ActiThings Toolkit

Towards Supporting Older Adults' Adherence to Home-based Physical Exercise Programs by Providing Notifications in Opportune Moments

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Keywords: Health, Primary Prevention, Older Adults, Physical Activity, Ambient Reminders, Opportune Moments, User Study.

Abstract: Home-based physical exercise programs can delay or even prevent age-related frailty among older adults, but insufficient adherence to these programs, especially long-term, is a reoccurring problem. We suggest aiding the integration of simple exercises into daily routine by using innovative interactive tools which provide older adults with environmental prompts for exercises in opportune moments. In this paper, we report on our lessons learned with exploring the usefulness of our ActiThings toolkit, which includes a broad range of unobtrusive, portable, ubiquitous sensing and feedback technologies.

1 INTRODUCTION

Lifelong physical activity is one of the key determinants of healthy aging. According to the World Health Organization, at least 150 min of moderate exercise per week has considerable benefits for health among older adults and could delay or even prevent age-related frailty. In particular for fall prevention, older adults are recommended to do muscle-strengthening activities and physical activity that enhances balance. However, globally, 1 out of 4 adults (18+ years) is insufficiently active. Embedding physical activity into the daily life requires changes of behaviours and habits, which is a considerable challenge for many, particularly elderly persons. There is a need for opportunities to conduct exercises during daily life, in an unobtrusive manner, and with little extra effort. Strength, coordination, and balance home exercises programs, such as HOPE (Clegg, Barber, Young, Iliffe, and Forster, 2014), LIFE, or OTAGO address these needs and are proven to be effective. Still, insufficient adherence to exercise programs, especially long-term, is a reoccurring problem. Approximately 50% of people who start a physical exercise programme will stop within the first 6 months (Robison and Rogers, 1994). Research on the factors for adherence to exercise programs has shown that besides demographic, physical and psychological factors, supervision and motivational support of the participating people provide encouragement to exercise and thus contribute to a better program adherence (Picorelli, Pereira, Pereira, Felício, and Sherrington, 2014; Chao, Foy, and Farmer, 2000; King, Taylor, Haskell, and Debusk, 1988).

2 RELATED WORK

A lot of research investigated the role of technology to support healthy sedentary elderly in doing physical activity *in general* (e.g., Fan, Forlizzi, and Dey, 2012). Within this paper we will focus on exploring how technological solutions can support the adherence of healthy older adults to *home-based physical exercise programs*.

Behaviour change theories offer numerous techniques to induce physical exercise habits such as providing information on consequences of behaviour, goal setting, or providing rewards for successful behaviour (Michie, Ashford, Sniehotta, Dombrowski, Bishop, and French, 2011). For instance, van het Reve, Silveira, Daniel, Casati, and de Bruin (2014) investigated a physical exercise intervention program for older adults, which comprised individual and social motivation strategies provided via a tablet-PC app. They found that these technology-supported techniques can lead

Beck, E., Holdt, K. and Meyer, J.
ActiThings Toolkit - Towards Supporting Older Adults' Adherence to Home-based Physical Exercise Programs by Providing Notifications in Opportune Moments .
DOI: 10.5220/0006647705190526
In *Proceedings of the 11th International Joint Conference on Biomedical Engineering Systems and Technologies (BIOSTEC 2018) - Volume 5: HEALTHINF*, pages 519-526
ISBN: 978-989-758-281-3

to higher adherence rates compared to traditional exercise plans (van het Reve et al., 2014).

Such intervention programs use of a multitude of motivation strategies in parallel (e.g. Irvine, Gelatt, Seeley, Macfarlane, and Gau, 2013; van het Reve et al., 2014): Educational approaches aim improving (health) knowledge among intervention participants. Plan related approaches help participants to do detailed planning of when and where to do physical exercises. Participants may be rewarded for attempting to achieve or actually achieving an exercise goal. Social connections and social awareness may be established between participants and coaches via technological means. Technology, such as a virtual gym application, can also create a group experience while exercising (Baez, Far, Ibarra, Ferron, Didino, and Casati, 2017), enabling also less fit individuals to train as much as fitter individuals. To support the (self-) monitoring of a person's physical exercise habits and performance, exercise program websites can prompt older adults to self-report activities and frequency of exercise (Irvine et al., 2013), and, activity-tracking technology can help older adults to get aware of their physical activity level through monitoring their physical activity and providing them with these data. Furthermore, motion-tracking technology can provide feedback on the correctness of physical exercise conduction. Increasing positive emotions may help the program participant with performing the physical exercise, e.g., by making exercise fun. This type is related to gamification of physical activity or so-called exergames (games that involve physical exercises).

To conclude, there are several different strategies to support older adults' adherence and motivation to physical exercise with technology, but there is one reoccurring effective characteristic among many of the discussed studies: taking individual needs and preferences of older adults towards physical exercises into account. Such an individualized tailoring of programs considers the personal level of fitness (Baez et al., 2017), level of motivation (Marcus, Bock, Pinto, Forsyth, Roberts, and Traficante, 1998), and recognizes unique barriers in older adults (e.g., intermittent illness or caregiving) (Brawley, Rejeski, and King, 2003).

To achieve long-term adherence to physical exercise beyond intervention participation, the formation of habits and routines for physical exercises in daily life is of utmost importance. Research studies (e.g., Opdenacker, Boen, Coorevits, and Delecluse, 2008) recommend following a lifestyle approach to promoting physical activity as an alternative to structured exercise programs. This approach encourages older adults to increase and maintain their physical activity level by embedding balance, strength, and flexibility exercises in their daily life through activities like, for instance, walking, cycling, or swimming. Still, identifying opportunities for physical exercise in daily life can be a challenge. A suitable behavior change strategy to overcome this issue is to use environmental prompts to cue older adults about performing physical exercises (Michie et al., 2011). Some technology-supported home-based physical exercise programs remind their participants via an alarm clock or display invitations to start due exercises (van het Reve et al., 2014), but these technology-delivered prompts hardly consider the suitability of this particular moment for an exercise.

Health intervention studies provide evidence that health-related messages shown to people in suitable points in time and place are effective in changing people's behaviour, e.g. in preferring to take the stairs instead of an elevator after a point-of-decision prompt. Intille (2004) explored the concept of non-intrusive, "just-in-time" messaging for behaviour change by using ubiquitous computing technology. We assume this concept to be of value also for triggering the conduction of physical exercises from a home-based intervention program during the daily lives of seniors.

Within our research about how technology can support the integration and long-term maintenance of a physical exercise program in the daily lives of elderly, we build on top by exploring the usefulness of innovative interactive tools which provide older adults with environmental prompts for exercises in opportune moments.

3 OUR APPROACH: ACTI-THINGS TOOLKIT

Our research goal is supporting older adults' adherence to home-based physical exercise programs by reminding them about physical exercises in possibly opportune moments. We understand opportune moments as points in time when a person has the capability and willingness to get reminded about a physical exercise *and* to conduct it. Such opportune moments are profoundly dependent on individual preferences and may happen any time throughout the day. They are influenced by, e.g., having a sufficient amount of time (a couple of minutes), being in a suitable spot at

home, when interrupting the prevalent activity is not a problem, and the like. Thus, the identification of opportune moments (in general, as well as for a single person) is a huge challenge. In our approach, we deal with this complexity by identifying a person's routine activities at home which may fulfill the conditions for doing a short physical exercise. For instance, a person may be engaged in the routine activity of making coffee, where she sits on a kitchen chair, waiting for a couple of minutes until the coffee machine is done. Such a moment could be appropriate for making an environmental prompt to the person, suggesting an instantaneous completion of a physical exercise. Thus, we aim to integrate physical exercises into the daily life of older adults by intertwining the exercises with already established activities at home, which should also ease the formation of physical exercise habits. Within our research, we are interested in examining sensor-based technologies for detecting such routine activities and interactive technologies for providing visual and/or acoustic feedback (i.e., environmental prompts to do a simple physcial exercise) to people.

Regarding the detection of opportune moments, we chose to explore a broad range of unobtrusive, portable and ubiquitous sensing technologies, which identify the traces a person leaves in the environment, when engaging in activities of daily living. While daily activities like lying, sitting, walking, running, or cycling can be recognized with wearable accelerometry-based motion detectors (e.g., Pärkkä, Ermes, Korpipaa, Mantyjarvi, Peltola, and Korhonen, 2006), we need to go beyond by capturing further data, such as a person's location at home, usage of objects (Tapia, Intille, and Larson, 2004), and interaction with devices. Next to detecting opportune moments for notification and physical exercise, suitable interactive technology needs to notify an older adult about this physical exercise opportunity. HCI research on reminders for older adults has shown that, in order to be effective, reminder systems need to be highly personalizable, enabling the person to choose between diverse modalities (vision, speech, sound, touch) (McGee-Lennon, Wolters, and Brewster, 2011). Older adults are a heterogenic group with different daily routines and habits, varying capabilities, and also considerable differences with regard to novel technology use and acceptance. When selecting and developing sensing and feedback technology for supporting older adults, we must take these user-group specific and personal differences into account. Therefore, our focus is on developing a modular toolkit, called *ActiThings*, with high- and low-fidelity, small, easy to use, ambient, sensor-based and interactive technologies.

We followed an iterative, human-centred interaction design approach for achieving our research goal. In a multi-stage process, we first developed and evaluated conceptual designs of the ActiThings toolkit. In a second stage, we iterated our concepts based on the evaluation findings and built functional prototypes, which we evaluated again. For each stage, we investigated the usefulness of the ActiThings toolkit by involving older adults in our evaluation activities.

4 FIRST STAGE: CONCEPTUAL DESIGNS

Within our first design stage, we developed three conceptual designs. Thereby, we explored different ways when – in which situations or activities – and how – via which interactive devices and with which information contents – to notify a person.

4.1 Three Prototypes

The first prototype, *ActiMove*, suggests to continue with some physical exercise *after* the completion of a routine (household) activity at home (e.g., opening drawers, watering flowers). It consists of a device with an accelerometer, which can be attached to many household items (e.g. a watering can) to identify their usage (see Figure 1). When the device detects the termination of the activity (the household item is inactive), it notifies the person with an acoustic alarm and a red light about a possibly opportune moment for an exercise. Moreover, the prototype indicates the number of planned and completed exercises via blue and green lights.

Figure 1: Conceptual design illustrations of the ActiMove prototype.

The second prototype, *ActiWait*, aims to identify potential waiting times of a person *during* an activity of an electric-powered device at home (e.g., waiting for the kettle to boil water). A power sensing device identifies e.g. the use of a kettle (see Figure 2). A

nearby placed tablet-based PC then suggests specific, simple physical exercises such as toe-heels-stand, repetitive chair rises or balance exercises from established programs such as HOPE (Clegg et al., 2014).

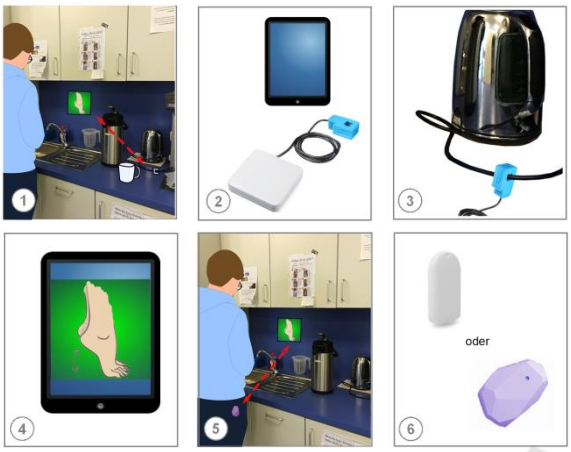

Figure 2: Conceptual design illustrations: ActiWait prototype (pic. 1-4); ActiConverge prototype (pic. 4-6).

The third prototype, *ActiConverge*, is a variation of the ActiWait prototype. Its aim is to make suggestions of the aforementioned simple physical exercises when a person arives and stays at a particular place at home (e.g., when entering the kitchen). Thus, it senses the proximity of a person to the tablet PC via near-body-worn Bluetooth beacons (Estimote or KST Particle) (see Figure 2).

4.2 Evaluation Process

To assess the usefulness of our conceptual designs, we conducted two focus groups with (in sum) five older adults who were actively participating in a p.a. intervention study (two females, 3 males, aged between 70 and 76 years). Each focus group lasted about 30-40 minutes and consisted of a moderated discussion. Participants discussed whether they wanted to get a reminder about doing physical exercises and, if so, how they would like to get reminded. They received handouts, which described and illustrated the conceptual designs of each prototype (see Figure 1 and 2 for the illustrations). These conceptual design handouts were used to stimulate a discussion about the pros and cons of each prototype, and to identify basic objections, as well as further ideas and wishes.

We noted the verbal expressions of the participants during the focus group in a protocol. We then categorized and summarized the information from these protocols in an explorative manner.

4.3 Evaluation Results

The focus group participants expected the prototypes to *do more than only providing a generic reminder* for physical exercises. They wanted the prototypes to provide rewards for conducting the exercises, make the benefit of the physical exercise clear to the user, monitor the completion of exercises, compare the number of conducted exercises with a training schedule and inform the user about deviations from this schedule. Some study participants appreciated the use of a tablet PC for the ActiConverge and ActiWait prototype, because it could have additional features, such as a possibility to document conducted or dismissed exercises.

At the same time, the study participants regarded the *ease of use* and *unobtrusiveness* of the prototypes as highly important. One participant criticized the ActiMove prototype for the smallness of its buttons and considered the interaction with the device as cumbersome. Moreover, ActiMove cannot be placed on every household item, because the item gets unhandy with the device on it or it is immersed in water (e.g., one participant puts the watering can in water when using it).

Albeit there are many opportune moments for physical exercises in daily life, there are *situations when being notified by the prototypes is not appreciated*. For instance, one participant does not want to get a reminder for a physical exercise when she has visitors around at home. Also our idea to sense power use in order to identify possible waiting times with physical inactivity is not always applicable. Participants explained that they did additional activities while they were waiting for an electrical device to complete a task (such as boiling water with a kettle). Due to the heterogeneity of people's daily activities and habits, identifying suitable opportune moments for reminding about physical exercises is a highly complex task.

4.4 Lessons Learned

Our focus group discussions showed that our prototypes should provide additional, motivational features, not only a notification to physical activity, to be of value for adhering to p.a. interventions. Further, the prototypes should not require the users to perform many interactions with the interface (pressing buttons, adjusting settings) during their daily life use. The focus groups also showed that the prototypes should tailor the notification much more towards individual needs of users. Based on the focus group discussion, we thus extended our list of

possible opportune moments for a short physical exercise, i.e.:

- After sitting or lying for one or more hours on a chair / couch (because of watching tv, reading a book or newspaper)
- When entering a room, e.g., the kitchen or the bed room
- While doing household chores, e.g., washing dishes, brushing teeth, cooking
- During waiting times, e.g., while the kettle is boiling water, the coffee machine is making coffee
- In the morning, after wake-up, when still lying in bed

5 SECOND STAGE: FUNCTIONAL PROTOTYPES

Based on our findings from user evaluation, we refined, as well as altered our conceptual designs and developed functional prototypes. Due to several critical issues with usability and use constraints which came up during the focus groups, we did not further pursue the concepts of sticking a device on household items (ActiMove prototype) and of using power sensing to identify waiting times (ActiWait prototype). While these concepts may be useful for some older adults in p.a. interventions, we aimed at identifying concepts which work for various situations at home, taking the heterogeneity of people's daily activities and habits into account. We therefore focused on extending the ActiConverge prototype with further motivational features and user input devices. Moreover, we explored another concept which focuses on providing unobtrusive reminders during sedentary behaviour.

5.1 Two Prototypes

We developed two functional prototypes for the ActiThings toolkit. A new prototype, called *ActiSit*, addresses prolonged sedentary behaviour. It collects sensor data on sitting activity to detect possibly opportune moments for physical activity. The relocatable pillow is equipped with a pressure sensor that identifies a sitting person and measures the time of sitting (see Figure 3).

Figure 3: ActiSit prototype (pillow, table lamp).

Based on the time passed, a table lamp, which serves as an ambient light display, is used to motivate some physical activity (i.e. doing a little exercise, or at least, stand up for a moment before sitting down again). The lamp gradually increases its light intensity and changes its colour from a neutral white to blue, until the maximum of a predefined sitting time is reached. The sitting time counter is resent by simply decreasing the weight on the pillow (e.g., standing up).

The *ActiConverge* prototype was refined with additional features for documenting the adherence to the physical exercise intervention. The tablet-based PC then presents exercises, gives guidance on how to conduct the exercises, allows writing an exercise diary, and presents badges and achievements. Moreover, we added two Bluetooth buttons for a quick logging of (non-)completion of physical exercises, which can be placed anywhere according to user preferences (see Figure 4).

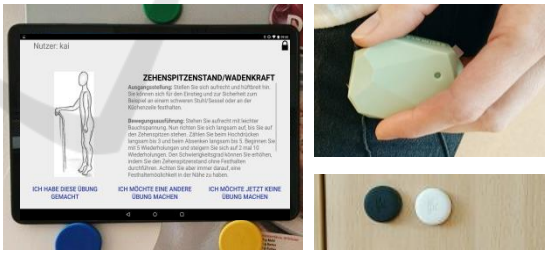

Figure 4: ActiConverge prototype (tablet-based PC with exercise program, Bluetooth beacon, Bluetooth buttons).

5.2 Evaluation Process

In the second stage, we conducted a user evaluation with five older adults (3 males, 2 females, aged between 71 and 80 years), who had indicated their interest in participating in a particular p.a. intervention (people on a physical activity intervention waiting list). The evaluation took place in an apartment-like lab, which allows testing the prototypes under more naturalistic conditions than in an artificial lab environment.

The evaluation session with each participant lasted approximately one hour and consisted of three parts. First, a pre-interview (5 to 10 minutes) about the participants' living situation (e.g., time spent at home/outside), activity habits in daily life, previously used reminder tools, and daily ICT use was carried out. In the second part, the participants were introduced to the prototypes, their purpose and functionality. We asked them to try out the prototypes and verbalize their experiences and first impressions with the prototypes. As a starting point, we also offered several examples for possible opportune moments for a short physical exercise (see section 4.4) and asked the participants to reflect on their appropriateness for their own daily life and/or to come up with further descriptions of opportune moments at home for a short physical exercise.

After this hands-on demo part, we conducted a short, semi-structured, focused interview with the participants, which aimed at discussing the experiences and perceptions of the participants in great detail. The interview was structured around topics. These topics focused the interview towards the research interests, and they acted as a guiding trigger for the study participants. During the interview the prototypes were also available for use. We discussed the prototypes with regard to overall / first impressions, positive and negative issues, usefulness, missing or undesired features, kind of information provided to user, design, and possible usage problems in social situations at home.

We noted all verbal expressions of the participant during the evaluation session in a protocol. These protocols were then used for categorizing and summarizing the information in an explorative manner.

5.3 Evaluation Results

All participants saw several opportunities for a reminder for physical exercise *within or after prolonged periods of physical inactivity* (sitting or lying when watching TV, listening to the radio, using the PC/laptop). Three participants also spotted opportune moments *right after periods of sleeping* in order to get some stimulation. In some cases, an interruption needs to be postponed *after finishing the primary activity*, such as not being interrupted during the after-lunch nap but after, and not when visitors are around. Two participants would also like to get reminded *during times of physical activity*, such as doing household chores.

Overall, participants experienced both prototypes (ActiSit and ActiConverge) as useful. While ActiConverge devices like the tablet PC were considered as *easy to use* and understand by all participants, three participants mentioned *difficulties to grasp the purpose and functionality of novel devices* like the beacon and the smart button.

Regarding the reminders for physical exercise by the ActiSit and the ActiConverge prototype, participants requested an additional *acoustic modality* for getting notified. Moreover, three participants would like to get reminders on their *own, personal devices*, such as smartphones or e-readers. First off, because they are already accustomed to their mobile devices. Secondly, a device used along with sedentary activities could itself be used for receiving a reminder, for instance, getting a notification on the e-reader after reading for a very long time.

Two participants stressed the need for a *temporal and spatial flexibility* of the provision of reminders. They want to be reminded on different places within the home and, moreover, the reminder system should adapt to the personal daily routine. As a solution, participants suggested to have a *multitude of devices* of the same kind placed at different spots in the home or to use a *wearable device* for feedback, because they would not carry the tablet or beacon around at home. One participant would prefer to have every physical activity measured by a *wrist-worn device* (like a standard fitness tracker). Moreover, one participant's preference for a reminder device depends on *environmental characteristics of a situation*, such as getting reminded by the light of the lamp in evenings when sitting in a comfy chair (fit to situation). Two study participants would put devices for reminding (like the tablet PC of ActiConverge) in a *central or highly frequented place* in the home, e.g., on a side table in the corridor or mounted on the wall. The device then reminds the person when passing by.

Three participants expressed their preference for the ActiConverge prototype, especially because they appreciated the *suggestion of particular exercises* on the tablet PC when getting a reminder. Two participants missed a *social communication feature* of the prototypes, in order to get animated by friends to do some physical exercise.

5.4 Lessons Learned

The user evaluation of the two functional prototypes has shown that older adults see opportunities for a reminder to physical exercise also during daily life

situations of sedentary behaviour. Moreover, this evaluation indicated again the importance of tailoring the provision of reminders and the collection of sensing and feedback technologies to the individual needs and preferences of older adults. The devices of the ActiThings toolkit need to be able to both sense behaviour and provide reminders at many different locations at home. Thereby, particular sensing and notification devices seem to fit particular situations at home. As McGee-Lennon et al. (2011) note, such a contextualisation (right location, time and device) is crucial for successful reminder strategies. Moreover, our prototypes should provide additional feedback modalities, e.g., acoustic notifications.

Our study results indicate that the toolkit should be extended with accustomed, personal smart devices (e.g., desktop PC, e-reader) for tracking their time of use (and consequently tracking sedentary behaviour related to device use) and for providing prompts to do a physical exercise. Familiar and easy to use devices like tablet PCs and smartphones are useful as basic interaction tools for providing the exercise program and deploying further motivational strategies (e.g., social interactions among people). This is in line with a study by Young, Willis, Cameron, and Geana (2013) on adoption barriers of home-based health information technologies among older adults. They found that people with a rather sceptical attitude prefer devices they are already familiar with and thus new health information systems should build on these preferences. Consequently, the ActiThings toolkit should also include "low-threshold" devices to mitigate possible adoption barriers within our addressed age group.

Moreover, tablet PCs work well as ambient reminder displays, when placed at central, highly frequented places at home. Bluetooth buttons should be offered as additional interaction possibilities if desired.

Based on our user evaluation, we need to rethink the use of Estimote or KST Particle Bluetooth beacons as portable devices. Our study findings suggest the use of wearable devices for tracking active and sedentary times, as well as the person's proximity to an ambient display during the day. Wearable devices can as well be used for providing prompts to do a physical exercise. As shown by research on wearable devices for older adults, smart watches offer useful notification services and activity tracker features, but these devices have the limitation of some people not wearing it every day or in every situation (Fernández-Ardèvol and Rosales, 2017). The same applies to head-mounted displays, which were found to be useful to provide reminders to older adults (Kunze, Henze, and Kise, 2014). However, there might be use constraints for such devices during some of our identified notification opportunities, such as periods of sleeping.

6 CONCLUSIONS

The effectiveness of home-based physical exercise programs to prevent frailty among older adults is very much dependent on people's long-term commitment to physical exercise. Within our research we aim at supporting the adherence to exercise programs by using ubiquitous, sensor-based, and interactive technologies for prompting older adults in opportune moments in daily life to do physical exercises. Based on our research findings so far, we see a high potential for our approach to integrate physical activity in daily life. The ActiThings toolkit prototypes enable environmental prompts to physical exercise in a variety of situations at home, taking individual needs and preferences of older adults into account. As for future work, we plan to conduct a field study to assess the effectiveness of the ActiThings toolkit to enhance older adults' adherence to a physical exercise program.

ACKNOWLEDGEMENTS

This research is funded by the German Federal Ministry of Education and Research (AEQUIPA, Project No. 01EL1422C).

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