0 (0)

Table 5. Number of Participants Who Performed the Task (N) and Average Number of Errors Made for Basic Tasks.

Expert task	Participants, n	Strategy errors	Interaction errors	Operation errors
Today4	4	0.0	0.5	0.0
Schedule5	8	0.4	0.4	0.6
Exercise2	4	0.8	0.0	0.0

Table 6. The Number of Participants Who Performed the Task (N) and the Total Number of Remarks Evaluated As Either Positive, Negative, Neutral, Or A Suggestion for Expert Tasks.

Expert task	Participants, n	Positive	Negative	Neutral	Suggestions
Today4 (expert)	4	5	1	0	0
Schedule5 (expert)	8	3	2	1	2
Exercise2 (expert)	4	1	1	0	1

Overall Satisfaction

During the posttest interview, the participants were overall positive; 31 positive remarks were made against 10 negative remarks. The number of participants in the posttest interview (n) was 14. In this interview, 31 remarks were validated as positive, 10 as negative, 10 as neutral, and 22 as suggestions. Typical positive remarks were "Nice. I found easy to operate and fun," "it was pretty clear and straightforward," and "it's nice to do different exercises now and then." Examples of negative remarks were "I am not sure if I would use this app, because it seems to me as an invasion of privacy if every time you have to enter what you have done" or "it wasn't always clear." The participants also made several suggestions, often in the line of giving more extensive instructions prior to the first use. A typical remark was "maybe you could provide some more information. Like it works so and so. Perhaps a manual or something." This bore relevance to the brief verbal introduction they received about the app.

Discussion

Principal Findings

Overall, the app that was designed to support older adults in doing exercises at home appears to be usable for first-time users. After a brief introduction, the vast majority of the participants could complete the assigned tasks. They did this not only effectively (as indicated by the high success rate) but also efficiently. Mostly within 1-2 minutes, they successfully performed the tasks. Furthermore, the think-aloud remarks and posttest interview revealed that the users were satisfied with the app in general.

The performance varied from task to task. Basic tasks that were associated with supporting behavior execution (Today and Exercise) and evaluation (Video Calling) were completed successfully by the majority of the participants, whereas tasks that were associated with tailoring (Weekly Schedule) were more difficult for the users, as indicated by the longer task completion times and higher rate of errors.

The fact that the older adults in this usability study needed some minor help with performing the assigned tasks is not considered to be a major issue by the authors. First of all, the average age of the participants was 77 years old. The majority had never operated a tablet before and only received a short introduction of a few minutes before they had to perform the assigned tasks under the scrutiny of 2 observers. Observer effects and the think-aloud protocol are known to decrease performance for complex tasks in usability studies [36-38]. It is plausible that the participants would have performed better in the privacy of their own home where they feel more free from prying eyes. Second, the expert tasks were developed with an experienced "power user" in mind. It was designed in an unobtrusive manner not to clutter the interface for first-time users. Therefore, it was not surprising that the participants in the study, as first-time users, had more difficulties executing those tasks. Third, the app is designed to be implemented in a blended intervention in which a coach will be appointed. This coach will give hands-on support, face-to-face and remotely. Thus, in this particular case, receiving help to operate the app is not an artefact of the usability study but reflects the actual context of use.

Limitations and Future Work

The app is part of a blended intervention in which older adults participate in weekly group-based classes, perform tablet-supported exercises at home, and receive

feedback by a personal coach. This study only evaluates if the app that is part of the blended intervention is usable for older adults. It does not evaluate other aspects of the intervention. Furthermore, the usability study was conducted in a lab where users interacted with the app for a short period of time. It provides an indication of the usability for first-time users but not for long-term users. Learnability and user acceptance can only properly be studied when older adults have used the app for an extensive period of time. To investigate these matters, follow-up studies are planned. A randomized controlled trial will evaluate the efficacy of the blended intervention in terms of health outcomes [35]. Parallel to this randomized controlled trial, participants that have been using the app for 6 to 12 months will be questioned about the perceived usefulness, ease of use, learnability, and satisfaction on the long term [39]. To optimize reliability and validity, both questionnaires and interviews will be used.

Conclusion

In line with the MRC framework, an evidence-based blended intervention was developed to support older adults in performing functional exercises at home. The feasibility of the tablet-based app that was designed for this purpose has been validated by a usability study with mixed methods. Older adults were able to use the app in an effective and efficient manner. They were mostly also satisfied with the app. These findings pave the way to implement and evaluate the intervention in practice.

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5

Evaluation of a Blended Physical Activity Intervention for Older Adults: Mixed Methods Study

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Abstract

Background: Physical activity can prolong the ability of older adults to live independently. Home-based exercises can help achieve the recommended physical activity levels. A blended intervention was developed to support older adults in performing home-based exercises. A tablet and a personal coach were provided to facilitate the self-regulation of exercise behavior.

Objective: In line with the Medical Research Council framework, this study aimed to carry out process evaluation of a blended intervention. The objectives were (1) to assess the long-term usability of the tablet adopted in the blended intervention and (2) to explore how the tablet, in conjunction with a personal coach, supported older adults in performing home-based exercises.

Methods: The process evaluation was conducted with a mixed-methods approach. At baseline, older adults participating in the blended intervention were asked to fill out a questionnaire about their general experience with information and communication technology (ICT) devices and rate their own skill level. After 6 months, participants filled out the Usefulness, Satisfaction, and Ease of use (USE) questionnaire to assess the usefulness, satisfaction, and ease of use of the tablet. With a random selection of participants, in-depth interviews were held to explore how the tablet and coach supported the self-regulation. The interviews were double coded and analyzed with the directed content analysis method.

Results: At baseline, 29% (65/224) of participants who started the intervention (mean age 72 years) filled out the ICT survey and 36% (37/103) of participants who used the tablet for 6 months (mean age 71 years) filled out the USE questionnaire. Furthermore, with 17% (18/103) of participants (mean age 73 years), follow-up interviews were held. The results of the baseline questionnaire showed that the large majority of participants already had experience with a tablet, used it regularly, and reported being skillful in operating ICT devices. After 6 months of use, the participants rated the usefulness, satisfaction, and ease of use of the tablet on average as 3.8, 4.2, and 4.1, respectively, on a 5-point scale. The analysis of the interviews showed that the participants felt that the tablet supported action planning, behavior execution, and self-monitoring. On the other hand, especially during the first few months, the personal coach added value during the goal setting, behavior execution, and evaluation phases of self-regulation.

Conclusions: The results of the process evaluation showed that older adults who participated in the study were positive about the blended intervention that was designed to support them in performing home-based exercises. Participants reported that the tablet helped them to perform the exercises better, more frequently, and safely. It supported them in various phases of self-regulation. The availability of a personal coach was nevertheless crucial. To support physical activity in older adults, a blended approach is promising.

Introduction

Background

As people age, they face a decline in daily functioning and mobility [1,2]. Physical activity can delay the onset and slow the decline associated with aging [3,4]. Older adults who exercise on a regular basis can prevent impairments and remain self-reliant for a longer period of time [5,6]. Accordingly, various community centers around the world offer senior citizens the opportunity to participate in group-based exercise classes under the guidance of an instructor [7-9]. For instance, in the Netherlands, over 400,000 older adults participate in the weekly activities of "More Exercise for Seniors" ("*Meer Bewegen voor Ouderen*," which is abbreviated as MBvO in Dutch). Despite the popularity of this program, its effects on physical health are limited. A previous study has shown that older adults who participate once a week in the exercise classes, do not achieve a higher health-related quality of life or an increased ability to perform daily tasks [10]. In order to capitalize on the health benefits of physical activity, the frequency, intensity, and duration of exercises have to be sufficient [9,11].

Older adults can increase the level of physical activity by doing exercises at home, either as an independent program or in conjunction with group-based classes [12-16]. The latter approach combines the motivational aspects of exercising along with peers with the flexibility of a home-based exercise program that is tailored to individual needs. However, in the absence of an instructor, older adults may have adherence and safety concerns about home-based exercises [17]. The use of mobile technology (mobile health [mHealth]) can help overcome these issues by providing detailed instructions, offering tailored programs, and tracking progress [18-23] for individuals, including older adults [24,25].

Development of a Blended Intervention

In order to enhance community-based exercise programs like MBvO, a blended intervention was developed as part of the MOTO-B (Motivating Technology for Older Adults' Behavior) and VITAMIN (VITal AMsterdam older adults IN the city) research projects. The aim of the intervention was to support older adults in performing home-based exercises. In line with the self-determination theory [26,27], the intervention was conceived to increase competence and stimulate the autonomy of older adults, but at the same time, to maintain relatedness with peers [17]. The intervention consisted of a home-based exercise program that was supported by

a tablet and a personal coach, and could be followed alongside community-based exercise programs or other sport activities.

Objective

According to the UK Medical Research Council (MRC), complex interventions need to be evaluated systematically [28]. Three different types of evaluations can be distinguished as follows: (1) assessing the feasibility, (2) assessing the effectiveness, and (3) understanding the underlying change process.

First, prior to assessing effectiveness, feasibility should be investigated thoroughly. For the blended intervention described here, a previous usability study that was conducted in a laboratory showed that older adults (age ranging from 69 to 99 years) who used the app for the first time during a 45-minute session could operate it without any relevant problems [29], suggesting that the blended intervention is feasible. However, a more thorough evaluation is needed to account for the long-term use in a real-world setting. The usability of mHealth apps is often not tested sufficiently, thereby limiting their effectiveness [30,31].

Second, the effectiveness of a complex intervention can be assessed with randomized controlled trials (RCTs). To assess the effectiveness of the blended intervention in terms of health outcomes, a trial study is currently ongoing and will be reported in the future elsewhere [32].

Third, an explorative process evaluation can provide insights into the underlying change process. By exploring the mechanisms of action, a process evaluation is a valuable extension of effectiveness studies. The aim of this study was to conduct such an evaluation. The objectives were as follows: (1) to assess the long-term usability of the tablet in a real-world setting and (2) to explore how the tablet, in conjunction with a personal coach, supported older adults in performing home-based exercises.

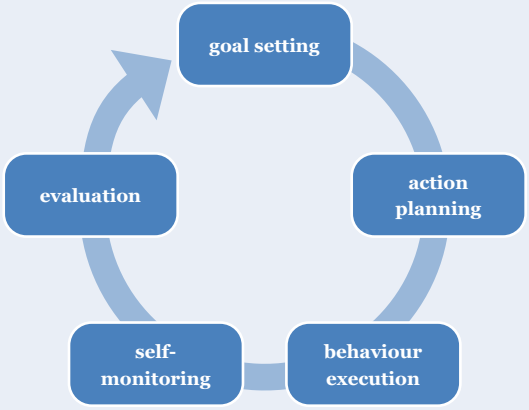
Methods

Intervention

The intervention consisted of two components to support older adults in performing exercises at home. The first component was the tablet containing a custom-developed app that was designed to ensure behavior change by facilitating self-regulation. Self-regulation is the process of consciously guiding one's own behavior

in order to achieve goals. In particular, behavior change techniques that support goal setting, action planning, behavior execution, self-monitoring, and evaluation appear to be important for the self-regulation of behavior [33-35]. Figure 1 presents a schematic representation. The app supported self-regulation by allowing older adults to set goals, tailor a weekly schedule to their individual needs, and watch video instructions. It also tracked their progress and facilitated remote guidance by a personal coach. An elaborate description of the app and its theoretical underpinning have been presented previously [36].

Figure 1. Behavior Change Through Self-Regulation.



The second component of the intervention was counselling. Each participant was appointed a personal coach. The coach paid house visits, helped the participants to get acquainted with the tablet, and counselled, either remotely or face-to-face, the participants in setting up and following the tailored exercise schedule. The coaches were third- and fourth-year physical therapy bachelor students. Prior to taking on their responsibilities, the coaches received a 2-week training on functional exercises, good clinical practice, and e-coaching by faculty staff members. Furthermore, during their 6-month internship, they received weekly supervision from faculty staff members. When the responsibilities of a coach ended at the end of a teaching semester, ongoing cases were transferred to a new coach. As a result, participants received in sequence counselling by two personal coaches during a 6-month period. The complete details of the intervention have been reported previously [32].

Study Design and Participants

An RCT was conducted to assess the effectiveness of the blended intervention in terms of health outcomes. Older adults were recruited from the surroundings of Amsterdam, the Netherlands, through postal mailing and local community-based centers offering weekly exercise programs. Applicants were included in the trial if they met the following criteria: (1) age 55 years or older, (2) ability to understand the Dutch language, and (3) absence of specific cognitive or physical impairments. The protocol that describes the RCT has been published, including detailed methods, inclusion criteria, measurement procedures, and interventions [32].

To increase the fidelity of the trial, an additional nested mixed-methods study was set up (described in this paper) by administering questionnaires to the participants who received a tablet and coaching, as well as conducting follow-up interviews among a random selection of those participants [37].

Measurements

Before commencing the intervention, at baseline, the trial participants filled out a three-item questionnaire about their general experience with information and communication technology (ICT) devices, such as computers, smartphones, and tablets. To assess the long-term usability of a tablet (objective 1), after 6 months, participants who received a tablet were asked to fill out a usability questionnaire that was based on the Usefulness, Satisfaction, and Ease of use (USE) questionnaire [38]. The first part of the questionnaire consists of 23 items (Likert) that measure the following three components of usability: usefulness, satisfaction, and ease of use. Each item consists of a statement with the following five response options: strongly disagree, disagree, neither agree or disagree, agree, and strongly agree. The second part of the questionnaire contains three general questions about tablet use in the past 6 months, whether participants would recommend the tablet to friends, and an item participants could use for general remarks. All questionnaires were administered by paper and pencil in the Dutch language.

Furthermore, to explore how the tablet, in conjunction with the coach, supported the self-regulation of exercise behavior (objective 2), 18 participants were randomly selected for an in-depth interview. The interview questions were previously piloted among two participants. The interviews were conducted in a home setting, were held in Dutch, and lasted for about 45 minutes. All interviews were recorded.

Analysis

The questionnaires were processed with double-entry verification. For usefulness, satisfaction, and ease of use, separate mean scores were calculated. The mean scores could range from 1 (very low) to 5 (very high). The interviews were transcribed verbatim and subsequently double coded by two researchers. The directed content analysis method was used to explore how the participant's experience related to the five key constructs of self-regulation that the intervention was based upon (goal setting, action planning, behavior execution, self-monitoring, and evaluation). Directed content analysis was deemed more appropriate than conventional content analysis, because of the focus on existing theoretical constructs [39-41]. To minimize differences in interpretation, first calibration sessions were held. Subsequently, both researchers coded all the transcripts independently with the key constructs of self-regulation and then compared the results. Differences were resolved via discussion. In the rare case no interrater consensus was reached, the first author settled the dispute.

Results

Questionnaire About ICT Experience and Skills

In total, 224 older adults with a mean age of 72 years (SD 7 years; 71% female) participated in the RCT at baseline. The questionnaire about the prior use of ICT devices and self-reported skill level was filled out by 29% (65/224) of the participants, of which 72% (47/65) were female. Their mean age was 71 years (SD 5.8 years). The tablet was one of the most popular devices among the participants. A large majority of the participants used this device several times a week. See Table 1 for the results.

Most participants rated themselves as somewhat skilled with ICT devices. Specifically, 6% (4/65) of the participants rated themselves as very unskilled, 2% (1/65) as unskilled, 38% (25/65) as somewhat skilled, 40% (26/65) as skilled, and 6% (4/65) as very skilled.

Table 1. Prior Use of Information and Communication Technology Devices (N=65).

Device[a]	Use, n (%)				
	Never	Rarely[b]	Sometimes[c]	Regularly[d]	Oftene
Personal computer	17 (26%)	1 (2%)	3 (5%)	8 (12%)	24 (37%)
Laptop	17 (26%)	3 (5%)	3 (5%)	7 (11%)	25 (39%)
Tablet	16 (25%)	2 (3%)	3 (5%)	3 (5%)	35 (59%)
Smartphone	13 (20%)	0 (0%)	2 (3%)	3 (5%)	41 (63%)
Mobile phone[f]	25 (39%)	1 (2%)	2 (3%)	5 (8%)	14 (22%)

[a]The values of individual items are less as some items were skipped by the participants.
[b]Once a year or less.
[c]Few times a year.
[d]Few times a month.
[e]Few times a week.
[f]Device without touchscreen.

Usability Questionnaire

The usability questionnaire was filled out by 36% (37/103) of the participants who had used the tablet for 6 months, of which 60% (22/37) were female. The mean age was 71 years (SD 5.1 years). The questionnaire had excellent internal consistency with Cronbach alpha of .89. The internal consistencies for the subscales were as follows: usefulness, .82; ease of use, .89; and satisfaction, .71.

Participants indicated that they found the tablet very useful (item 1) and it helped them to perform their exercises better (item 3) and safely (item 4). They were, however, neutral about how this affected their daily lives (item 6 and item 7). Overall, they were satisfied with the tablet and found it easy to use. Table 2 presents the results of the USE items. Finally, 68% (25/37) of the participants indicated that they would recommend the tablet to friends. Participants who indicated that they would not recommend the tablet provided varying reasons like “it didn’t work properly,” “I don’t need it to be active,” or “it’s too noncommittal.”

Interviews

In total, 17% (18/103) of the participants who used the tablet for 6 months were approached for a follow-up interview. One participant declined without giving a specific reason. The interviews were conducted with the remaining 17 participants, of which 53% (9/17) were female. Their mean age was 73 years (SD 7.0 years). The results of the interviews are described below according to the following five phases of self-regulation: goal setting, action planning, behavior execution, self-monitoring, and evaluation.

Table 2. Scores of Usefulness, Ease of Use, and Satisfaction Items (5-Point Likert Scale) (N=37).

Questionnaire item[a]	Score[b], mean (SD)
Usefulness	3.8 (0.6)
1. The tablet is useful.	4.5 (0.6)
2. With the tablet, I can follow an individual exercise program that suits me.	4.0 (0.7)
3. The tablet helps me to perform my exercises better.	4.2 (0.7)
4. With the tablet, I can perform exercises safely.	3.9 (0.9)
5. The tablet helps me to perform exercises more often.	3.8 (1.1)
6. Since using the tablet, I have a more active life.	2.9 (1.0)
7. The tablet supports my daily activities.	3.0 (1.1)
8. The tablet has everything I need to be physically active.	3.6 (1.1)
9. The information about the exercises is understandable.	4.4 (0.6)
Ease of use	4.2 (0.6)
10. I learned to use the tablet quickly.	3.9 (1.1)
11. I easily remember how to use the tablet.	4.3 (0.9)
12. I am capable of using the tablet.	4.2 (0.8)
13. I can use the tablet without any help.	4.3 (0.7)
14. I understand how the tablet operates.	4.3 (0.7)
15. I can easily find what I am looking for on the tablet.	4.2 (0.9)
16. The tablet is easy to use.	4.4 (0.7)
17. Using the tablet is effortless.	4.4 (0.5)
Satisfaction	4.1 (0.6)
18. I am satisfied with the tablet.	4.2 (0.7)
19. The tablet is pleasant to use.	4.1 (0.8)
20. The tablet is fun to use.	4.0 (0.7)
21. I am going to keep on using the tablet.	4.0 (1.1)
Miscellaneous	
22. Family and friends believe I should use the tablet.	1.9 (0.9)
23. The trainer/coach believes that I should use the tablet.	3.3 (1.3)

[a]Translated from Dutch.
[b]The minimum score is 1, and the maximum score is 5.

Goal Setting

Goal setting involves the process of determining the objective a person aspires. Setting goals was the departure point of the blended intervention. The tablet was designed to support the participants by letting them rank a set of daily activities and subsequently formulating their goals. It was also the main topic of the first two meetings with the coach.

The participants' goals varied greatly (ie, from decreasing backache to improving balance). For some participants, the goal was not to improve physical health but to maintain it. Occasionally, participants formulated the goals with only the tablet, but most participants first consulted with the coach to explore related issues and translate top-level goals to specific and challenging, but realistic and measurable, goals. The attention the coach paid to the individual situation of the participant was appreciated. For instance, participants commented as follows:

> *... then we looked what is useful for me, what will help me to improve?... well, this was decided in consultation.* [Participant #14]
> *I believe it is important that the coach kept in mind: what does this person want to achieve?* [Participant #6]
> *well... they asked me about everything... which problems do I face?* [Participant #1]

In summary, the tablet, in conjunction with the coach, supported the participants in setting goals. The sensitivity of the coach for the personal circumstances was valued by the participants.

Action Planning

Action planning involves the process of making a plan regarding how the goals will be achieved. After determining the goals, participants could draw up a personal exercise schedule on the tablet. They could select functional exercises that would increase balance, strength, flexibility, and endurance. Each exercise was available in three variations that differed in difficulty.

The choice of different exercises was valued. For instance, participants commented as follows:

> *... then you always can choose your own exercises. I think it is great you have a lot of choice.* [Participant #4]
> *That's good. Then I can adjust it entirely to my own needs.* [Participant #6]

Some participants commented that customizing the exercise schedule was not easy to do, either because of technical limitations of the tablet or because of limited knowledge about the benefits of each exercise. In those cases, the coach was available to help. For instance, participants commented as follows:

… well, which exercise should you choose? … that I could do this together with my coach was very effective. [Participant #4]
with his help I had in no time an entire exercise program. [Participant #3]

The weekly overview of planned exercises helped the participants to be physically active. The majority of participants exercised daily. They commented that this was due to the intervention as follows:

I am chaotic and have no discipline, this helped me a lot! [Participant #17]
I do the exercises every day at home. I did not do that before. [Participant #13]
now I am consistently doing exercises, every day. Actually, because of this [tablet]. [Participant #10]

When asked about the underlying reason for this, they mentioned different aspects. Several participants indicated that the tablet provided them structure to build a routine. For many, this was doing the exercises at a fixed time of day, generally in the morning. Participants commented as follows:

before taking a shower and getting dressed, first those exercises. A fixed structure, that helped. [Participant #2]
… well, that rhythm is a good feeling. [Participant #15]

Others commented that the exercises were more integrated in their daily activities as follows:

… sometimes I also do the exercises as I go; then I walk step by step back into the living room after a visit to the bathroom. [Participant #11]
… I do the exercises in between times. I stand on one leg when I am brushing my teeth for instance. Well, I kind of integrate it. [Participant #14]

Besides providing structure, some participants mentioned that the tablet also acted as a cue to action as follows:

… when I sit down and see it [tablet] I think 'ah, a reminder! [Participant #16]

In summary, participants felt that the blended intervention supported them in action planning. It provided them with structure to develop a routine. Several participants indicated that it helped them to do exercises daily, a frequency they previously did

not achieve. They valued the possibility to personalize the exercise schedule to their own needs. The help of the coach was essential for some participants.

Behavior Execution

Behavior execution involves performing the actual behavior that should lead to achieving the goals. The tablet was designed to support this by various features like giving an overview of today's exercises, providing background information about each exercise along with video demonstrations, and providing a countdown timer or the ability to modify each exercise with three parameters (duration, number of repetitions, and intensity level).

Participants found the daily overview of exercises to be useful. It provided them in a brief glance which exercise had to be performed today and with what duration, repetition, and intensity level. The countdown timer was used especially in the beginning when participants had to familiarize themselves with the exercise routine. The same applied for the video demonstrations. It helped them to see how the exercises could be performed correctly. For instance, participants remarked as follows:

> *… but I did need it [video demonstration] to do it [the exercise] in the correct manner*. [Participant #6]
> *… that was nice, I could perform the exercises better this way*. [Participant #7]

Additionally, attention to safety was valued, with the following statements:

> *the exercises are safe. Well, at least a lot safer than riding a bike. Biking is dangerous*. [Participant #12]
> *… yes, attention was paid to this [safety]. That you had to hold on to something, when you stand on one leg, for instance*. [Participant #6]

One of the participants stressed the benefit of using a tablet for the instructions as follows:

> *I can write it down, but it's nice to have visual image of what is meant…. instructions written down are always subject to different interpretations. I think, as it has been done now, is very instructive*. [Participant #4]

Nevertheless, numerous participants mentioned that the additional instructions of

the coach were also valuable as follows:

> *I also asked the coach, "am I doing it right?" He said "yes, that's right" or "you have to do it like this and that".* [Participant #11]
> *… that was nice. Sometimes he would demonstrate the exercise, or I would demonstrate it and ask him if I was doing it correct.* [Participant #6]

The coach also helped participants modify exercises if they were struggling with limitations or wanted more of a challenge. The latter was often needed. Many participants stressed that the exercises were too easy, despite the possibility to increase the difficulty level with the tablet. Apparently, this was not sufficient for numerous participants. An illustrative remark was as follows:

> *… yes, I can say that I wished they were a bit more challenging.* [Participant #10]

Some felt very strongly about this. For instance, a participant remarked as follows:

> *Look, I believe these exercises are meant for people who are in a retirement home and, more or less, don't do anything the entire day.* [Participant #15]

Two participants indicated that they stopped doing the exercises because of this reason. Others found creative ways, together with their coach, to increase the intensity level, for instance, by increasing the repetitions, skipping breaks, or adding weight. For instance, a participant commented as follows:

> *… such as the exercise with shopping bags… I added dumb-bells to it, now it's really challenging.* [Participant #10]

Finally, as participants developed a routine, they relied less on the tablet and on the coach for performing the exercises. Some participants kept on having the tablet in sight during the performance of the exercises, while others merely glanced at which exercises had to performed today and then executed them without the tablet. Watching the video demonstrations or using the countdown timer was not needed anymore. In some cases, participants even did all the exercises by heart, and one participant mentioned the following:

> *… I can do the exercises when I am at work, in between times. I just count the*

exercises myself. [Participant #8]

When asked about the necessity of a coach, most of the participants felt that after 2 or 3 months, the coach's help was not needed anymore.

In summary, the video demonstrations and countdown timer helped the participants to perform the exercises safely and correctly, especially during the early stages of the intervention. The coach played an important role in adapting the exercises to meet the capacity of the participants, as many of them sought a bigger challenge. In time, the participants developed a routine and performed the exercises more autonomously.

Self-Monitoring

Self-monitoring involves the process of keeping track of one's progress. The tablet was designed to support this by letting users tick off exercises that had been completed. In a weekly overview, users could see which exercises had been done and which had not been done. Additionally, a progress bar indicated how many exercises still had to be done today and for the current week. Furthermore, the coach could remotely monitor the progress of the participants.

The moment at which participants ticked off exercises varied. Some did this directly after completing the exercises, whereas others did it at the end of the day. The majority of participants felt that keeping track in this manner gave them insights into their own behavior and was motivating. For instance, one participant made the following statement:

… for me it's very easy…it gives insight and lets me follow what I have done. [Participant #9]

Remarkably, various participants expressed that the mere action of ticking off exercises was not only easy but also rewarding. It left them with a feeling of accomplishment. For instance, one participant made the following statement:

… look, in the end you want to finish off your list. [Participant #8]

However, the progress bar, which indicated how many exercises were completed, was hardly used. Many participants did not seem to have noticed this feature, indicating a usability issue. A couple of participants also expressed the desire for

more advance features to investigate their progress, like graphs and tables.

Several participants mentioned that remote monitoring by the coach was an important factor for them to keep doing the exercises. For instance, some participants remarked as follows:

> *… the tablet motivates me, but…I must say. I think this is also because…that it is being monitored.* [Participant #7]
> *…I think it helps… there is someone keeping an eye on you.* [Participant #14]
> *you are participating in study, you want to show that you are cooperating.* [Participant #10]

On the other hand, other participants indicated that this was not the case for them. They would keep doing the exercises if there was no coach involved.

In summary, keeping track of progress with the tablet was easy and motivating. Ticking off completed exercises was experienced as rewarding and gave participants insights into their progress. For some participants, the fact that they were remotely being monitored was motivating, while for others, the social presence of a coach was not important.

Evaluation

Evaluation involves the process of reflecting on the effort and the progress that has been made in relation to the goals that were set out to be achieved. First, the tablet was designed to support the evaluation process by letting participants rate each exercise on three aspects (effort, complexity, and enjoyment). Second, either via video calls on the tablet or with face-to-face meetings, the participants had the opportunity to reflect on the progress together with their personal coach.

The ability to rate exercises with the tablet was superfluous according to several participants. The need to evaluate each exercise after completion seemed tedious. One participant made the following statement:

> *Well, look. This bothers me. I think 'come on guys. Everything is so easy and simple. For me there is no difference in it [the effort, complexity or enjoyment of the various exercises].* [Participant #2]

Some participants suggested that it would have been better if they could rate

exercises on a weekly basis instead of on a daily basis or only when they felt the need to do so. In contrast, the participants were more positive about the evaluation with the coach. They felt that it helped them to identify issues. Several participants mentioned, however, that toward the end of the 6-month intervention, the coaching was not needed anymore.

Finally, some participants reported that they experienced an improvement in vitality. They found themselves to be in a better shape than before and attributed this to the blended intervention. One participant made the following comment:

> *…yes, I now really get up without any backache, although this was previously the case. The pain returns in the evening when I am tired, but in the morning it's different. That is a huge benefit.* [Participant #5]

Others did not notice an improvement, despite performing exercises, but also expressed more modest expectations. Maintaining their health status was more important than achieving progress for them, as indicated by the following remarks:

> *Do I notice an improvement in the gym? No. But if I don't do my exercises for a week or two…then I can notice the difference.* [Participant #6]
> *I notice, I am 85, that I am declining… my goal is to stay steady.* [Participant #4]

Another participant mentioned the following:

> *…when you are 18 you can expect to keep on getting better, but for me, after one year I am even more old again… Can I perform some exercises that I couldn't do before? Sure. In that sense there is progress. But it isn't so that I am going to keep on improving.* [Participant #16]

When asked if they would like to keep the tablet for exercising, the vast majority of participants expressed the wish to do so, regardless of whether they notice an improvement.

In summary, the blended intervention supported participants in evaluating their progress. Specifically, the conversations with the coach were responsible for this. Overall, the participants evaluated the blended intervention to be useful. Some felt that their health improved, but others did not have this feeling. Nevertheless,

almost all participants indicated that they wanted to continue their exercise routine with support of the tablet.

Discussion

The Value of the Blended Approach

The objectives of this study were to assess the usability of the tablet and how it supported older adults in performing home-based exercises, in conjunction with a personal coach. A previous usability study showed that first-time users (age ranging from 69 to 99 years) could successfully complete various predefined tasks on the tablet during a 45-minute session in a laboratory [29]. This study extends those findings by showing that the tablet can be not only successfully operated in a standardized setting for a short period of time, but also useful, satisfying, and easy to use within the context of exercising at home during daily life for an extensive period of time. The participants indicated that the tablet allowed them to follow a tailored exercise program that suited them. It also helped them to perform the exercises more often, better, and safely. From the perspective of older adults, it can be concluded that the use of the tablet successfully supported them in their exercise behavior.

The interviews revealed a more detailed view on the underlying processes. The tablet was useful in developing an exercise routine. The tablet supported the participants in action planning and behavior execution by providing them with a tailored schedule that gave structure and video instructions demonstrating the appropriate behavior. Furthermore, ticking off exercises as a simple form of self-monitoring appeared to be motivating. On the other hand, the interviews revealed that the personal coach played an essential role. The interactive and social nature of coaching was especially useful during the self-regulation phases of goal setting and evaluation. The ability to interact with users in this manner is yet to be achieved by a virtual coach or avatar [24,42,43]. In addition, although the tablet allowed users to tailor the exercise program to their own needs, the exercises in the app did not sufficiently match the needs of the participants. The expertise of the coach was crucial for adapting the exercises to accommodate preferences. Finally, the presence of the coach in the form of remote monitoring was motivating for some participants. These findings are in line with other research showing that physical activity interventions incorporating access to a remote expert for advice and social support tend to be effective [34,44,45]. This study indicates that the coach might,

in particular, be beneficial during the initial period, when participants familiarize themselves with the intervention and develop a routine.

Improvements

Although the participants were overall positive about the blended intervention, the evaluation also revealed several possibilities to improve the intervention. First, fit older adults should be able to add more challenging exercises to their schedule. Taking into account the preferences of some older adults, adding support for outdoor activities to the tablet would be enriching. For instance, a map with walking trails in the vicinity could stimulate older adults in achieving daily physical activity. Second, the tablet should offer more detailed reports of user progress (eg, graphs that display long-term trends). Some participants requested such a feature. Third, the extent participants relied on a coach varied from person to person. Owing to the protocol of the RCT, coaches contacted the participants with a fixed frequency. When the intervention is implemented in practice, the intensity of counselling should be tuned to the preferences of individuals. Presumably, some older adults will extensively make use of counseling, while others will merely limit it to initial support.

Study Limitations

The aim of the blended intervention was to support older adults in performing home-based exercises. Questionnaires as well as interviews showed that older adults felt that the intervention accomplished this. However, an underlying assumption of the intervention was that regularly performing exercises would support older adults in their daily activities and lead to an active lifestyle and an increase in their vitality. The interviews showed mixed results on this topic, and no support was found for these assumptions from the questionnaires. More challenging exercises or a more comprehensive approach for the vitality of older adults might be needed for such secondary effects; however, the effectiveness of such strategies is also debatable [46-50].

The results of the questionnaires have to be interpreted with caution though. All older adults who participated in the clinical trial were given at the start of the trial a questionnaire about their prior experience with ICT devices. Only 65 of the 224 trial participants completed this baseline questionnaire. Furthermore, the 6-month trial had a 18% drop-out rate [51]. Among the remaining 103 older adults who were part of the group that received a tablet, only 37 filled out the USE questionnaire about the usability of the tablet. The usability results may therefore be biased. Perhaps only

participants who had a positive experience with the tablet filled out the usability questionnaire. We do not, however, think this is plausible. First, the baseline questionnaire had a high rate of nonresponses. This fact cannot be explained by a negative experience with tablet use in the blended intervention. The participants were yet to embark on the intervention when filling out the baseline questionnaire. The high nonresponse rate for both the questionnaires might have been caused by the numerous tests that were administered by the researchers as part of the larger clinical trial [32]. The testing procedure, including body measurements, took half a day. This might have led to fatigue, causing participants to skip questionnaires. Second, the positive evaluation based on the questionnaire is in line with the results from the interviews. Although the sample size of the interviews was small, it was not susceptible to selection bias. The interviews were based on random selection of participants. Only one participant declined to be interviewed. Therefore, the sample that was drawn for the interviews can be considered to be representative of the older adults participating in the intervention. The previous usability study among first-time users and the questionnaires and interviews of this study all point in the same general direction of a favorable evaluation.

The extent to which the findings can be generalized to older adults in general is a different issue. The baseline questionnaire showed that prior use of tablets was high among the participants. Studies have shown that among older adults, tablets are easier to operate than smartphones or personal computers owing to the large touchscreen [52-54]. This was one of the reasons to choose a tablet as the delivery device for the blended intervention [36]. The usability of tablets can also explain the increasing popularity of tablets among older adults. In the United States, tablet ownership among adults aged 65 years or older rose from 1% in 2010 to 32% in 2016 [55]. In the Netherlands, a similar trend has taken place, where tablet ownership among those aged 65 to 75 years grew from 28% in 2012 to 60% in 2016 [56]. In this light, the prior use of tablets among the participants of this study is representative of the larger population. Nevertheless, perhaps only older adults with a positive attitude about ICT in general or a tablet in particular signed up to participate in the blended intervention. More research is needed to assess how a wider range of older adults will experience a physical activity intervention that incorporates the use of tablets.

Conclusion

A mixed-methods process evaluation showed that older adults are positive about a blended intervention designed to support them in performing home-based

exercises. Participants rated the adoption of a tablet as useful, satisfying, and easy. They indicated that it helped them to perform exercises better, more frequently, and safely. It supported them in various phases of self-regulation. The interactions with a personal coach strengthened this by offering deeper reflection and more fine-grained tailoring during the earlier stages of the intervention. A blended approach appears to be a promising strategy for delivering physical activity interventions in older adults.

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Aging and Physical Activity: A Qualitative Study of Basic Psychological Needs and Motivation in a Blended Home-Based Exercise Program for Older Adults

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Abstract

Physical activity can prolong the ability of older adults to live independently at home. A blended intervention was developed to sustain healthy ageing. During a clinical trial 133 participants, with an average age of 71 years old, received a tablet and coaching to support them in performing home-based exercises for 6 months. To investigate how the blended intervention influenced exercise motivation, 17 participants were interviewed. Transcripts were analyzed according to the directed content analysis method. The analysis revealed that the intervention supported the autonomy of participants, by letting them set their own personal goals and compile a personalized exercise program. It also supported their feelings of competence, by offering clear instructions, structure and the ability to track their progress. Finally, some participants valued the emotional support offered by the personal coach, while others preferred combining the home-based exercises with group-based activities with peers to fulfill their relatedness needs.

Introduction

Physical Activity and Healthy Aging

Increasingly, people are living longer [1]. In the United States, 16% of the population is 65 years old and above. In the Netherlands, about 20% of the population falls into this age demographic, similar to other European countries [2]. In 2050, the United Nations expects that in Europe, 35% of the population will consist of older adults aged 60 and above. Although this trend is the most pronounced in developed nations, developing countries are undergoing similar changes. By 2050, it is projected that 25% of the population of Latin America and Asia will be 60 years and above. In fact, 8 out of the 10 older adults will then be living in a developing country [3], attesting it as a global phenomenon that impacts a large part of the world.

The trend of aging populations is driven, in part, by an increase in life expectancy [4,5]. Unfortunately, this progress is not equally being matched by an increase in years of living in good health [6]. Nations also struggle with the growing burden on healthcare and social issues related to aging. In the Netherlands, as in many other countries, an appeal is being made on the resilience of older adults to age in place, that is to say "the ability of older people to live in their own home and community safely, independently and comfortably" [7].

To live independently at home, older adults should have sufficient capabilities for basic and instrumental activities of daily living, such as taking a bath, getting dressed, doing general housekeeping and going out for shopping [8]. Aging is, however, characterized by a functional decline, during which older adults experience a loss of the ability to carry out those tasks without the help of others [9–12]. There is a wide body of evidence that physical activity can delay the onset of functional decline and diminish its severity, thereby contributing to aging-in-place [13–16].

Declining Adherence Over the Years

Despite the benefits of physical activity, a large part of the population has a sedentary lifestyle. The adherence to physical activity guidelines is low. That is to say, often adults do not meet the criteria to do at least 150 minutes moderate-intensity physical activity throughout the week, plus activities that strengthen the bones and muscles twice a week [17]. Thirty-one percent of the adults worldwide do not meet those guidelines [18]. According to some estimations, even 80% of the Americans are insufficiently active [19]. The recommendations for older adults are

similar to adults in general, except that they should undertake activities that involve keeping one's balance at least three times a week [20–22]. It should be noted that what qualifies as physical activity of moderate-intensity is relative to the physical capabilities of a person. Some light gardening, slow-paced walking or Tai Chi might be sufficient as moderate-intense physical activity for a 75-year-old adult, but not for a healthy 30-year-old adult. Although the effort needed to meet the recommended guidelines is relative, the proportion that is sufficient physical activity decreases as people age. In the Netherlands, for instance, 55% of the 18- to 25-year-old adults are sufficiently active, but this declines to 44% for 60 to 70 years old, drops further to 33% for 70 to 80 years and finally bottoms to 16% for older adults above 80 years old [23]. This is a universal trend. For instance, in England, a similar pattern can be seen, where adherence to physical activity guidelines starts at 53% for young adults and drops off to 9% for older adults of 75 years and above [24]. In general, older adults are physically less active than younger adults, despite its protective effect on independent living and quality of life [18].

Motivators and Barriers

The reasons that a majority of older adults are not sufficiently physically active are diverse. Various studies have shown that older adults experience various motivators as well as barriers. Older adults often cite health benefits as the main reason to be physically active [25,26]. They believe it will contribute to independent living [27–29]. Likewise, social interactions with others is frequently cited as a motivator. Group cohesiveness and social support are driving factors of community-based physical activity programs for older adults [29,30]. On the other hand, there are various barriers that refrain older adults from being physically active. The reciprocal relationship with health is striking. Physical health conditions and discomfort are often cited as reasons for not engaging in physical activity [25]. Physical capability is a limiting factor. Exercises can, however, be performed at various levels to accommodate functional impairments. Instead, the low adherence to exercise programs might be explained by the beliefs of older adults. Symptoms of exercising, like increased heartbeat, respiration or perspiration are often negatively interpreted by older adults [26]. Similarly, the fear of falling and injuries are a substantial barriers [31–33]. Underlying those concerns, self-efficacy plays a major role. The lacking belief of older adults to be able to perform exercises safely and successfully is a significant barrier [34–36]. Finally, environmental barriers like lack of facilities, the need to participate in a community-based groups, costs and time to travel to exercise location are reported to form barriers to exercise [37–39].

A Blended Intervention to Increase Physical Activity in Older Adults

To increase the physical activity levels of Dutch older adults and address their concerns about exercising, a novel blended intervention was developed at the Amsterdam University of Applied Sciences. The blended intervention consisted of performing home-based exercises, supported by a tablet PC in conjunction with a personal coach. To ensure effectiveness, a custom-made tablet application (app) was based on behavior change techniques designed to reinforce self-regulation [40]. Furthermore, the blended approach was conceived to be an effective strategy for several reasons. First, as opposed to community-based programs, a home-based program allows older adults to exercise frequently within the comfort of their own homes, thereby eliminating the cost and time needed to travel. Second, a tablet can give older adults the possibility to tailor an exercise program to their own needs. This is hard to achieve in a traditional group-based setting. Moreover, the tablet can be used to deliver multimodal instructions to increase self-efficacy. Third, guidance by a personal coach can motivate older adults and provide social support.

A previous focus group study has shown that Dutch older adults that were already participating in a community-based physical activity program were receptive to a blended intervention to increase their exercise frequency [29]. In addition, a usability study showed that the tablet app could be operated by older adults in an efficient and effective manner [41]. Although promising, both studies have limitations. The attitudes of the older adults in the focus group study were based on a hypothetical concept of a home-based exercises supported by a tablet. Second, the participants in the usability study used a prototype of the app in a laboratory setting for a short period of time. Moreover, only the use of the tablet was studied; not the support of a personal coach. To address those issues, a process evaluation was conducted amongst older adults that participated in the blended intervention for an extended period of time, including the support of a personal coach. A primary analysis showed that the blended intervention facilitated older adults in self-regulating their exercise behavior [42]. However, this study did not address motivation aspects. Self-determination theory (SDT) is a dominant motivation theory that has proven to be useful for understanding adherence to exercise programs [43–45]. In order to be intrinsically motivated to perform certain behaviors, SDT postulates that three basic psychological needs have to be met: autonomy, competence and relatedness [46–49]. To determine how the novel intervention influenced exercise motivation, interviews with participants were analyzed according to this framework of basic psychological needs.

Methods

Design and Participants

To assess the effectiveness of the blended intervention in terms of health outcomes, a randomized control trial was conducted [50]. Older adults of at least 55 years old were recruited through local community centers offering weekly group-based exercise classes. In total, 133 older adults participated in a 6–month-intervention during which they received a tablet and a personal coach to support them in performing home-based exercises. The average age of the participants was 71 years old (M = 71.48, SD = 6.38) and 69% was female. The aim of the clinical trial was to determine to which extent the blended intervention would lead to improved physical functioning (e.g. walking speed) and changes in body composition (e.g. muscle mass). Besides evaluating the effectiveness of complex interventions, the Medical Research Council recommends to conduct process evaluations [51,52]. This fosters an understanding of underlying change processes, such as motivation aspects. To gain such a deeper understanding, 18 participants were randomly selected for an in-depth interview. The interview questions were previously piloted with two participants. The interviews were conducted in a home setting and lasted about 45 minutes. All interviews were audio-recorded.

Analysis

To explore the relationship between the blended intervention and the basic psychological needs, the transcripts of the interviews were examined according to the directed content analysis method [53,54]. Similar to the grounded theory approach, conventional content analysis is an inductive process where the starting point is the observations that have been made. The data is categorized with codes that are based on themes and concepts that emerge directly from the data itself. It is imperative that this is done without preconceived ideas. Relations with existing theories are only identified in the concluding phase. In contrast, the directed content analysis method involves existing theories right from the start. Although there is room for open codes that emerge from the data, the main codes are derived from literature or previous research. This is not considered to bias the analysis, but help researchers to focus their efforts and to build on existing theories [54]. Since SDT has successfully been applied to exercise motivation, for the current study the directed content analysis was deemed to be the most suitable method to investigate the interviews [44,45,49,55].

To increase the reliability of the content analysis, the following procedure was undertaken. In the first step, two researchers read independently from each other all the transcripts to get a general overview and noted down key concepts. In the second step, they synthesized their key concepts and discussed it with a third researcher. In the third step, a preliminary taxonomy of descriptive codes was developed, based on the three basic psychological needs, and complemented with key concepts identified in step two. In the fourth step, the taxonomy was calibrated by applying it to a random selection of transcripts by both coders. In the fifth step, the merits and caveats of the taxonomy were discussed with the third researcher, leading to revised version of the taxonomy. In the sixth step, all the transcripts were coded independently by the two researchers. In the seventh step, the applied codes were compared and differences were resolved through discussions. In the rare cases when no consensus was reached, the third researcher settled the dispute. In the eighth and final step, general patterns were identified and conclusions were abstracted. Table 1 shows the schematic overview of the steps that were undertaken.

Table 1. Steps Undertaken To Study Interview Transcripts According To the Directed Content Analysis Method

Step number	Activity
Step 1	Exploring transcripts and noting down key concepts by two researchers
Step 2	Synthesizing key concepts of both researchers
Step 3	Developing preliminary coding taxonomy, based on existing theory and findings from step 2
Step 4	Calibrating the taxonomy by applying it to a random selection of transcripts by two researchers
Step 5	Elaborating the taxonomy into a revised version, based on the results from step 4
Step 6	Applying the revised taxonomy to all transcripts by two researchers
Step 7	Comparing codes and reaching consensus between both researchers
Step 8	Identification of patterns and abstracting conclusions

Results

Participants

In total, 18 participants were approached for the in-depth interview. One participant declined without giving a specific reason. Interviews were held with the remaining 17 participants. The average age of the older adults that participated in the interviews was 73 years old (M = 73.12, SD = 6.96). Nine of the seventeen (53%) were female. The results of the 17 interviews are described below from the perspective of the

three basic psychological needs of SDT.

Autonomy

Autonomy is the basic psychological need of people to feel in control of their own behavior and being able to pursue personal goals. The blended home-based intervention was designed to support this. In contrast to a group-based program, participants could choose the time, duration and location of their exercise routine. This flexibility was valued by the participants. For example, participant 11 (P11) commented that "… I don't want that [fitness classes] anymore. I am retired. I don't want any obligations anymore. I am sick of it…. but I am more free [with the home-based intervention]. I can do it in the morning or in the evening. If I have [previously] skipped it, then I can do it today. Then I will do it two days in a row". Participant 5 (P5) compared the tablet-supported exercises with an exercise program on the cable television and mentioned "… you can grab the tablet any moment of the day, but that television program is at 9.15 in the morning and then it's finished".

Besides offering an exercise program that was independent of time and location, the content of the exercise program could be personalized. After ranking a list of daily activities on the tablet according to importance, participants recorded personal goals they wished to achieve. Although participants could do this by themselves on the tablet, the blended approach of the intervention appears to have been crucial during this step. Many participants initially could not formulate a goal more specific than 'staying healthy'. The personal goals often only emerged during the interaction with the coach. Through counseling, they were able to determine more specific, challenging and realistic goals. They appreciated the fact that their personal circumstances and ambitions were the departure point of the counseling sessions. Participants commented, for instance, "well… they asked me about everything… which problems do I face?" (P1), "…then we looked what is useful for me, what will help me to improve?… well, this was decided in consultation" (P14) or "I believe it is important that the coach kept in mind: what does this person want to achieve?" (P6).

After determining their goals, participants were able to compile a personalized exercise program that would fit their needs. Based on the goals, exercises could be selected from a library of 17 exercises. Each exercise was available in three versions that varied in difficulty, amounting to a total of 51 exercise variations. Participants appreciated this freedom of choice. For instance, participant 4 (P4) stated, "… I think it is very valuable that such a tablet is full of these possibilities [exercise variations]

... the idea that there is a lot of choice, I think is good". Participant 5 (P5) mentioned, "Yes, there is enough choice", while participant 14 (P14) remarked that "...you can completely adjust it to your own needs". Nevertheless, despite the amount of default exercises available to the participant, there was a need to further tailor exercises to specific needs, for instance to account for physical limitations or to increase the difficulty beyond that was offered. In particular, the expertise of the coach was helpful in selecting and adapting the default exercises, as some participants put it, "...well, which exercise should you choose? ... that I could do this together with my coach was very effective" (P4) and "with his help I had in no time an entire exercise program" (P3). Participant 7 (P7) mentioned, "I wanted extra exercises for my back. After consulting my coach, I added three or four extra exercises". Although the tablet was designed to support home-based exercises, participants were pleased with the possibility to add outdoor activities or ongoing group-based classes to their schedule on the tablet, like yoga, biking or tennis.

In summary, participants felt that the blended intervention designed to increase physical activity facilitated their autonomy. They valued that their own goals and preferences served as the base for counselling. They could compile a personalized exercise program that was tailored to their needs. If wanted, they could customize default exercises, with the help of the coach, or added outdoor activities that were already part of their routine.

Competence

Competence refers to the basic psychological need to feel effective in achieving desired outcomes. People strive to a sense of mastery by maintaining or enhancing their skills and capabilities by interacting with their environment. This was the core component of the blended exercise intervention.

To accommodate varying capabilities of older adults, participants could not only choose from a wide range of exercises when compiling a personalized exercise program, they could also modify the duration, difficulty and intensity level of each exercise during the execution phase. Despite this possibility, many participants still found the exercises to be too easy. An illustrative remark was, "...yes, I can say that I wished they were a bit more challenging" (P10). Some felt very strongly about this: "Look, I believe these exercises are meant for people who are in a retirement home and, more or less, don't do anything the entire day" (P15). After completing each exercise, participants could rate the effort they needed, the complexity and the enjoyment they experienced. This revealed the same sentiment. As participant 2

(P2) put it "Well, look. This bothers me. I think 'come on guys. Everything is so easy and simple. For me there is no difference in it [the effort, complexity or enjoyment of the various exercises]". A few participants indicated they stopped doing all together the default exercises because of this reason and solely concentrated on outdoor activities. In contrast, others found creative ways to increase the intensity level of the home-based exercises by, for instance, increasing the repetitions, skipping breaks or adding weight. For example, participant 10 (P10) mentioned, "… such as the exercise with shopping bags… I added dumb-bells to it, now it's really challenging".

The intervention did appear to have helped the participants to exercise more regularly. The majority of participants exercised daily. They commented that this was due to the intervention: "I am chaotic and have no discipline, this helped me a lot!" (P17), "I do the exercises every day at home. I did not do that before" (P13) and "now I am consistently doing exercises, every day. Actually, because of this [tablet]" (P10). When asked about the underlying reason for this, they mentioned different aspects. Several participants indicated that the weekly schedule depicted on the tablet provided them a structure to build a routine. For many, this was doing the exercises at a fixed time of day, generally in the morning: "before taking a shower and getting dressed, first those exercises. A fixed structure, that helped" (P2) and "… well, that rhythm is a good feeling" (P15). Others commented that the exercises were more integrated in their daily activities: "…sometimes I also do the exercises as I go; then I walk step by step back into the living room after a visit to the bathroom" (P11) or "…I do the exercises in between times. I stand on one leg when I am brushing my teeth for instance. Well, I kind of integrate it." (P14). Besides providing structure, some participants mentioned that the tablet also acted as a cue to action: "…when I sit down and see it [tablet] I think 'ah, a reminder!'" (P16). Participants also valued the possibility of keeping track of their efforts by ticking off exercises in their weekly overview. It helped them to persevere. Participant 9 (P9) mentioned, for instance, "…for me it's very easy…it gives insight and lets me follow what I have done". Several participants remarked that ticking off exercises was motivating, as participant 8 (P8) put it "…look, in the end you want to finish off your list". Some participants did express the desire for more advanced features to track their progress, like graphs and tables.

Besides exercise frequency, the intervention also showed participants how the exercises should be performed. The tablet provided a daily overview that depicted which exercises had to be performed with which duration, repetition and intensity

level. Participants found that a countdown timer that showed the remaining time to be useful, especially in the beginning when they had to familiarize themselves with the exercise routine. The same applied for video demonstrations that were available on the tablet. It helped them to visualize how the exercises could be performed correctly. For instance, participants mentioned that "…but I did need it [video demonstration] to do it [the exercise] in the correct manner" (P6) or "…that was nice, I could perform the exercises better this way" (P7). Also, the attention to safety was valued: "the exercises are safe. Well, at least a lot safer than riding a bike. Biking is dangerous" (P12) and "…yes, attention was paid to this [safety]. That you had to hold on to something, when you stand on one leg, for instance" (P6). One of the participants stressed that the benefit of using a tablet for the instructions: "I can write it down, but it's nice to have visual image of what is meant…. instructions written down are always subject to different interpretations. I think, as it has been done now, is very instructive" (P4). Nevertheless, numerous participants mentioned that the additional instructions of the coach were also valuable: "I also asked the coach, 'am I doing it right?'. He said 'yes, that's right' or 'you have to do it like this and that'" (P11) and "…that was nice. Sometimes he would demonstrate the exercise, or I would demonstrate it and ask him if I was doing it correct" (P6).

Finally, asking participants if they felt that the intervention helped them to achieve desired health outcomes, a multifaceted perspective emerged. Some participants reported that they experienced an improvement in vitality. They found themselves to be in a better shape than before and attributed this to the blended intervention. A participant (P5) commented, for instance, "…yes, I now really get up without any backache, although this was previously the case. The pain returns in the evening when I am tired, but in the morning it's different. That is a huge benefit". Others did not notice an improvement, despite performing exercises, but also expressed more modest expectations. Maintaining their health status was more important than achieving progress for them, as indicated by the following remarks: "Do I notice an improvement in the gym? No. But if I don't do my exercises for a week or two…then I can notice the difference" (P6), "I notice, I am 85, that I am declining… my goal is to stay steady" (P4) and "…when you are 18 you can expect to keep on getting better, but for me, after one year I am even more old again… Can I perform some exercises that I couldn't do before? Sure. In that sense there is progress. But it isn't so that I am going to keep on improving' (P16). When asked if they would like to keep the tablet for exercising, the vast majority of participants expressed the wish to do so, regardless if they noticed an improvement or not.

In summary, participants felt that the blended intervention supported them doing exercises correctly and more regularly. The tablet provided them with structure and clear instructions. The ability to keep track of their efforts was motivating. On the other hand, many participants felt that the exercises were not challenging enough. Some adapted the exercises to their needs, while others relied on outdoor activities instead. The extent that participants felt that the intervention helped them to achieve health outcomes varied, but the overall sentiment was positive.

Relatedness

Relatedness is the basic psychological need to interact with other people, to be connected and feel a sense of belonging. By definition, a home-based physical activity intervention has an individualistic character, compared to a group-based program. Many participants did, however, combine the home-based exercises with group-based community programs or outdoor activities. They indicated that they found the company of others motivating. For instance, participant 2 (P2) mentioned that "…that means outdoor tennis is starting again… then you meet people, have a coffee. Look, that are the things, the triggers, you need …as long as you join in [in group activities], you do a lot more" or "… because a group is much nicer" (P17). When they were asked if they would appreciate it if the tablet supported electronic communication with peers in the future, they indicated to have no such need. As participant 15 (P15) put it "no, not for me [electronic communication]. I prefer just normal personal contact". They felt that the existing social interactions with peers during group-based activities were sufficient. On the other hand, some participants preferred doing the home-based exercises exclusively, circumventing group-based activities all together. For instance, "some like to exercise in a group, others not. It's all the same to me. I like team sports, but also alone" (P9), "I am not a group person. Don't put me in a group. One on one is perfect for me" (P3), "I am a hermit, I just do my own thing [laughing]" (P15) and "I have been a few times to those meetings in the community center, but that didn't interest me much" (P9).

The blended approach of the home-based physical activity program did, however, entail the use of a personal coach. Besides sharing their in-depth knowledge about the exercises, they also offered emotional support and a sympathetic ear. This was appreciated by the participants. Participant 7 (P7), for instance, remarked that "that [the coaching] was very pleasant. You have some natural interaction with someone else. He listens to you, provides advice. That was nice". Some participants clearly felt connected to the coach, as indicated by a remark of participant 15 (P15) "… oh, John, lovely! What a delightful boy he was! He was so serious. We had the same

hobby. He started with photography. I also do that for many years now, so we had the same hobby." By default, after three months participants were appointed a new coach. Various participants expressed a preference for this first coach. In general, they were less enthusiastic about their relation with the second coach, as illustrated by the following remarks: "… then I was appointed a new coach. That was a pity. I did not have the same bond with him" (P15) and "I would have liked to have continued with the first coach, because he was so special. You hardly ever meet people like that" (P3). Notably, the participants had the possibility to consult their coach with a video call on the tablet, but almost all the participants preferred face-to-face contact. Similarly, not all participants felt a personal attachment to their coach. Several participants indicated that the coaching did not have a value-add after a few months when they were accustomed to their exercise program and did not need help anymore. For instance, participant 16 (P16) commented that "… four months or so. I think that is the proper duration. Because later, I got a boy [second coach] which was not needed anymore. I hardly learned anything new from him. It was just a reiteration of what the girl [first coach] told me". Others made similar remarks; "for me it could have been shorter [than the 6 months of coaching that was offered]. After three months I felt 'well, this is enough'" (P14) or "I think it [coaching] should have been a bit shorter … just three months" (P11). Some participants even expressed that they only needed support for the first few weeks. The coaching for those participants seemed tied to autonomy and competence support, not relatedness.

Besides being in contact with participants, the coach could also remotely monitor their progress. Some participants felt that this motivated them to keep up doing the exercises, as illustrated by the following remarks "the tablet does motivate me… because as I have understood, when I work on the tablet and pass on my results, that it will be received and looked at by you" (P7), "it's a big stick… if I don't complete it [the exercises], then you will notice it" (P6), "…you want to show that you are cooperating" (P10), "…that you can see that I am active" (P5) or "it's really an incentive… that people are keeping an eye on you, I think that helps a lot of people. There is someone who pays attention if you don't fill out anything" (P14). Nevertheless, when asked if they would continue doing the exercises with the tablet, but without a coach to remotely monitor them, participants responded as an affirmative. They indicated that the tablet was also useful without this feature and that they valued the health benefits. Illustrative remarks were "yes… [because of] the guidelines that I can follow, the videos, what I should do" (P7), "I still would do it [sustain exercising]…, because I just like it" (P6), "yes, I would keep up the

exercises. I have noticed myself that it's good for my body" (P10) and "… it will become easier to it skip it occasionally. That is the danger… but what I am saying is 'for whom am I doing the exercises? I am not doing it for you guys. I am doing it for myself' … I notice it pays off" (P14).

In summary, depending on the temperament, participants chose to either exclusively focus on the home-based exercises or combined it with group-based activities with peers. Some participants appreciated the emotional support of their coach and developed a special bond with them, while for others the interaction with the coach had a more functional nature. Participants preferred face-to-face over electronic communication with peers, as well as with their coach. Furthermore, remote monitoring of activities by the coach created a virtual presence that was for some participants motivating to persevere in the physical activity program.

Discussion

The aim of the study was to explore to which extent the blended intervention satisfied the basic psychological needs of autonomy, competence and relatedness. Interviews with older adults have shown that the intervention supported their autonomy. Participants indicated they could compile a personalized exercise program with the tablet that suited their needs. The intervention also supported the older adults in the development of their competence. The participants indicated that the tablet provided them with structure and clear instructions that helped them to perform exercises correctly and more regularly. Competence refers, however, to the need of people to interact with the environment in such a way that it challenges them to gain mastery [48]. In contrast, many participants felt that the exercises did not challenge them enough in this regard. As a result, participants modified the home-based exercises or focused on outdoor activities instead. On the one hand, this is indicative of the limitations of tablet-supported exercises. A greater variety in difficulty would have better accommodated older adults' needs. On the other hand, the adaptations made by the older adults and their coaches also demonstrated the flexibility of the blended approach of the intervention. The differences between individuals are virtually endless. It is hard to address all the personal preferences with a single tablet application. A too extensive set of exercises and customization options would create usability difficulties. In addition, the home-based exercises were often combined with group-based community programs or outdoor activities. This can be seen as a shortcoming of the intervention, or as a pragmatic approach

in a real-world setting where interventions are never conducted in isolation. Nevertheless, support for a greater variety of physical activities and difficulty levels would be a valuable improvement of the blended intervention, so that it can meet the various needs of a diverse population of older adults.

Besides giving participants a chance to seek greater challenges, outdoor activities also gave them the opportunity to meet other people. This may be one of the reasons the participants did not miss contact with peers while following the home-based exercise program. Various studies have shown that group-based exercises motivate older adults to be physically active due to the social support of peers [29,56,57]. The current study, however, shows that some older adults preferred exercising alone. Previous research suggests that gender differences exist [58–60]. Women are more likely to be motivated by social support than men. In addition, large age differences within a group may be a reason why some older adults prefer exercising alone [61].

Although the blended intervention did not include peer support, coaching was an intrinsic part of the intervention. For some participants, this tied into their need for relatedness, as they developed an emotional bond with their coach. Face-to-face contact appeared to be a prerequisite. In contrast, for other participants the coach fulfilled autonomy and competence needs, especially during the adoption phase. The coach helped them to articulate specific goals, translate those to an exercise schedule and adapt exercises. Furthermore, feedback on performance fostered participants' feelings of competence. This is in line with a large body of evidence that feedback is a decisive factor in physical activity interventions [62–65]. Notably, in the present study, merely monitoring participants' behavior remotely also seemed to have an effect. Several participants indicated that it motivated them to persistent in their exercises. The virtual presence of the coach appears to have incited a form of social facilitation. It increased their exercise frequency. Participants expressed feelings of not wanting to disappoint others. This raises the question though, as to which extent were those participants intrinsically motivated. SDT distinguishes various forms of regulation that determine the degree that motivation has been internalized [48]. With introjected regulation a person is motivated, for instance, by pride or guilt towards others. With identified regulation, on the other hand, a person is motivated by the results they believe a certain behavior will deliver. For instance, the belief that exercising will lead to health benefits. Remarks from the participants hinted at forms of introjected regulation, as well as identified regulation. Empirical evidence has demonstrated that, overall, only the latter form of regulation is effective for long-term adherence to exercise programs [44,66]. There are, however, findings

that suggest introjected regulation can also sustain exercise behavior for women [45]. The ways in which these various forms of motivations affect the long-term adherence to the blended intervention should be addressed by a follow-up study.

Study Limitations

Overall, the blended intervention appears to have met, with some caveats, autonomy, competence and relatedness needs of the older adults that participated in the study. Nevertheless, these conclusions should be drawn with caution. First of all, to which extent coaching contributed distinctively to autonomy, competence or relatedness needs could not always be discerned. For instance, listening to the concerns of participants can be either identified as a form of emotional support, as an effort to adjust the exercise schedule, or both. An interaction with the coach may foster feelings of competence and, at the same time, satisfy the need for relatedness. In general, it seems plausible that an emotional bond did not develop in isolation, but during the counselling on autonomy and competence issues.

Second, the virtual presence of the coach may be seen as an intrinsic part of the intervention, but participants also expressed of being aware that they were part of a scientific study and felt that is was important to adhere to the exercise program. This is clearly a demand effect of the study that most likely influenced both the behavior of the participants, as well as the opinions they have expressed during the interviews. With the salient nature of the intervention, it was not possible to counter these effects with, for instance, a double-blind experimental design.

A third limitation concerns the implementation of the intervention. Due to its reliance on a personal coach, there are scalability issues, particularly if the intervention takes the participants' preference for face-to-face communication into account. The frequency of the contact between the coach and participant was determined by a protocol. The interviews, however, demonstrated that the need for counselling varied a lot amongst participants. If the coaching is limited to the first few crucial months, as several participants have suggested, then the resources needed for coaching can be reduced.

Conclusions

A blended approach to stimulate older adults to be physically active seems to be promising. Technology can support autonomy by letting older adults compile a personalized home-based training that suits their needs. Furthermore, it can foster competence by providing structure, deliver video instructions and track

progress. During the adoption phase, however, involvement of a coach does appear to be crucial to tailor the program to a greater extent. For some older adults, the presence of a coach also helps them to sustain their exercise behavior and leads to an emotional bond. For others, combining the home-based exercises with group-based programs fulfils their needs.

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7

Predicting Exercise Adherence and Physical Activity in Older Adults Based on Tablet Engagement: A Post Hoc Study

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Abstract

Sufficient physical activity can prolong the ability of older adults to live independently. Community-based exercise programs can be enhanced by regularly performing exercises at home. To support such a home-based exercise program, a blended intervention was developed that combined the use of a tablet application with a personal coach. The purpose of the current study was to explore to what extent tablet engagement predicted exercise ad-herence and physical activity. The results show that older adults (n=133; M=71 years of age) who participated for 6 months in a randomized con-trolled trial performed an average of 12 home-based exercises per week and exercised an average of 3 days per week, thereby meeting WHO guidelines. The participants used the tablet app on average 7 times per week. Multiple linear regressions demonstrated that the use of the app statistically predicted the number of exercises that were performed and the number of exercise days. Physical activity, however, did not increase and could not be predicted by exercise frequency or app use. We conclude that engagement with a tablet can contribute to sustained exercise behavior.

Introduction

Aging is associated with a decline in daily functioning and mobility [1,2]. Physical activity can delay the onset and slow down the decline associated with aging. Older adults who exercise on a regular basis can prevent functional impairments and prolong their ability to live independently [3,4]. Various community centers across the world offer senior citizens the opportunity to exercise on a weekly basis in a group under the guidance of an instructor [5–7]. Participating once a week in an exercise group, however, is not sufficient for achieving health benefits [8–10]. The World Health Organization (WHO) guidelines prescribe a higher frequency, intensity and duration of physical activity [11]. Due to the limitations of group-based programs, meeting the guidelines is often not possible [12].

Over the past few years, various eHealth or mHealth interventions have been developed to increase physical activity in older adults [13–19]. To enhance existing community-based exercise programs, a novel blended intervention, VITAMIN, was developed with end users 20,21. The intervention consisted of a personalized home-based exercise program that was supported by a tablet in combination with a personal coach [22,23]. The intervention distinguished itself by a) being designed to complement existing community-based programs rather than a stand-alone intervention, b) specifically supporting home-based exercises, c) using blended technology as a mode of delivery and d) a design that was theoretically based on behavior change techniques. Furthermore, to increase the efficacy of the exercise program, nutrition counseling was also included. A previously conducted randomized controlled trial (RCT) compared the blended home-based exercise program – with or without nutrition counseling – to a control group that only participated weekly in existing community-based exercise programs. The study showed that during the 6-month intervention period, the majority (64.5%) of participants adhered to the recommendation to perform home-based exercises at least two times a week [24]. It remains unclear, however, how participants' engagement with the tablet contributed to exercise adherence. The aim of the present study was not to study the effectiveness of the intervention by comparing it to a control group, which was performed in a recently published RCT study [24], but to explore to what extent tablet engagement predicts exercise adherence in older adults by conducting a secondary analysis of the aggregated data of both RCT groups that received a tablet.

Methods

Technology

A client-server system was developed that consisted of a front-end tablet application for end-users and a back-end web-based dashboard for coaches that guided the participants. The design of the tablet application was based on behavior change techniques that are rooted in self-regulation [22]. The components of the app included an interactive module for goal setting, a library containing over 50 instructional videos of home-based exercises, the possibility to compose a personal training schedule, and the ability to track progress and receive feedback from a personal coach (Figure 1 to Figure 4). A usability study demonstrated that the intended users could operate the app in an effective and efficient manner [21].

Study Design and Recruitment

A randomized clinical trial (RCT) was conducted to assess the effectiveness of the blended intervention regarding health outcomes. The trial consisted of a 6-month intervention period. The RCT had three arms: 1) a control group of older adults who only participated once a week in group-based exercise classes offered by local community centers, 2) a blended exercise group of older adults who received a tablet and coaching to perform individual home-based exercises, in addition to the weekly group-based exercises and 3) a blended exercise plus nutrition group of older adults who received nutrition counseling, in addition to the weekly group-based exercises and individual home-based exercises. Concerning the home-based exercise program, both intervention groups (arms b and c) were identical. The groups only differed whether they received additional nutrition counseling.

Older adults were recruited in the surroundings of Amsterdam, the Netherlands, through either a) addressing visitors of local community centers that were offering weekly group-based exercise classes or b) citizens of Amsterdam through a postal mailing. Applicants were included in the trial if they met the following criteria: 1) 55 years of age or older, which matched the age restrictions the local community centers use, 2) ability to understand the Dutch language and 3) absence of specific cognitive or physical impairments. The protocol that describes the RCT in detail has previously been published [23].

Figure 1. Library of 17 Home-Based Exercises, Each Available In 3 Versions

Figure 2. Example of A Personalized Exercise Schedule

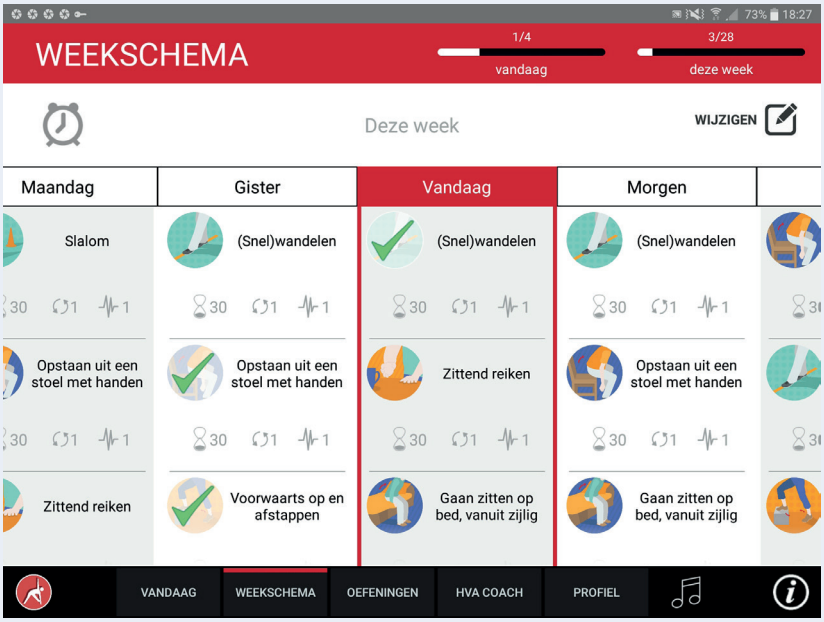


Figure 3. Ability To Modify Each Exercise With Three Parameters

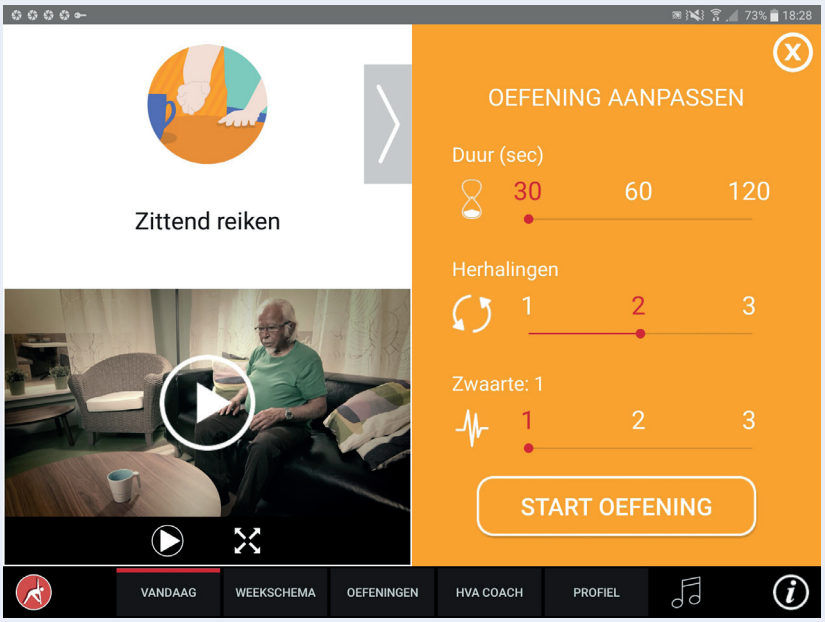
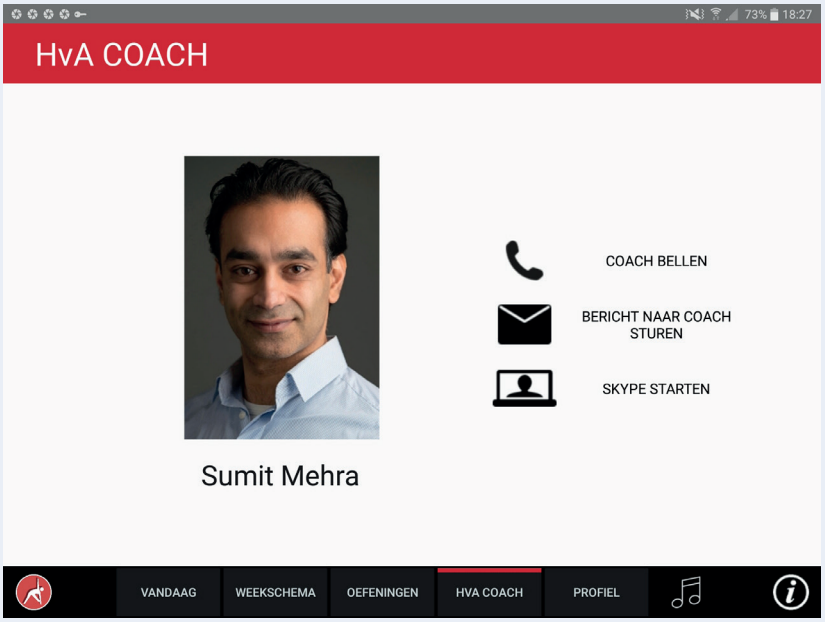


Figure 4. Communication With the Coach (Telephone Call, E-Mail, Video Call)



Measures

Home-based Exercise Adherence

Participants compiled, with the help of an appointed coach, a personalized exercise program with exercises that varied in duration, repetitions and difficulty level. Participants were recommended to perform home-based exercises at least two times a week. During the 6-month intervention period, participants registered with the tablet when they completed their personalized home-based exercises. Based on log data, the following frequencies were determined: a) how many days per week they performed exercises, for example, 4 out of 7 days, and b) the total number of exercises they completed per week.

Tablet Engagement

Based on the log data, the number of times the tablet app was opened per week was determined (app logins) during the 6-month intervention period.

Physical Activity Level

As an exploratory measure, at baseline and after 6 months, the participants' physical activity in daily life was assessed by asking participants to keep track of all activities during a period of 3 days using a paper diary. For each participant, a physical activity level (PAL) was determined by calculating the average metabolic equivalent of task (MET) per 24 hours. A MET value of 1 represents no physical activity, 1 to 3, 4 to 6 and more than 6 MET represents light, moderate and vigorous intensity activity, respectively.

The difference between exercise and physical activity (PA) is that the term exercise refers to planned, structured, repetitive and intentional movement intended to improve or maintain physical fitness [9,25]. In contrast, physical activity refers to all activities that involve bodily movement that requires energy. Thus, the term physical activity is a broader concept that encompasses exercise but also includes, for example, activities such as walking, gardening or doing household tasks.

Motivation

At baseline and after 6 months, motivation to exercise was measured by the Behavioral Regulation in Exercise Questionnaire-2 (BREQ-2), a validated questionnaire containing 19 Likert items on a 5-point scale [26]. The BREQ-2 distinguishes five forms of motivation derived from the self-determination theory: amotivation (4 items), external regulation (4 items), introjected regulation (3 items), identified regulation (4 items) and intrinsic regulation (4 items).

Season

To account for possible seasonal effects, for each participant, the offset to midsummer was calculated by determining the number of days between the date the participant started the intervention and the median of the calendar year (day 183). The minimum score (0) represents midsummer, and the maximum score (182) represents midwinter.

Other

Age, gender, recruitment strategy and assignment to the RCT arm were recorded for all participants.

Table 1. Overview of the Measures Analyzed During the 6-Month Intervention Period.

Start of intervention (baseline)	During intervention (0 to 6 months)	End of intervention (6 months)
Physical Activity Level (PAL)	Exercise adherence: • Number of performed exercises per week • Number of days exercises were performed per week	Physical Activity Level (PAL)
Motivation (BREQ-2)	Tablet engagement: • Number of times app has been used per week	Motivation (BREQ-2)
Participants & intervention characteristics: age, gender, recruitment strategy, RCT-group, season		

Data analysis

Data from participants who were assigned to either group 2 (blended exercise program) or group 3 (blended exercise program with nutrition counseling) were aggregated, resulting in a dataset of all trial participants who received a tablet and coaching to support home-based exercises. For motivation, the five BREQ-2 sub-scales were converted to a single score using the relative autonomy index [27]. For home-based exercise adherence and tablet engagement, after data cleansing, an average score was calculated for the 6-month intervention period. These scores were treated as continuous data in further analyses. To compare differences in physical activity levels before and after the intervention, Student's paired-samples t-test was conducted. The test used a two-sided significance level of .05. Furthermore, multivariate linear regressions were conducted to determine which included variables predicted home-based exercise adherence and physical activity level. The

inclusion of variables as predictors was based on subject-matter knowledge of the authors. The software package SPSS Statistics version 25 was used to perform the analysis (IBM Corp., 2017).

Results

Participants

At baseline, 133 participants were randomly assigned to an intervention group. The average age was 71.48 (SD 6.39) years old, and 92 of the 133 (69.2%) participants were female. In total, 103 of the 133 (77.4%) participants completed the 6-month intervention.

Physical Activity Level, Exercise Adherence and Tablet Engagement

At baseline, the average physical activity level of the participants was 1.49 (SD .14), and after 6 months, it was 1.52 (SD .15). A paired sample t-test revealed that the difference between the physical activity level before and after the intervention was not significant (t_{96}=-1.63, P>=.05).

During the 6-month intervention period, the average app logins per week was 6.72 (SD 4.81). The participants performed, on average, 12.53 (SD 11.34) home-based exercises per week and exercised, on average, 2.88 (SD 1.74) days per week. See Figure 5 to Figure 7 for the weekly progress during the 6-month intervention period.

Figure 5. Average Number of App Logins Per Week During the 26-Week Intervention Period.

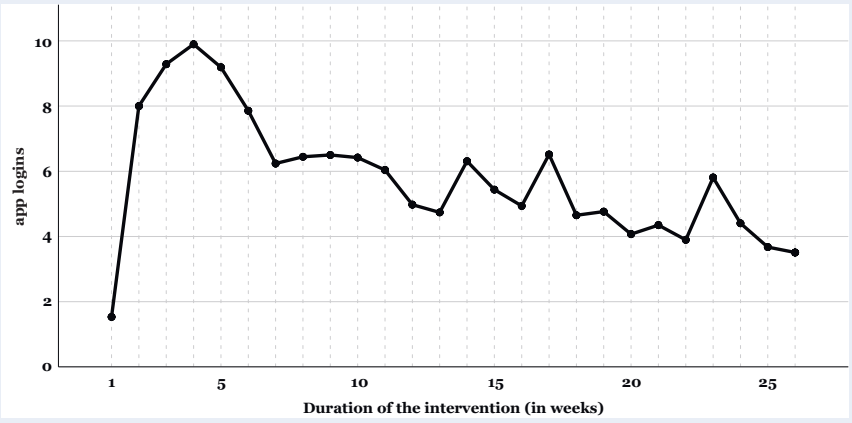


Figure 6. Average Number of Exercises Per Week That Were Performed During the 26-Week Interven-Tion Period.

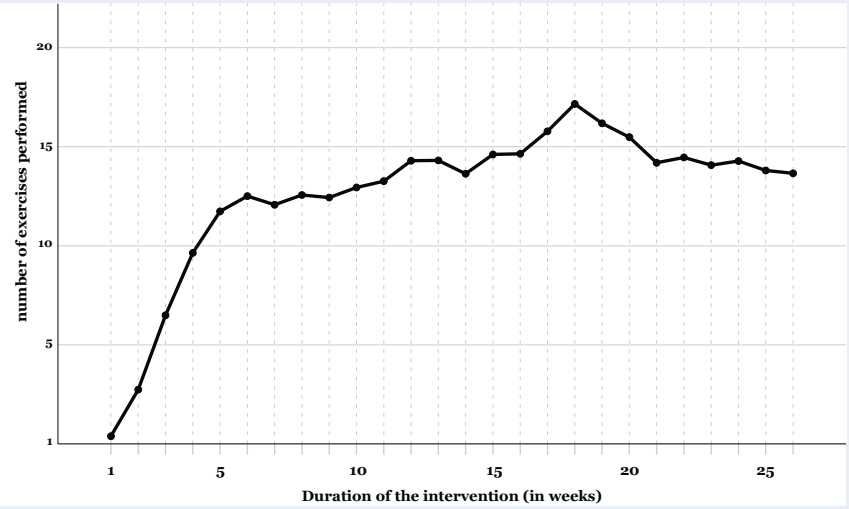
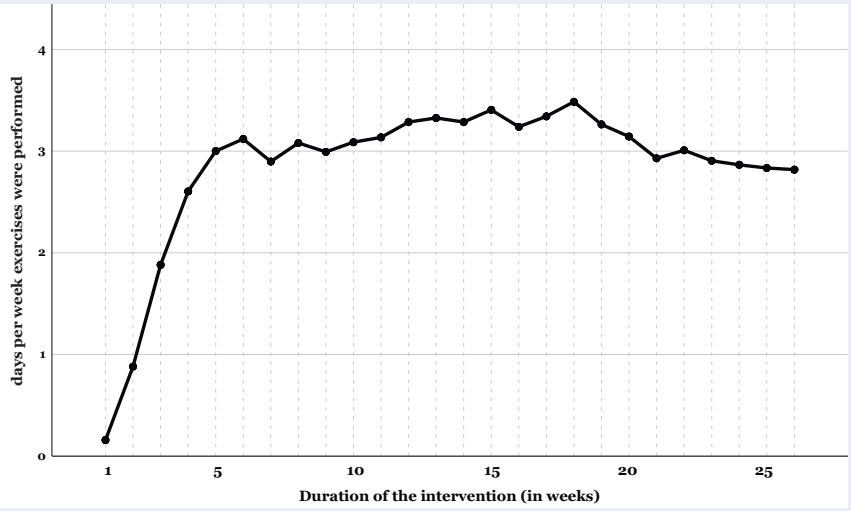


Figure 7. Average Number of Days Per Week Exercise Was Performed During the 26-Week Intervention Period.



Prediction of Exercise Adherence

Prediction of the Number of Exercises Performed Per Week

A multiple linear regression analysis was performed to predict the number of exercises performed per week based on age, gender, motivation (baseline), physical activity level (baseline), RCT group, recruitment strategy, season and average app logins. A significant regression equation was found ($F_{8,115}$=10.26, P<0.001), with an R^2 of .42. Tablet logins, season and recruitment strategy were significant predictors for the number of performed exercises (P<.0005, P=.018, P<.0005, respectively). The number of performed exercises was equal to -2.48 + 1.12 (app logins) + 1.68 (30*offset to midsummer) + 13.43 (recruitment strategy), where recruitment through local community centers is coded as 0 and recruitment through postal mailing is coded as 1. The number of performed exercises increased by 1.12 for each app login, 1.68 for every 30 days the start of the intervention deviated from midsummer and participants recruited through postal mailing performed 13.43 more exercises than participants recruited through local community centers. Age, gender, motivation (baseline), physical activity level (baseline) and RCT group did not significantly predict the number of performed exercises (P>=.05).

Prediction of the Number of Days Per Week Exercises Were Performed

A second multiple linear regression analysis was performed to predict the number of days per week exercises were performed based on age, gender, motivation (baseline), physical activity level (baseline), RCT group, recruitment strategy, season and average app logins. A significant regression equation was found ($F_{8,115}$=8.81, P<0.001), with an R^2 of .38. Tablet logins, season and recruitment strategy were significant predictors for the number of days per week exercise was performed (P<.0005, P=0.029, P=0.007, respectively). The number of days per week exercises were performed was equal to 1.74 + .20 (app logins) + .24 (30*offset to midsummer) + 1.18 (recruitment strategy), where recruitment through local community centers is coded as 0, and recruitment through postal mailing is coded as 1. The number of days per week exercises were performed increased by .20 for each app login, .24 for every 30 days the start of the inter-vention deviated from midsummer and participants recruited through postal mail-ing performed 1.18 more days per week exercises than participants recruited through local community centers. Age, gender, motivation (baseline), physical activity level (baseline) and RCT group did not significantly predict the number of days per week exercises were performed (P>=.05).

Prediction of Physical Activity Level

A third multiple linear regression analysis was performed to predict the physical activity level at the end of the intervention (6 months), based on age, gender, motivation (baseline), physical activity level (baseline), RCT group, recruitment strategy, season, average app logins, average number of exercises performed per week and the average number of days per week exercises were performed. A significant regression equation was found ($F_{10,85}$=11.74, P<0.001), with an R^2 of .58. Age and physical activity level at baseline were significant predictors of physical activity level at 6 months (P=.043, P<.0005, respectively). The physical activity level at 6 months was equal to .77 – 0.03 (10*age) + .63 (PAL-baseline). The physical activity level at 6 months decreased by 0.03 MET for every 10 years increase of participants' age and increased by .77 MET for each increase of MET at baseline. Gender, motivation (baseline), RCT group, recruitment strategy, sea-son, average app logins, average number of exercises performed per week and the average number of days per week exercises were performed did not significantly predict the physical activity level at 6 months (P>=.05).

Discussion

Principal Findings

The aim of the intervention was to support older adults in performing home-based exercises. In a process evaluation performed earlier, participants indicated that they felt the tablet and coach were useful [28]. The results of the current study complement these findings. Data derived from the tablet shows that the participants performed, on average, approximately 13 home-based exercises per week, distributed over 3 days. Participants demonstrated substantive exercise behavior. Participants' engagement with the tablet appears to have contributed to this finding. The frequency of tablet use predicted the number of days and the number of exercises performed. This finding affirms the rationale of the intervention that technology can support exercise behavior in older adults.

Although the main goal of the intervention was not to increase the general physical activity of older adults, PA was included as an explorative measure that could provide evidence for secondary effects of the intervention. This appears, however, not to be the case. The participants' physical activity level after completing the 6-month intervention did not differ from their physical activity level before starting the intervention. Additionally, no association was found between performing home-

based exercises and physical activity. Two competing explanations could account for these findings. First, an increased exercise frequency may not lead to a change in the more general notion of physical activity level. Performing a number of exercises per week may not necessarily lead to a more active lifestyle. The sedentary time can remain unchanged, despite the increase in exercise frequency [29]. To stimulate an active lifestyle in older adults, a broader approach is needed [30–32]. A second competing explanation for the results is that there was an increase in physical activity, but that has gone unnoticed due to the employed procedure of measuring physical activity. The physical activity levels were measured by calculating an average MET score over a 24-hour period. As a result, a meaningful increase in physical activity for one hour each morning, for example, may average out over the day. The lack of variation between participants' physical activity levels, indicated by the low SD in the PAL scores, supports this assumption. A solution could be to calculate the duration and average MET only for periods that contain substantive activity, thereby resulting in a more sensitive measure.

In addition to intervention characteristics, numerous other predictors were found. A seasonal effect on exercise behavior was observed. Participants tended to perform more frequent home-based exercises in the winter than in the summer. The reason for this could be that older adults prefer outdoor activities if the weather allows it, thereby limiting the intensity of a home-based exercise program. Physical activity was also predicted by age. Surprisingly, this effect was minute. The strongest predictor was the participants' physical activity at baseline. Existing habits appear to play a dominant role.

Limitations

Previously, a process evaluation was performed by interviewing participants after they completed the intervention. The conclusions of that study were based on a small number of participants who reflected on their behavior over the past 6 months. In contrast, the current study uses log data of the tablet as a more objective and accurate estimation of exercise behavior for all participants. The study does not rely on participants' recollection from memory. Nevertheless, this data source also has limitations. It cannot be ruled out that participants registered on the tablet that they completed exercises, while in reality they did not perform any exercises. The tablet data on exercise completion remains a self-report measure.

Tablet engagement was measured by tracking how often users opened the app. Based on the log data, however, it was not possible to observe how users interacted with

the app. Consequently, no conclusions can be drawn regarding which components within the app played a specific role. Furthermore, due to technical issues, the number of app logins was not registered flawlessly. As a result, some data points on tablet engagement were unusable. To determine if this influenced the results, an alternative measure for tablet activity was used. Participants were asked with a questionnaire how often on average they used the app over the past 6 months. Analysis of this alternative measure was similar to the analysis based on app logins, indicating that use of the app logins was not problematic, despite technical errors.

This post hoc study combined data from two groups that participated in the randomized controlled trial: a group that received tablets and coaching and a group that received tablets, coaching and nutrition advice. Although the two groups differed in which intervention component they were exposed, the analysis used in this study did not reveal any association between group membership and exercise behavior or physical activity. This validated the choice of the authors to pool the data of both groups instead of performing the described analysis for both groups separately.

Conclusions

The blended exercise intervention successfully increased the exercise frequency in older adults. Tablet engagement appears to have contributed to this increase. The frequency of app use predicted the number of exercises, and the number of days exercises were performed. The findings suggest that the use of a tablet, in combination with coaching, is a promising strategy to stimulate exercise behavior in older adults. More research is needed on how to incorporate general physical activity.

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8

General Discussion

Principal Findings

The central research question of this thesis was *"how can mHealth be employed, in a blended manner, to support older adults in performing home-based exercises, as a supplement to a group-based community exercise program?"*. This research question was addressed by developing and evaluating an intervention according to the MRC framework for complex interventions. In Chapter 2, the current evidence base is identified by exploring the motives and attitudes of older adults who were participating in existing group-based exercise classes offered by More Exercise for Seniors. In line with the three basic psychological needs of the self-determination theory – autonomy, relatedness and competence – the focus group interviews revealed that maintaining self-reliance and keeping in touch with others were the main motives to participate in the group-based exercise classes. The participants recognized the benefits of performing additional home-based exercises but had concerns regarding safety, guidance and perseverance. The majority of the participants were open to the idea that technology could address those concerns. Chapter 3 describes how this can be implemented. A blended intervention was developed that consisted of a tablet application that was combined with personal guidance by a coach. The underlying design choices were underpinned by behavior change techniques that were rooted in self-regulation. The key components of the blended intervention were designed to support goal setting, action planning, behavior execution, monitoring and evaluation. Chapter 4 describes how the usability of the tablet application was studied in a laboratory setting. First-time users completed a series of tasks in an efficient and effective manner. Overall, the participants reacted positively to the app. However, they did require some help with complex tasks such as tailoring a personal training schedule. Chapter 5 describes a process evaluation of the experiences of older adults who had used the tablet in conjunction with coaching in daily life for six months. Participants who completed the USE questionnaire assessed the tablet application as useful, satisfying and easy to use. The tablet helped them to perform the exercises more often, better and safely. Follow-up interviews revealed the underlying change process. Participants felt that the tablet supported them in action planning, behavior execution and self-monitoring by providing a weekly exercise schedule that could be tailored, including video demonstrations how to perform the exercises safely and the ability to track their progress. Nevertheless, they also felt the availability of the coach to be crucial, especially during the first few months. The coach could adapt the exercises to a greater extent to the needs of the individual and reflect on the progress that had

been made. Furthermore, for some participants, the fact that they were remotely monitored was motivating. Chapter 6 expands on the motivational aspects by presenting a secondary analysis of the interviews. The blended intervention supported the autonomy of participants, fostered competence and, for some, met the need for relatedness by offering emotional support. Finally, Chapter 7 describes the exercise behavior the participants exhibited. Older adults who participated in the blended intervention performed on average 13 home-based exercises per week and exercised 3 days per week on average, in line with WHO guidelines [1]. Linear regressions revealed that the application logins predicted the number of exercises and the number of days exercises were performed, suggesting that the tablet contributed to the exercise behavior of the older adults.

Contribution

This thesis has demonstrated in a transparent manner how a blended intervention can support older adults in performing additional home-based exercises. The intervention expands on the infrastructure and social relations of an existing group-based program. It is rooted in behavior change techniques that support self-regulation of exercise behavior, is implemented on a user-friendly tablet application and is enhanced by a coach for personal guidance and emotional support. The strength of the intervention lies in the blended use of technology. The tablet application supports older adults in self-regulating their exercise behavior in their own home environment, not solely depending on group-based exercise classes offered by community centers. The intervention, however, also keeps human aspects in the loop. Coaches can adapt exercises on the spot beyond the tailoring abilities of an app. Furthermore, they offer emotional support and social facilitation that technology-only solutions yet have to achieve [2–4]. At the same time, the tablet provides participants with the opportunity to engage with a personalized exercise program at any time or in any place they see fit. This blended combination can increase the efficacy of health interventions. The older adults who participated in the VITAMIN intervention demonstrated an exercise pattern in line with WHO guidelines and reported the blended intervention to be supportive.

Recommendations

The MRC framework was a useful model to develop and assess the blended intervention described in this thesis. It provides a general structure, describing during which stage each activity should be undertaken, but is flexible at the same time. It does not prescribe which techniques should be employed during each phase. In this thesis, for instance, various research paradigms were combined.

Focus groups, user-centered design, task performance, think-aloud protocol, questionnaires, interviews and inferential statistics were used to develop and evaluate the intervention. The MRC framework does not provide guidance on how these techniques should be employed. In contrast, it provides a helicopter view that challenges researchers to take a broader perspective, such as combining practice-based evidence with academic theories and conducting rigorous piloting, not relying only on randomized controlled trials as a gold standard but also conducting auxiliary evaluations of underlying change processes. The flexibility and broad scope of the MRC framework make it, understandably, a popular model that can be recommended to other researchers developing interventions similar to that described in this thesis.

For future work, some more specific recommendations can be given. Tailoring is an important success factor of eHealth and mHealth interventions [5]. The form of tailoring a digital application offers has been determined in advance during the design and development phase. Furthermore, the extent to which it has been used in practice by participants can, in principle, be determined afterwards by studying the log data, under condition the interactions with the app are carefully logged. The intricate tailoring offered by a coach, however, is less well defined. Although coaches can be trained to follow a set of standardized techniques, each coach draws on his own set of skills, experiences and approaches. For instance, it is difficult to keep track of which coaching techniques were used for which participant at which moment. To study the effects of coaching, researchers should incorporate the assessment of intervention fidelity, i.e., the extent to which the intervention is implemented as intended by the developers [6]. Various frameworks exist that can help researchers achieve this task [7–10]. Furthermore, studying the coaching process in more detail provides developers with a basis to decide which aspects can be automated and which not [11].

Another recommendation is related to the modality of the intervention. By definition, in a blended intervention, such as the VITAMIN app, the use of technology and human effort are inherently intertwined. Although the relative contribution of each component could be denoted in the process evaluation, no firm conclusions can be drawn regarding the general usefulness of each component. For instance, participants may have evaluated the usefulness of the tablet entirely differently if no coaching was offered, or vice versa. If the research aim is to qualify the contribution of each component, then a factorial design should be applied that includes both technology- and coaching-only groups. This could further the case of blended

interventions by benchmarking them against other intervention modalities.

A final suggestion for future work is to explore other combinations of technology and personal guidance. Incorporating human coaching is labor-intensive and limits the possibility of scaling up the intervention. Technology can, however, assist coaching by making it a more effective and efficient process. The blended intervention described in this thesis, for instance, allows coaches to remotely review participants' progress before initiating a conference call. In future work, perhaps the tablet can provide an ongoing analysis of deviating exercise performance and signal a coach to intervene, thereby increasing the timeliness of the guidance and sparing resources when they are not needed. Furthermore, in-depth analysis of exercise patterns can also be directly fed back to participants with various visualizations, thereby increasing their self-insight.

Another option to enhance coaching with technology is to provide coaches with predefined motivational messages [12–14]. This allows coaches to interact more frequently with participants, thereby increasing their virtual presence. This thesis has shown that this can motivate participants to persevere in their exercise habits. These are merely a few examples of how technology and human guidance can reinforce each other in helping older adults attain health benefits.

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Abbreviations
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Abbreviations

ADL	activities of daily living
App	software application
AUAS	Amsterdam University of Applied Sciences
BCT	behavior change techniques
BREQ-2	Behavioral Regulation in Exercise Questionnaire-2
CALO-RE	Conventry, Aberdeed & London-Refined taxonomy
eHealth	the use of information and communication technologies for health
ICT	information and communication technology
IT	information technology
MBvO	Meer Bewegen voor Ouderen (More Exercise for Seniors community program)
MET	Metabolic Equivalent of Task
mHealth	the use of mobile technologies for health
MOTO-B	AUAS research project Motivating Technology for Older Adults' Behavior
MRC	Medical Research Council, UK
NWO	Nederlandse Organisatie voor Wetenschappelijk Onderzoek (Dutch Research Council)
PA	Physical Activity
PAL	Physical Activity Level
RCT	Randomized Controlled Trial
USE	Usefulness, Satisfaction and Ease of Use
VITAMIN	AUAS research project VITal Amsterdam elderly IN the city
WHO	World Health Organization

Statement of Contribution

Chapter 1 General Introduction

- This chapter has been written by Sumit Mehra. Bart Visser, Peter J.M. Weijs and Ben J.A. Kröse have guided the writing.

Chapter 2 Attitudes of Older Adults in a Group-Based Exercise Program Toward a Blended Intervention; A Focus-Group Study

- This publication has been written by Sumit Mehra. Tessa Dadema, Ben J.A. Kröse, Bart Visser, Raoul H.H. Engelbert, Jantine van den Helder, Peter J.M. Weijs were co-writers. All authors have approved the content.
- The research was set up by Sumit Mehra, Tessa Dadema, Ben J.A. Kröse, Bart Visser, Raoul H.H. Engelbert and Peter J.M. Weijs.
- The research was carried out by Sumit Mehra and Tessa Dadema.
- The research was supervised by Ben J.A. Kröse, Bart Visser, Raoul H.H. Engelbert and Peter J.M. Weijs.

Chapter 3 Translating Behavior Change Principles Into a Blended Exercise Intervention for Older Adults: Design Study

- This publication has been written by Sumit Mehra. Bart Visser, Tessa Dadema, Jantine van den Helder, Raoul H.H. Engelbert, Peter J.M. Weijs and Ben J.A. Kröse were co-writers. All authors have approved the content.
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- The research was carried out by Sumit Mehra.
- The research was supervised by Bart Visser, Raoul H.H. Engelbert, Peter J.M. Weijs and Ben J.A. Kröse.

Chapter 4 Supporting Older Adults in Exercising With a Tablet: A Usability Study

- This publication has been written by Sumit Mehra. Bart Visser, Nazli Cila, Jantine van den Helder, Raoul H.H. Engelbert, Peter J.M. Weijs and Ben J.A. Kröse were co-writers. All authors have approved the content.
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- The research was carried out by Sumit Mehra.
- The research was supervised by Bart Visser, Raoul H.H. Engelbert, Peter J.M. Weijs and Ben J.A. Kröse.

Chapter 5 Evaluation of a Blended Physical Activity Intervention for Older Adults: Mixed Methods Study

- This publication has been written by Sumit Mehra. Jantine van den Helder, Bart Visser, Raoul H.H. Engelbert, Peter J.M. Weijs and Ben J.A. Kröse were co-writers. All authors have approved the content.
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- The research was carried out by Sumit Mehra.
- The research was supervised by Bart Visser, Raoul H.H. Engelbert, Peter J.M. Weijs and Ben J.A. Kröse.

Chapter 6 Aging and Physical Activity: A Qualitative Study of Basic Psychological Needs and Motivation in a Blended Home-Based Exercise Program for Older Adults

- This publication has been written by Sumit Mehra. Jantine van den Helder, Ben J.A. Kröse, Raoul H.H. Engelbert, Peter J.M. Weijs and Bart Visser were co-writers. All authors have approved the content.
- The research was set up by Sumit Mehra, Jantine van den Helder, Ben J.A. Kröse, Raoul H.H. Engelbert, Peter J.M. Weijs and Bart Visser.

- The research was carried out by Sumit Mehra.
- The research was supervised by Ben J.A. Kröse, Raoul H.H. Engelbert, Peter J.M. Weijs and Bart Visser.

Chapter 7 Predicting Exercise Adherence in Older Adults Based on Tablet Engagement: A Post Hoc Study

- This publication has been written by Sumit Mehra. Jantine van den Helder, Ben J.A. Kröse, Raoul H.H. Engelbert, Peter J.M. Weijs and Bart Visser were co-writers. All authors have approved the content.
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- The research was carried out by Sumit Mehra.
- The research was supervised by Ben J.A. Kröse, Raoul H.H. Engelbert, Peter J.M. Weijs and Bart Visser.

Chapter 8 General Discussion

- This chapter has been written by Sumit Mehra. Bart Visser, Peter J.M. Weijs and Ben J.A. Kröse have guided the writing.

Summary

Chapter 1. Many countries are facing an aging population. Aging is associated with a decline in the ability to carry out daily tasks. Physical activity can delay or diminish this decline and to increase the ability of older adults to live independently at home. To promote physical activity in older adults, local community centers offer exercise classes for senior citizens. In the Netherlands, for instance, approximately 300,000 older adults participate weekly in the nationwide program More Exercise for Seniors ('*Meer Bewegen voor Ouderen*' in Dutch, or in short MBvO). Exercising once a week in programs such as MBvO, however, is not enough to have an effect on fitness or physical health. To attain health benefits, World Health Organization (WHO) recommends adults the following:

a) At least 150 minutes of moderate-intensity aerobic physical activity should be done throughout the week, in bouts of at least 10 minutes duration
b) Muscle-strengthening activities involving major muscle groups should be performed on 2 or more days a week.
c) Older adults with poor mobility should perform physical activity to enhance balance and prevent falls on 3 or more days per week.

Combining a weekly group-based exercise program with additional home-based exercises can help older adults to meet the WHO guidelines. In recent years, various eHealth interventions have delivered home-based exercise programs. eHealth interventions that incorporate human guidance and feedback are associated with increased efficacy. Such blended interventions for older adults, nonetheless, are rare. This has led to the following research question:

How can mHealth be employed, in a blended manner, to support older adults in performing home-based exercises, as a supplement to a group-based community exercise program?

To address this research question, the VITAMIN intervention was developed and evaluated according to the Medical Research Council (MRC) framework.

Chapter 2. To explore the attitudes of older adults toward a blended exercise program, eight focus groups were held with 48 older adults who were participating in the MBvO program. Because of the certain circumstances, the results of 30

participants, who had an average age of 74 years, were included in the analysis. Transcripts were analyzed according to the three constructs of the self-determination theory: autonomy, competence and relatedness. To increase reliability, the transcripts were coded independently by two researchers. The analysis of the transcripts shows that maintaining self-reliance (autonomy) and keeping in touch with others (relatedness) were the main motives to participate in the weekly group-based exercises. Participants recognized the benefits of doing additional home-based exercises, but they had concerns regarding motivation, guidance and safety (competence). Furthermore, a few participants strongly rejected the idea of using technology to support them in performing exercises at home, but the majority were open to it.

Chapter 3. Physical activity interventions that are based on scientific theory are associated with increased efficacy. The ACM, IEEE, Google Scholar, PsycINFO and PubMed databases were consulted to identify the relevant literature. This led to three design considerations that formed the basis of the VITAMIN intervention:

1) Rather than promoting general physical activity, the intervention should consist of functional exercises that target the four domains that are relevant for activities of daily living: muscle strength, flexibility, balance and endurance.
2) To increase exercise adherence, the intervention should be based on behavior change. In particular, the behavior change techniques that support self-regulation should include the following: goal-setting, action planning, behavior execution, self-monitoring and evaluation.
3) The intervention should use blended technology. Interventions, such as eHealth and mHealth, which incorporate personal guidance, feedback and tailoring, appear to be more effective.

The design considerations have been translated into numerous requirements and functional components. The intervention has been implemented on a client-server system that combines a tablet application (app) for older adults with a web-based dashboard for coaches who remotely monitor and guide participants. The choice of using a tablet was based on the usability of the device and its popularity among older adults in the Netherlands and other countries. Key components of the app are an exercise schedule that can be tailored to individual needs, video demonstrations of functional exercises, a stopwatch timer, (self-)monitoring of exercise adherence and the possibility of receiving feedback from a remote coach.

Chapter 4. The MRC framework prescribes thorough piloting of an intervention prior to conducting a randomized controlled trial. Assessing the usability of eHealth and mHealth applications is often overlooked, leading to efficacy studies of interventions that have not yet matured, resulting in problems that could have been prevented with sufficient testing. To assess usability, 15 older adults, ranging from 69 to 99 years old, tested the VITAMIN app in a laboratory setting. The study used mixed methods, combining task performance, verbalization and interviews. To evaluate effectiveness and efficiency, time-on-task and success rates were calculated for a series of tasks that participants had to execute on the tablet. Satisfaction was evaluated by asking the participants to think aloud during the execution of the tasks. After performing the tasks, participants were interviewed about their overall impression of the app. Analysis of the results showed that the participants spent 13 to 85 seconds time-on-task. Moreover, 79% to 100% of the participants successfully completed basic tasks with either no help or after having received 1 hint. For expert tasks, they needed a few more hints. During the posttest interview, the participants made 3 times more positive remarks about the app than negative remarks. The study indicates that the app that was developed is usable by the target audience. First-time users were able to perform basic tasks in an effective and efficient manner. Tasks that were associated with behavior execution and evaluation were performed with ease. Complex tasks such as tailoring a personal training schedule needed more effort. In general, the participants were satisfied with the app.

Chapter 5. A process evaluation was carried out to assess the long-term use of the app in a real-world setting as well as to explore how the app, in conjunction with a personal coach, supported older adults in performing home-based exercises. The study used mixed methods, combining questionnaires with interviews. Older adults who participated in a randomized controlled trial completed a survey about prior experience with ICT devices (N=65) and, after 6 months of participation, completed the USE questionnaire (N=37) that assessed the usefulness, satisfaction and ease of use of the VITAMIN app. Furthermore, with a random selection of participants, follow-up interviews were held (N=17) to assess how the blended intervention supported them in performing home-based exercises. To increase reliability, two researchers independently coded the transcripts with the five phases of self-regulation: goal setting, action planning, behavior execution, self-monitoring and evaluation. Analysis of the ICT survey showed that the large majority of participants already had experience with a tablet, used it regularly, and reported being skillful in operating ICT devices. After 6 months of use, the participants rated the usefulness, satisfaction, and ease of use of the tablet on average as 3.8, 4.2, and 4.1, respectively,

on a 5-point scale. The analysis of the interviews showed that the participants felt that the tablet supported action planning, behavior execution, and self-monitoring. On the other hand, especially during the first few months, the personal coach added value during the goal setting, behavior execution, and evaluation phases of self-regulation. The results of the process evaluation show that older adults who participated in the study were positive about the blended intervention. Participants reported that the tablet helped them to perform the exercises better, more frequently, and safely, and that it supported them in various phases of self-regulation. The availability of a personal coach was nevertheless crucial.

Chapter 6. Self-determination theory is a dominant motivation theory that has proven to be useful for understanding adherence to exercise programs. To be intrinsically motivated, this theory postulates that three basic psychological needs have to be met: autonomy, competence and relatedness. To determine how the blended intervention influenced exercise motivation, the interviews were analyzed from a basic needs perspective. To increase reliability, two researchers independently coded the transcript with the three basic needs by following the directed content analysis method. The analysis revealed that the intervention supported the autonomy of participants by letting them set their own personal goals and compile a personalized exercise program; it also supported their feelings of competence by offering clear instructions, structure and the ability to track their progress. Finally, some participants valued the emotional support offered by the personal coach, while others preferred combining home-based exercises with group-based activities with peers to fulfill their relatedness needs. In conclusion, the blended intervention appears to meet the three basic psychological needs that lead to intrinsic motivation, which in turn is associated with exercise adherence.

Chapter 7. To investigate the behavior participants exhibited, a post hoc study was conducted on clinical trial data that were logged with the tablet. The tablet data demonstrated that older adults (n=133; M=71 years of age) who participated for 6 months in a randomized controlled trial performed an average of 12 home-based exercises per week and exercised an average of 3 days per week, thereby meeting WHO guidelines. To explore how the use of the tablet contributed to this pattern, multiple linear regressions were performed on the data. The analysis shows that the use of the app predicted the number of exercises that were performed and the number of days that exercises were performed. Furthermore, effects of season and recruitment strategy on exercise behavior were also found. Physical activity, however, did not increase during the 6-month intervention period and could not be

predicted by either exercise behavior or app use. The findings suggest that the use of the tablet contributed to the success of the blended intervention to stimulate exercise behavior in older adults. More research is needed on how blended interventions can also include general physical activity.

Chapter 8. In summary, the principal findings of this thesis are that older adults are motivated to perform technology-supported home-based exercises if they help them maintain self-reliance and there is sufficient guidance, safety is taken into account, and adherence is stimulated. A blended intervention that incorporates functional exercises is based on behavior change and relies on human guidance to meet those needs. The tablet application that has been developed for this purpose is usable by the target audience. A process evaluation has shown that the tablet as well as the coach support older adults in the various phases of self-regulating their exercise behavior. The blended intervention stimulates intrinsic motivation by supporting the autonomy of participants, fostering competence and, for some, meeting the need for relatedness by offering emotional support. Data derived from the tablet demonstrate that older adults participating in the intervention exhibit exercise behavior that is in line with WHO guidelines and that engagement with the tablet was a contributing factor. Future work should include assessment of intervention fidelity and explore which aspects of coaching can and cannot be further automated.

Samenvatting

Hoofdstuk 1. Veel landen kampen met een bevolking die vergrijst. Veroudering gaat gepaard met een afnemende capaciteit om dagelijkse taken uit te voeren. Lichamelijke activiteit kan deze achteruitgang vertragen of verminderen en daarmee bijdrage aan het vermogen van ouderen om zelfstandig thuis te wonen. Om actief bewegen bij ouderen te stimuleren bieden buurtcentra beweegprogramma's voor senioren aan. In Nederland, bijvoorbeeld, participeren circa 300.000 ouderen wekelijks in het landelijke programma Meer Bewegen voor Ouderen (MBvO). Om de fysieke conditie te verbeteren, is één keer per week deelnemen aan een groepstraining zoals MBvO echter onvoldoende. Om gezondheidswinst te boeken raadt de Wereldgezondheidsorganisatie het volgende aan:

a) Minimaal 150 minuten per week matig-intensieve aerobe fysieke activiteit, in periodes van minstens 10 minuten
b) Twee keer per week spierversterkende activiteiten, waarbij de belangrijkste spiergroepen worden gebruikt
c) Ouderen dienen minimaal 3 keer per week fysieke activiteiten te doen die het evenwichtsgevoel vergroten en vallen voorkomen

Het beweegprogramma met wekelijkse groepsbijeenkomsten combineren met het thuis doen van oefeningen kan ouderen helpen om de richtlijnen van de Wereldgezondheidsorganisatie te behalen. De afgelopen jaren zijn er verschillende eHealth interventies ontwikkeld die het thuis uitvoeren van oefeningen ondersteunen. Vooral eHealth interventies die gebruik maken van menselijke begeleiding en persoonlijke feedback zijn succesvol. Dergelijke blended beweeginterventies voor ouderen zijn echter zeldzaam. Dit heeft geleid tot de volgende vraagstelling:

> Hoe kan mHealth, op een blended wijze, worden ingezet om ouderen te ondersteunen in het thuis uitvoeren van oefeningen, in aanvulling op beweegprogramma's die buurtcentra aanbieden?

Om deze onderzoeksvraag te beantwoorden is de VITAMINE interventie ontwikkeld en geëvalueerd volgens het Medical Research Council (MRC) raamwerk.

Hoofdstuk 2. Om de attitudes van ouderen over een blended beweegprogramma te verkennen, zijn er acht focusgroepen gehouden met 48 ouderen die deelnamen aan

het MBvO programma. Door omstandigheden zijn bijdragen van 30 deelnemers, met een gemiddelde leeftijd van 74 jaar, geanalyseerd. Om de betrouwbaarheid te vergroten hebben twee onderzoekers onafhankelijk van elkaar de transcripten van de interviews gecodeerd met de drie determinanten van de zelf-determinatie theorie: autonomie, competentie en verbondenheid. De uitkomsten toonde aan dat behoud van zelfredzaamheid (autonomie) en het in contact blijven met anderen (verbondenheid) de belangrijkste drijfveren waren om deel te nemen aan de wekelijkse groepstraining. De deelnemers zagen de voordelen van het thuis uitvoeren van oefeningen, maar hadden bedenkingen over de motivatie die nodig is om vol te houden, het ontbreken van begeleiding en de veiligheid zonder toezicht (competentie). Een aantal deelnemers was sceptisch over het gebruik van technologie, maar de meerderheid stond ervoor open.

Hoofdstuk 3. Beweeginterventies die zijn gebaseerd op wetenschappelijke inzichten zijn effectiever. De ACM, IEEE, Google Scholar, PsychINFO en PubMed databanken zijn geraadpleegd om relevante literatuur te vinden. Dit heeft geleid tot drie uitgangspunten waarop de VITAMINE interventie is gebaseerd:

1) In plaats van algemene lichaamsbeweging, dient de interventie te bestaan uit functionele oefeningen die gericht zijn op de vier domeinen die relevant zijn voor het dagelijks functioneren: spierkracht, flexibiliteit, evenwicht en uithoudingsvermogen.
2) Om deelname aan het beweegprogramma langdurig vol te houden, dient de interventie gericht te zijn op gedragsverandering. In het bijzonder, dienen gedragsveranderingstechnieken worden ingezet die zelfregulatie ondersteunen: doelen stellen, actieplan opstellen, doelgedrag uitvoeren, zelfmonitoring en evaluatie.
3) De interventie dient gebruik te maken van blended technologie. eHealth en mHealth interventies die persoonlijke begeleiding, feedback en maatwerk integreren, blijken effectiever te zijn.

De uitgangspunten zijn vertaald naar diverse ontwerpeisen en functionaliteiten. De interventie is geïmplementeerd met een client-server systeem dat een tabletapplicatie (app) voor ouderen combineert met een website voor coaches die deelnemers op afstand kunnen monitoren en begeleiden. De keuze voor een tablet was gebaseerd op de gebruikersvriendelijkheid en de populariteit van het apparaat onder ouderen. Kernonderdelen van de app zijn het opstellen van een persoonlijk weekschema dat aansluit bij de individuele behoeften, een timer functie, de mogelijkheid om

bij te houden welke oefeningen zijn uitgevoerd en de mogelijkheid om feedback te ontvangen van een coach op afstand.

Hoofdstuk 4. Het MRC-raamwerk schrijft voor dat de interventie eerst grondig getest moet worden, voordat een gerandomiseerde studie naar de effectiviteit wordt uitgevoerd. De bruikbaarheid van eHealth en mHealth interventies evalueren wordt vaak over het hoofd gezien. Dit leidt tot effectiviteitsstudies van interventies die niet voldoende zijn doorontwikkeld en derhalve tekortkomingen bevatten die voorkomen hadden kunnen worden. Om de bruikbaarheid te beoordelen, hebben 15 ouderen, variërend van 69 tot 99 jaar oud, binnen een gestandaardiseerde laboratorium omgeving de VITAMINE app getest. Het testen bestond uit het uitvoeren van een serie taken waarbij *mixed-methods* werd ingezet om verschillende aspecten van bruikbaarheid te bepalen. De effectiviteit en efficiëntie zijn beoordeeld op basis van prestatiematen zoals de benodigde tijdsduur en het succesvol kunnen uitvoeren van de taak met of zonder aanwijzingen. De tevredenheid met de app werd bepaald aan de hand van de *think aloud* (hardop denken) methode. Tot slot werden de deelnemers geïnterviewd over hun algemene indruk van de app. De resultaten laten zien dat de gemiddelde taakduur varieerde van 13 tot 85 seconden. 79% tot 100% van de deelnemers kon de standaardtaken succesvol afronden zonder hulp of met slechts een enkele aanwijzing. Voor complexe taken hadden de deelnemers meer aanwijzingen nodig. Tijdens het afsluitende interview maakten de deelnemers 3 maal zo vaak een positieve opmerking dan een negatieve opmerking over de app. Het onderzoek wijst uit dat de VITAMINE app bruikbaar is voor de doelgroep. Nieuwe gebruikers konden de standaardtaken efficiënt en effectief uitvoeren. Taken die betrekking hadden op het uitvoeren van oefeningen en de evaluatie, werden met gemak uitgevoerd. Complexe taken zoals het opstellen van een persoonlijk weekschema vergde meer inspanning. In het algemeen waren de deelnemers positief over de app.

Hoofdstuk 5. Om het langdurig gebruik van de app in de praktijk te bestuderen, en de combinatie met persoonlijke coaching, is een procesevaluatie uitgevoerd. Voor het onderzoek werden zowel vragenlijsten als interviews afgenomen. Ouderen die deelnamen aan een gerandomiseerde studie met controlegroep (RCT) vulden bij aanvang een vragenlijst in over hun ervaring met ICT-apparaten (N=65), en na 6 maanden deelname de USE-vragenlijst (N=37) waarmee ervaren nut, tevredenheid en gebruiksgemak van de VITAMINE app werd gemeten. Hiernaast is er met een aantal willekeurig geselecteerde deelnemers (N=17) een aanvullend interview gehouden om te achterhalen op welke wijze de blended interventie hen hielp bij het

uitvoeren van thuisoefeningen. Om de betrouwbaarheid te vergroten hebben twee onderzoekers onafhankelijk van elkaar de transcripten van de interviews gecodeerd met de vijf fasen van zelfregulatie: doelen stellen, actieplan opstellen, doelgedrag uitvoeren, zelf-monitoring en evaluatie. De uitkomsten van de ICT-vragenlijst laat zien dat de overgrote meerderheid van de deelnemers al ervaring had met tablets, deze regelmatig gebruikte en zichzelf bekwaam voelde in het bedienen van ICT-apparaten. De deelnemers beoordeelden na 6 maanden gebruik ervaren nut, tevredenheid en gebruiksgemak van de VITAMINE app met respectievelijk een 3,8, 4,2 en 4,1 op een 5-puntsschaal. De analyse van de interviews laat zien dat de deelnemers de indruk hadden dat de tablet hen ondersteunde bij het maken van een actieplan, het doelgedrag uitvoeren en de zelf-monitoring. Hierbij werd aangegeven dat de persoonlijke coach, vooral tijdens de eerste paar maanden, een toegevoegde waarde had met betrekking tot het stellen van doelen, het doelgedrag uitvoeren en de evaluatie. De procesevaluatie toont aan dat de ouderen die deelnamen aan het onderzoek positief zijn over de blended interventie. De deelnemers gaven aan dat de tablet hen hielp om de oefeningen beter, vaker en veiliger uit te voeren, alsmede hen hielp bij de verschillende fasen van zelfregulatie. Hiernaast bleek dat de ondersteuning van een persoonlijke coach in de eerste paar maanden cruciaal te zijn.

Hoofdstuk 6. De zelfdeterminatie-theorie is een toonaangevende motivatietheorie die nuttig is om volharding van deelnemers aan een beweegprogramma te begrijpen. Om intrinsiek gemotiveerd te zijn, stelt deze theorie dat aan drie psychologische basisbehoeften voldaan moeten worden: autonomie, competentie en verbondenheid. Om na te gaan hoe de blended interventie beweegmotivatie heeft beïnvloed, zijn de interviews ook geanalyseerd vanuit het perspectief van deze psychologische basisbehoeften. Om de betrouwbaarheid te vergroten hebben twee onderzoekers onafhankelijk van elkaar de transcripten van de interviews met de drie basisbehoeften gecodeerd, volgens de *directed content analysis* methode. Uit de analyse blijkt dat de interventie de autonomie van deelnemers ondersteunde door hen de mogelijkheid te bieden om persoonlijke doelen te stellen en een gepersonaliseerd weekschema te samenstellen. Tevens werd de competentie bevorderd door het bieden van duidelijke instructies, structuur en de mogelijkheid om de voortgang te bijhouden. Ten slotte, sommige deelnemers waardeerde de emotionele steun die de coach bood, terwijl andere deelnemers de verbondenheid opzochten door de thuisoefeningen te combineren met het buitenshuis samen sporten met anderen. Samenvattend, de blended interventie blijkt de drie psychologische basisbehoeften te vervullen die nodig zijn voor de intrinsieke motivatie om het beweegprogramma

vol te houden.

Hoofdstuk 7. Om het beweeggedrag van de deelnemers te bestuderen, is er een post-hoc analyse uitgevoerd op de data die is verkregen door de tabletactiviteit te registreren. De tabletdata toonde aan dat de ouderen die 6 maanden hebben deelgenomen aan de gerandomiseerde studie (N=133, M=71 jaar oud) gemiddeld 12 oefeningen per week uitvoerde, verspreid over 3 dagen in de week. Dit is in lijn met de aanbevelingen van de Wereldgezondheidsorganisatie. Om te verkennen in welke mate het tabletgebruik hieraan heeft bijgedragen, zijn er lineaire regressies uitgevoerd. De analyses tonen aan dat het gebruik van de VITAMINE app het aantal oefeningen en het aantal beweegdagen voorspelde. Hiernaast is er een effect van seizoen en wervingsstrategie op beweeggedrag gevonden. De bevindingen wijzen uit dat het tabletgebruik heeft bijgedragen aan het succes van de interventie om ouderen te stimuleren om thuisoefeningen te uitvoeren. Er is meer onderzoek nodig op welke wijze blended interventies hiernaast ook algemene beweging kan stimuleren.

Hoofdstuk 8. Samenvattend, de belangrijkste bevindingen van dit proefschrift zijn dat ouderen bereid zijn om thuis oefeningen uit te voeren indien ze overtuigd zijn dat het bijdraagt aan hun zelfredzaamheid. Belangrijke randvoorwaarden zijn dat er voldoende begeleiding geboden wordt, de oefeningen veilig zijn om zelfstandig uit te voeren en het volhouden van het beweegprogramma gestimuleerd wordt. Een blended interventie die is gebaseerd op functionele oefeningen, gedragsverandering en menselijke begeleiding komt daaraan tegemoet. De tabletapplicatie die daarvoor is ontwikkeld, blijkt voor de doelgroep bruikbaar te zijn. Een procesevaluatie toont aan dat zowel de tablet, als de coach, ouderen ondersteunt bij de verschillende fasen van zelfregulatie. De blended interventie stimuleert intrinsieke motivatie door de autonomie van ouderen te ondersteunen, de competentie te bevorderen en, voor sommigen, ook verbondenheid te realiseren door het bieden van emotionele steun. Data afkomstig van de tablet laat zien dat de ouderen die deelnamen aan de interventie, beweeggedrag vertonen die in lijn is met de aanbevelingen van de Wereldgezondheidsorganisatie, en dat het gebruik van de tablet hieraan heeft bijgedragen. Toekomstig onderzoek zou de beoogde uitvoering van de interventie nauwkeurig moeten nagaan en verkennen welke aspecten van coaching zich lenen om te automatiseren, en welke niet.

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10. **Mehra S**. Increasing physical activity in older adults with a tablet and e-coaching. Poster presented at: *8th Annual ARPH Conference*; January, 2019; Egmond aan Zee, the Netherlands.

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16. **Mehra S**, Helder JV, Dadema T, Cila N, Visser B, Engelbert RHH, Weijs PJM, Kröse BJA. The Design and Usability Testing of a mHealth Application for Supporting Self-Regulation of Exercising Older Adults. *Front. Public Health. Conference Abstract: 3rd UCL Centre for Behaviour Change* Digital Health Conference 2017: Harnessing digital technology for behaviour change; February, 2017; London, UK. doi: 10.3389/conf.FPUBH.2017.03.00002

17. **Mehra S**. Harnessing the potential of persuasive technology: Getting Older Adults to Exercise at Home with a Blended Intervention. Poster presented at: *6th Annual ARPH Conference*; February, 2017; Leiden, the Netherlands.

18. **Mehra S**. Harnessing the potential of persuasive technology: Getting Older Adults to Exercise at Home with a Blended Intervention. Poster presented at: *E-coaching for Health and Wellbeing Conference*; January, 2017; Amsterdam, the Netherlands.

19. van den Helder J, van Dronkelaar, C, Tieland, M, **Mehra S**, Dadema, T, Visser B, Kröse BJA, Engelbert RHH, Weijs PJM. A digitally supported home-based exercise program and dietary protein intervention for community dwelling older adults: protocol of a cluster randomized controlled study (VITAMIN study). Poster session presented at: *Science Exchange Day*; 2017; Amsterdam, the Netherlands.

20. **Mehra S**, Dadema T, Kröse BJA, Visser B, Engelbert RHH, Van Den Helder J, Weijs PJM. Attitudes of Older Adults Towards a Blended Exercise Program. Poster presented at: *Supporting Health by Technology VII*; May, 2016; Groningen, the Netherlands.

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22. **Mehra S**. *Motiverende Technologie voor Ouderen in Beweging*. Poster presented at: *VvBN conference Enabling Technology for Human Functioning*; September, 2015; Enschede, the Netherlands.

Professional symposia & invited talks

1. **Mehra S**, Brons A *. Hoe krijgen we ouderen en kinderen in beweging? Oral presentation at: *Opening Schooljaar Hogeschool van Amsterdam*; August, 2019; Amsterdam, the Netherlands.

2. **Mehra S**. Technologie en gedragsverandering bij ouderen. Keynote presentation at: *Veiligheid.nl Themabijeenkomst Valpreventie Innovatie en de valpreventiepraktijk*; October, 2018; Amersfoort, the Netherlands.

3. **Mehra S**, Vermeer W. Het analyseren van kwalitatief onderzoek: een vergelijking van methodieken. Oral presentation at: *Applied Psychology R&D symposium*; October, 2017; Amsterdam, the Netherlands.

4. **Mehra S**. Onderzoek en onderwijs integreren; het vormen van learning communities met studenten. Oral presentation at: *Applied Psychology R&D symposium*; June, 2017; Amsterdam, the Netherlands https://hva.

mediamission.nl/Mediasite/Play/d4837cb5b1ae4c0ea59bd80b6cd7bbc31d

5. **Mehra S**, Veer C van 't *. Bezint Eer ge Begint. Moderator at: *NWO voorlichtingsmiddag Promotiebeurs voor leraren*; April, 2017; The Hague, the Netherlands.

6. **Mehra S**. Persuasive Technology for Older Adults. Oral presentation at: *Digital Life exchange Chinese delegation of visiting scientist*; December, 2016; Amsterdam, the Netherlands.

7. **Mehra S**, Hamers A *. Oral presentation at: *ARPH symposium Using videos for research in health psychology*; October, 2016; Utrecht, the Netherlands.

8. **Mehra S**. Attitudes of Older Adults Towards a Blended Exercise Program. Poster presented at: *AKMI showcases*; April, 2016; Amsterdam, the Netherlands.

9. **Mehra S**. Supporting older adults to exercise with a tablet. Oral presentation at: *Digital Life Info.nl symposium*; April, 2016; Amsterdam, the Netherlands.

10. **Mehra S**. Supporting older adults to exercise with a tablet. Demonstration at: *Sense in the City symposium*; April, 2016; Amsterdam, the Netherlands.

11. **Mehra S**, Kesler D, Cornelissen J, Dadema T *. Get together! Studenten betrekken bij praktijkgericht onderzoek. Oral presentation at: *De HvA Onderwijsconferentie*; April, 2016; Amsterdam, the Netherlands.

12. **Mehra S**. VITAMIN research project. Oral presentation at: *Showcases of Digital Life at TU Twente*; March, 2016; Enschede, the Netherlands.

13. **Mehra S**. Interviewed by R. Endert at: *Uitreiking NWO lerarenbeurs*; November, 2015; Amsterdam, the Netherlands.

14. **Mehra S**. Motiverende Technologie voor Ouderen in Beweging. Oral presentation at: *DMR Research Awards*; September, 2015; Amsterdam, the Netherlands.

15. **Mehra S**. Motiverende Technologie voor Ouderen in Beweging. Poster presented at: *NWO Inspiratiedag*; September, 2015; Amersfoort, the Netherlands.

16. **Mehra S**. Motiverende Technologie voor Ouderen in Beweging. Poster presented at: *Opening of the Digital Life Lab*; September, 2015; Amsterdam, the Netherlands.

17. **Mehra S**. Persuasieve Technologie & Gezondheid. Oral presentation at: *international conference of Applied Psychology Colleges*; April, 2015; Brugge, Belgium.

Professional magazines, popular media & awards

1. **Mehra S**, Visser B, Cila N, van den Helder J, Engelbert RHH, Weijs PJM, Kröse BJA. Supporting Older Adults in Exercising With a Tablet: A Usability Study. *Fysiopraxis*. 2020; 29(6).

2. **Mehra S**, van den Helder J *. Fit met pit. Magazine article in: *Creating Tomorrow Together, 25 jaar HvA Magazine*, p30. 2018

3. **Mehra S**, van den Helder J *. Audience Award at: *HvA Research Awards 2017*. URL https://www.folia.nl/actueel/117130/margriet-pol-met-so-hip-grote-winnaar-hva-research-awards, URL http://www.hva.nl/onderzoek/hva-onderzoek/research-awards/research-awards.html

4. **Mehra S**, Beun RJ *. Dag Ongezond Gedrag (D. Riksen & S. Knols, interviewer). Magazine article in: *I/O Magazine*. 2017; 14(2), 4-7.

5. **Mehra S**, van der Helder J *. Samen promoveren: twee werelden in een onderzoek. Magazine article in: *HvA Campus Nieuws*. 2016; jaargang 6, nummer 2.

6. **Mehra S**. Amsterdam Leeft (interview by Vonk MCC & van de Water P). Radio interview at: *Amsterdam FM*; April, 2015; URL https://soundcloud.com/maatschappij-en-recht/ouderen-en-bewegen

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About the Author

Sumit Mehra obtained a master's degree in Cognitive Psychology and a master's degree in Social Science Informatics with a specialization in Human-Computer Interaction, at the University of Amsterdam. He subsequently worked as lecturer, educationalist and researcher at the University of Amsterdam, Utrecht University and Amsterdam University of Applied Sciences (AUAS).

Mehra's research focuses on behavior change, health and persuasive technology. In 2015, he was awarded an NWO grant for his proposal for an eHealth intervention for older adults, which was rated as outstanding. His work has been featured in various international journals, conferences and popular media, and he has received awards from UCL and AUAS. Furthermore, he was co-editor of the Dutch version of *The Behaviour Change Wheel* by Suzan Michie, a leading authority on behavior change. In 2020, in addition to his teaching responsibilities, Mehra's research efforts culminated in the PhD thesis *Development and Evaluation of a Blended Home-Based Exercise Intervention for Older Adults*.

For additional information about the author, see www.mehra.nl/sumit