Living with Smartwatches and Pedometers: The Intergenerational Gap in Internal and External Contexts

Jayden Khakurel[1(✉)], Susanna Tella[2], Birgit Penzenstadler[3], Helinä Melkas[1], and Jari Porras[1]

[1] Lappeenranta University of Technology, Lappeenranta, Finland
{jayden.khakurel,helina.melkas,jari.porras}@lut.fi
[2] Saimaa University of Applied Sciences, Lappeenranta, Finland
[3] California State University, Long Beach, CA, USA

Abstract. The purpose of this article is to explore and present the range of commonalities and differences between internal and external contexts that influence elderly and younger users' intentions to use commercial off-the-shelf (COTS) smartwatches and pedometers as motivational tools for physical activity. Therefore, this article follows the contextual action theory and the usability evaluation approach, in which "testing" and "inquiry" were applied to 21 younger participants and 13 fit, elderly participants who were in either the pre-contemplation, contemplation, action, or maintenance behavior-change stage. The results revealed no differences in internal context between the target groups due to both the effect and the useful-ness of the external context. However, there were distinctions between the younger and elderly participants regarding external context, especially in certain aspects of device usability, such as font size, touchscreen interaction, interaction technique, and applications installed, which were the core factors that affected the use of COTS smartwatches and pedometers by the study groups. In addition, the external and internal contexts had a cause-effect relationship, which significantly influenced the use of COTS smartwatches and pedometers.

Keywords: Wearable devices · Wearable applications · Smartwatches Pedometers · Elderly · Intergenerational gap · Commercial-off-the-shelf (COTS) Usability

1 Introduction

Much effort has been paid recently to exploring how technologies can promote older adults' well-being and independent living [13]. One area of technology and its user engagement features—such as data, gamification, and content [2]—that has recently become popular among young populations for well-being, and which can be effective to motivate the elderly to be more physically active, is commercial off-the-shelf (COTS) wearable devices. Wearable devices are smart electronic devices available in various forms, worn near or on the body, to sense and analyze physiological and psychological data, such as feelings, movements, heart rate, and blood pressure [12].

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This can be done via an application that is either installed on the device or on external devices (e.g. smartphones connected to the cloud) [12]. Wearable devices like activity trackers that measure motion and steps enable users to monitor their behavior and could support a healthier lifestyle [19]. They feature different degrees of usability and a varying range of user experiences [12]; the International Organization for Standardization [9] defines "usability" as the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context. Currently, this definition doesn't apply to the elderly, as they have a more difficult relationship with COTS devices than their younger counterparts [3], primarily because hardware and software have not been designed to suit their physical or mental abilities [14], which can discourage the elderly's adoption of devices such as smartwatches and pedometers as tools to perform physical activities.

Despite growth in the use of COTS smartwatches and pedometers, few studies have drawn technological comparisons between the elderly and their younger counterparts [5, 21, 30]. However, no studies have considered how elderly and younger users' perceptions of, and usability challenges associated with, COTS smartwatches and pedometers varies and affects their adoption due to contexts. Context encompasses an internal and external context [7, 20]. The internal context describes users' state and consists of internal parameters of human experience and activity [7] such as emotional responses (e.g. a decrease in user satisfaction and motivation [20]) and manifested behavioral responses such as an increase in errors, in reactions, or in inefficient or inappropriate activities [20]. The external context describes the environmental state and consists of proximity to objects [7], such as devices and their associated applications. To fill the research gap, the present study explores the divide in contexts (internal and external) that appears between target user groups (fit elderly users and younger users) while using the same COTS smartwatches and pedometers and participating in the same usability experiments. Thus, the research question (RQ) is: "Which internal and external contexts can obstruct the use of COTS smartwatches and pedometers among both elderly and younger users while using them as motivational tools for physical activities?" To answer this RQ, we will follow the contextual action theory (CAT) presented by Stanton et al. [20] and a usability evaluation method [10] to explain human action in terms of coping with technology within a context. The outcomes of this study identify challenges associated with wearables that need to be addressed by stakeholders, including device manufacturers, researchers, and caregivers, to enhance user experience, by understanding factors relating to internal and external context.

2 Related Work

Gregor et al. [6] classified the elderly into two categories: fit, who do not appear—nor would consider themselves—disabled, but whose functionality, needs, and wants are different to those they had when they were younger; and frail, considered to have one or more "disabilities," often severe, and who will have a general reduction in many functionalities and require general assistance from caregivers or relatives. Chodzko-Zajko et al. [4] concluded that regular exercise by the fit elderly can have significant psychological and cognitive benefits for their health, which is consistent with the 2008 Physical Activity Guidelines for Americans [25]. Nelson et al. [15] and Tudor-Locke et al. [24] pointed out that regular physical activity can help both the fit and frail elderly in preventing and treating disease and reducing the risk of developing other chronic diseases, premature mortality, functional limitations, and disabilities.

The elderly population is the least physically active of any age group [25], and little is known about how they can be motivated to engage in physical activities to enhance their well-being and independent living. Siek et al. [21] found no major differences in performance between older and younger users when physically interacting using mobile computing devices and completing tasks that are not complex and don't require maximum cognitive effort. However, they found differences in terms of preferences, such as for font sizes. Fukuda and Bubb [5] compared younger and elderly users' web use and found differences related to navigational behavior due to the decline of elderly users' visual and fine motor functions. Meanwhile, Zhou et al. [30] concluded that ageing has significant negative effects on performance and accuracy.

3 Study

Methodological approach. To enhance our understanding of commonalities and differences among elderly and younger participants using the same device in the same experiments, CAT and a usability evaluation method [10] form the foundation of this methodology. According to CAT, human behavior can be segmented into actions by assuming, attributing, or reporting a goal for the behavior [29]. Stanton et al. [20] pointed out that CAT explains human actions in terms of coping with technology within a context, with five phases associated with contextual actions: (i) actual demands and resources are presented to the user, which comprise the design of the device, the tasks to be performed on the device, environmental constraints (e.g. time) and so on; (ii) appraisal of those demands and resources by the actor; (iii) a comparison of the perceived demands and resources; (iv) possible degradation of pathways; and (v) the effects of these responses on the interaction with the devices.

The type of internal and external data we gather from action is also dependent on the data-gathering procedures [29]. Therefore, we applied a usability evaluation method composed of a series of well-defined activities to collect data related to the interaction between the end user and device characteristics to determine how the specific properties of a particular device contribute to achieving specific goals, as shown in Fig. 1. We applied two (testing and inquiry) of five method classes (testing, inspection, inquiry, analytical modeling, and simulation) proposed by Ivory and Hearst [10]. Under "testing," a "think-aloud session" was conducted, where an evaluator observed participants' actions (i.e. interacting with the device and performing the task) to determine various usability challenges and witness users' emotional responses (e.g. a decrease in user satisfaction and motivation [20]) and manifested behavioral responses (e.g. an increase in errors, in reactions, or in inefficient or inappropriate activities [20]). Under "inquiry," participants reflected on their emotional and behavioral responses, and the effect those responses had on their use of the devices and associated applications, using a method type "diary". **Participants.** The experiments were carried out in Finland with two age groups (younger than 60 and older than 60) and three different target user groups (students, university staff, fit elderly adults older than 60). Of the sample of 34 participants, 21 were younger or middle-aged, had relatively substantial technological knowledge, and had a positive view of using technology in their daily lives. The second group of 13 were fit elderly participants who were living independently and keen to use new technology to improve their well-being; this group was recruited through direct contact and networking. Members of both groups were at different health-behavior-change stages, as described by the Transtheoretical model (TTM) [18]: pre-contemplation (younger (n = 8), elderly (n = 4)); contemplation (younger (n = 7), elderly (n = 3)); action (younger (n = 1), elderly (n = 2)); and maintenance (younger (n = 5), elderly (n = 4)). The Lappeenranta University of Technology's ethical committee approved the study. All participants were presented with an ethical review statement and informed consent (participants' right to confidentiality, risks, data storage, the use of anonymized data, voluntary participation, no health-related data collected), and a signed consent form was obtained in return. **Procedures and tasks.** In phase 1 (see Fig. 1), we presented the actual demands and resources to the participants, which consisted of:

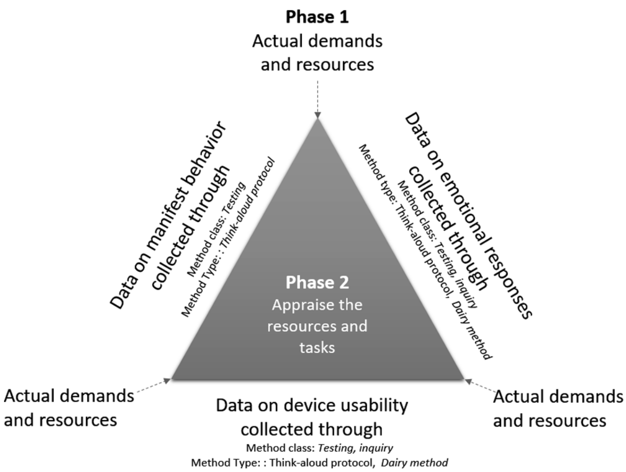

Fig. 1. Methodological approach, image adapted from [28]

- Device presentation: Functioning wearable COTS smartwatches (Apple Watch, Samsung Watch) and pedometers (Misfit Shine 2, Fitbit Charge 2, and Polar A360) were presented to help us to explore the significance of various types of data for future design, as noted by Kanis [11]. These devices were selected based on market availability. No requirements were provided for device selection.
- Timeline: Participants were asked to participate in two one-hour controlled environment sessions (i.e. first meet-up session and final meet-up session), with four weeks of everyday device use between the sessions in a semi-controlled environment.

Experimental tasks: During the first and final meet-up sessions, we assigned experimental tasks (see Appendix A[1]) to be performed to test usability and its effect on participant's emotions and behavior. Usability is one of the most important aspects for the success of any technological product [17], and it has positive correlations with three motivation measures: attention, relevance, and satisfaction [8]; participants' interaction with the device can determine how its specific properties can affect their emotional and behavioral responses. During both sessions, participants were asked to follow a "think-aloud" protocol while performing the presented tasks. In the semi-controlled environment, participants were asked to (i) use devices in real conditions and (ii) complete an open-ended questionnaire in their diaries regarding the devices and associated applications, including any issues they faced or change in the levels of motivation to conduct physical activities, or any other issue they experienced. The aim was to make participants comfortable using the device and to gather data on their emotional and behavioral responses.

In phase 2 (see Fig. 1), consent to collect and use data was presented prior to asking both sets of participants to appraise the resources and tasks set in phase 1. This allowed participants to understand their own perceived demands and resources in using the COTS smartwatches and pedometers. Their appraisal reflected the possible degradation of pathways (i.e. emotional responses and behavioral responses). The effects of these responses on the interactions with the devices were gathered from the participants through diary entries. From this data, we identified commonalities and differences in terms of external and internal contexts.

4 Results

In this section, we synthesize the findings and emphasize commonalities and differences, particularly regarding internal and external contexts (see[2] for Matrix of Study).

C1 Internal Context

C1.1 learning new behavior. Both target groups had to learn new behaviors, such as remembering to charge the device, which affected their daily use of the device. One younger participant stated, "Remembering to charge the device was an issue. I couldn't wear the device because I forgot to put [it] on to charge." Similarly, an elderly participant said, "I didn't put the watch on in the morning, since I took a shower. After that, I forgot to put it on completely." Some general confusion occurred during the evaluation among elderly users when they had to switch between using the external devices and the smartwatches and pedometers. One elderly participant with a Fitbit Charge 2 reported, "Why can't I see my sleep data on the device, while I can see it on my smartphone?" Similarly, another elderly participant noted, "I really can't remember which data I can see on my pedometer and on my mobile phone." However, the younger participants made no such comments.

[1] https://doi.org/10.5281/zenodo.832159.

[2] https://doi.org/10.5281/zenodo.832167.

C 1.2 Meaning of technology and its usefulness. During the first activity, it was surprising to see (i) color of the device and design and (ii) "sleep," "number of steps," and "calories burnt" data being more important than other pedometer/smartwatch functionalities among elderly participants. For example, one elderly participant stated, "I am so excited to see how much I walk a day." Another said, "I just need the band that measures my sleep." However, younger participants placed importance on advanced functionalities, such as receiving calls and texts and the ability to use various applications. One young participant stated, "I would like to have the smartwatch because I want to receive calls." Similarly, during the think-aloud session, in the midst of a lively discussion about privacy invasion by smartwatches and pedometers, there was a positive reaction from both elderly and younger participants regarding how health and physical activity-related data is collected, stored, and analyzed by pedometers and smartwatches. These findings illustrate that the elderly ascribe different meanings to technology than their young counterparts who grew up in a more technological environment [16]. We also found that participants from both groups formed favorable attitudes toward the technology if the devices were useful and relatively easy to utilize.

C 1.3 Transformation in motivation. Some young and elderly participants reported a decrease in motivation after a week of device usage, particularly non-physically active participants who were not willing to engage through data, content, and gamification. In addition, some participants lost motivation due to usability challenges. Indeed, most of the participants in the pre-contemplation or contemplation stage felt that the content did not motivate them, as highlighted in the following: "I see the same information every day; it didn't motivate me to be more physically active." However, participants in the action or maintenance stage [18] engaged though data, content, and gamification; one stated, "The number of goals that have to be achieved motivated me to take more steps."

C 1.4 Transformation of perception towards device characteristics. It was astonishing that, in both groups, the participants' requirements regarding the devices' color and design changed within a week of using them. For example, one elderly participant stated, "I don't like to wear it anymore, because it's white in color and doesn't match my outfit." Conversely, one participant noted, "This color is perfect for me." One younger participant stated, "I have to be very careful when I wear this device, because it's too big," while another younger participant stated, "I can't go to sleep wearing this smartwatch; it's irritating." However, the same participants stated, when selecting the devices, that they looked nice. This change during transformation from the experimentation to habit stage reflects this statement from a previous study [23]: "Doing *something once was an experiment, doing it every day for a week was a habit, and doing it every day for a month was a lifestyle. When attempting to take some new action on a regular basis, one is confronted with many different aspects of the change —how it makes one feel over time" (p. 131).*

C 1.5 Cognitive effort. Our findings revealed that previous knowledge of technological devices (e.g. computers or smartphones) does not decrease the cognitive effort required by the elderly in adapting to new devices. For example, there was an increase in cognitive needs while interacting with smartwatches and pedometers for the first time, and while conducting tasks such as account registration and connecting the pedometers and smartwatches to external devices. Further, increased cognitive effort led to frustration among participants. The participants stated, "I got this device but I don't know where to start." Similarly, two other participants said, "It says I have to first register my device, how do I do it?" and "I don't have an email address, how can I use this?" Another elderly participant commented, "There are so many details to be filled." Following the elderly users' frustration, moderators carried out activities such as application installation on external devices, account registration, and connecting the device to Bluetooth.

Another striking observation of cognitive effort requirements occurred while restoring the device. When elderly participants were asked to restore the device during the think-aloud session (i.e. while returning the loaned device), they were unable to do so because of difficulties with navigation or the need for smartphones or computers. One elderly participant remarked, "I cannot find it on my Fitbit; it's too confusing, do I really have to do this?" This result matched observations from a previous study [26], stating that "the ongoing advance of technology suggests that younger people's experience with computers will not be a crucial advantage when they grow older." Young participants also required greater cognitive effort while restoring device. One responded, "It looks like I need my phone to reset my device, which I forgot to bring." Similarly, another participant commented, "I cannot remove this device from my account using [my] phone; it seems I have to download [an] application on my computer and do it manually." Participants explained that they lacked practice in restoring devices, and did not have proper instructions for how to do so from the device manufacturer. It seems cognitive effort may occur among younger participants when complex tasks, coupled with a lack of information, are introduced to their busy life schedules.

C2 External Context

C 2.1 Engaging factors. We found that the number of steps taken and data on exercise, heartbeats, calories burned, and sleep statistics were engaging factors for both young and elderly participants. Communication tools such as Skype, Slack, and Telegram were also engaging factors for younger participants.

C 2.2 Device Usability. The COTS smartwatches and pedometers used during the evaluation could be worn on wrists, necks, or ankles; thus, these devices were in close proximity to the bodies [22] of all participants. However, they reported that the device interactions did not satisfy their body shape, size, ability, and dimensions, nor their preferences, interests, and wishes [22]. *The subsequent section describes some commonly reported commonalities and differences in usability factors.*

Font size. Elderly participants complained that the text size on COTS devices with touchscreens was too small to read, stating for example, "I cannot read the text with my reading glasses, can I make this font larger?."

Interaction with touch screen. During the think-aloud sessions, some elderly participants had difficulties using the touchscreen on pedometers, smartwatches, and external devices due to dexterity problems. In addition, scrolling and navigating within the applications proved difficult for elderly participants. For example, a participant using a pedometer asked, “I pressed the screen on the device but it doesn’t respond; is this device broken?” Another participant who used the smartwatch said that the “touch-screen reacts so fast when I press on it.”

Interaction techniques. During the evaluation, elderly and younger participants regarded the push notifications and reminders differently. A younger participant reported, “I like the device because I could receive all notifications about calls and text data on my watch; I don’t have to use my phone all the time.” This comment reflected a statement from a previous study [14]: “Reminders are the most effective when delivered at the right location, at the right time and the right devices.” However, an elderly participant stated, “Having all the notifications on my watch with vibration feels so irritating and like getting an electric shock.” While the young group of participants found receiving notifications and reminders through COTS devices useful, their counterparts felt the opposite, which is in line with a previous study’s finding [14] that “age might however influence the interaction techniques.”

Reliability and accuracy. The data’s reliability was a concern for both groups of participants. For example, one of the elderly participants reported, “It didn’t record one of my afternoon naps. How can I rely on the sleep analysis data?” Similarly, a younger participant stated, “I had the device with me when I went to the fitness center, but there was no change in fitness activities.” According to another younger participant, “Sometimes I feel the measuring data isn’t accurate. For example, I was sitting and working, but the app shows I am resting.”

Device connectivity. Connecting the wearables and the external device, and synchronizing the data using Bluetooth technology, were the most commonly reported usability challenges by both groups of participants. For example, one younger participant stated, “Connecting the phone with the watch, I had to turn on and off the Bluetooth all the time.” An elderly participant reported, “I got an error on my application. My Charge 2 isn’t syncing because my phone’s Bluetooth is off, but the Bluetooth on my phone is on.”

Battery: Both older and younger participants raised concerns about the battery. As one of the younger participants reported, “Using the watch is easy, but keeping track of the battery is a problem.” Another participant stated, “The battery runs out quickly.” Participants with an integrated battery (e.g. Misfit COTS pedometers) had usability advantages over the other smartwatches and pedometers, as there were no comments regarding battery issues. Elderly users reported that it was difficult to parallel the use of the application installed on the external devices and COTS pedometers without any display. One participant commented, “When I was walking and wanted to see how long I had walked, it was difficult to take out the phone and view data.”

5 Discussion and Conclusion

Here, we will discuss the results of the evaluation of both elderly and younger participants, present implications for practice, and reveal our research findings. In addition, we will offer suggestions for future work. This study involved a small number of participants in a limited geographic location, meaning the generalizability of the results may not be possible; thus, all stakeholders, including device manufacturers and application developers, should take the findings as suggestions rather than conclusive evidence.

The first finding showed that both the internal and external contexts had a cause-effect relationship with both target groups, with more commonalities than differences in terms of the internal context, especially regarding usability factors of the external context and the users' own perceptions of the devices. Therefore, it would be beneficial to integrate both contexts during the design of wearable devices and their associated applications. The data gathered from emotional responses and manifested behavior showed that the internal context can strongly influence any age group if the effect on the external context appears or vice-versa; it can obstruct the acceptance of COTS smartwatches and pedometers by changing an individual's motivation. Further, the higher the degree of external context (i.e. usability factors), the better the internal context.

The most common external context usability elements that affected the use of wearable devices included font size, interaction with the touchscreen, interaction techniques, and applications installed; these strongly influenced age-related deficits and are in line with previous studies [1]. Device connectivity, battery life, reliability, and accuracy were the most commonly cited common important internal factors, which also aligns with previous studies [27]. Further, these results may change, depending on the context in which individuals use COTS devices. Future studies should measure how quickly both the internal and external contexts that can obstruct device usage appear in large numbers within both target groups over a specified period, and both elderly and younger individuals could retain the COTS device after appearance of cause-effect relationships.

Interestingly, despite having all user engagement features, such as data, gamification, and content, on either wearable devices or external devices with associated applications, these extrinsic motivational factors did not have a long-term effect on physically inactive participants who were in either the pre-contemplation or contemplation stage. Hence, for a person to be physically active, intrinsic motivation must evolve on its own, while extrinsic motivation will only enhance intrinsic motivation. Further studies can implement self-determination theory to discover which influential factors might awaken the intrinsic motivation of individuals in the pre-contemplation or contemplation stages of behavior change. First impressions of the devices were temporary for both groups, which likely faded based on the individuals' context of use and hierarchy of needs, whether cognitive or psychological. This finding led us to understand that a changed impression might affect the motivation to use the wearable device long term. Therefore, future work could develop guidelines that include the hierarchy of needs of both younger and elderly individuals based on the context of use of COTS wearable devices, which could help device manufacturers and application developers create sustainable COTS devices and associated applications.

To understand the commonalities and differences between younger and elderly participants using the same COTS devices, we developed experimental tasks. The results found commonalities in terms of internal context in both participant groups, apparently due to both the effect and usefulness of the external context. Therefore, certain measures should be taken regarding the external context, such as including age-appropriate smartwatch and pedometer device characteristics to reduce the cause-effect relationship of the internal and external contexts. Users will then feel comfortable and develop a high degree of satisfaction, motivation, and enjoyment regarding these devices' usefulness. The new design could decrease manifested negative behaviors and emotional responses by increasing the acceptance of COTS smartwatches and pedometers. For the elderly, appropriate font sizes and better interaction with the touchscreen and associated applications, as based on their hierarchy of needs, could improve their manifested behaviors and emotional responses and increase their satisfaction, leading to them adopting the devices for longer. Our future work will investigate: (i) how the internal and external contexts differ when secondary users, such as caregivers or relatives, use COTS smartwatches and pedometers on behalf of frail elderly users; (ii) the strong bond between the two contexts through an empirical study; and (iii) differences caused by geographical area, gender, and/or culture when repeating the same study with a larger sample of participants.

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