Requirements for Gesture-Controlled Remote Operation to Facilitate Human-Technology Interaction in the Living Environment of Elderly People

Susan Vorwerg[1(✉)], Cornelia Eicher[1], Heinrich Ruser[2], Felix Piela[3], Felix Obée[3], André Kaltenbach[4], and Lars Mechold[4]

[1] Charité – Universitätsmedizin Berlin, Reinickendorferstr. 61, 13347 Berlin, Germany
{susan.vorwerg,cornelia.eicher}@charite.de

[2] Universität der Bundeswehr München, W.-Heisenberg-Weg 39, 85577 Neubiberg, Germany
heinrich.ruser@unibw.de

[3] August & Piela Konstruktiv GbR, Tempelhofer Weg 11, 10829 Berlin, Germany
{piela,obee}@konstruktiv-berlin.de

[4] Laser Components GmbH, Werner-von-Siemens-Str. 15, 82140 Olching, Germany
{a.kaltenbach,l.mechold}@lasercomponents.com

Abstract. The “SmartPointer” (SP) technology comprises a universal buttonless gesture-controlled handheld remote device with a simple quasi-intuitive operating structure. With this handset, elderly people will be able to control various household devices in their living environment. In order to develop an age-appropriate SP system, the aim of the study was to determine the requirements of elderly people and people with tremor. For this purpose, a mixed-method design, involving several assessments, a guideline-based interview, a task-based investigation and a questionnaire using a gesture catalog, was applied. The whole sample included 20 seniors being 60 years and older. In the process, qualitative requirements were collected on the topics of device use, operating problems, desired devices for gesture control, receiver unit, gestures, feedback and safety. The interview results emphasized the elderly participants’ needs to an easy and intuitive system use. Furthermore, concerns should be prioritized in order to the development of the system. In the quantitative evaluation, the use of various technical devices was analyzed and the frequency of used gestures was determined based the gesture catalog and the task-based investigation. The most frequently used gestures were horizontal, vertical, circular and targeting gestures. In summary, the elderly people were very interested in, and open-minded towards, the SP-system. In a comparison between healthy persons and persons with tremor, the results demonstrated only minimal differences regarding the requirements.

Keywords: Gesture and eye-gaze-based interaction · SmartPointer · Gesture control · Remote · Human-technology interaction · Elderly people

J. Zhou and G. Salvendy (Eds.): HCII 2019, LNCS 11592, pp. 551–569, 2019.
https://doi.org/10.1007/978-3-030-22012-9_39

1 Introduction

1.1 Age and Technology

In 2018, the proportion of people aged 65 and above in Germany was 22% of the country's total population. Up to 2040, the number of people over 65 is expected to rise from 17.9 million to 23.2 million (+9%) [1]. With increasing life expectancy, the majority of people in this population group are characterized by deficits such as mobility impairments, cognitive impairments and reduction in vision and hearing [2]. Despite existing illnesses and deficits, older people strive for an independent life, especially in their own living environment. According to statistics, almost 93% of people over 65 in Germany still live in private homes [3]. Technical devices and functions such as assistive technologies (AT) can provide great support in coping with everyday life and maintaining independence [4]. These techniques can be summarized under the concept of Ambient Assisted Living (AAL), where strategies include orientation, support and assistance services for older people. The aim of AAL is to combine new technologies and the social environment in order to improve people's quality of life [5, 6]. AAL services also include smart home solutions, which are becoming increasingly important in maintaining independence in old age. A smart home means a private home in which household technologies (such as heating, lighting, ventilation, consumer electronics and communication equipment) become intelligent objects [5]. However, technological progress may comprise challenges for people over 70 years of age, and therefore it is important that innovative smart home solutions are adapted to the requirements and limitations of older people. On the one hand, technical devices have different functions and complex operating modes. On the other hand, they are usually controlled via computers or mobile devices such as smartphones and iPads. In this context, it should be noted that less than half (45%) of people over 70 living in Germany use the Internet [7]. The use of terminals for this purpose is also low in this age group (26% laptop, 25% PC, 22% smartphone, 13% tablet) [8, 9]. Consequently, if smart home controls are connected to mobile devices, this can lead to uncertainties and avoidance of technical support among older people, since comprehensive understanding of such technologies is not yet established in the current generation of older people.

Furthermore considerable research activities have been directed to buttonless controls based on the recognition of gestures. Many of these systems use images from video cameras to determine the relative positions of the fingers of one or both hands. However, changing backgrounds, occlusions and different directions the gesture is pointed to still make video-based gesture recognition difficult [10–12]. Moreover, considerable hardware costs are involved and camera applications are often controversially discussed due to data privacy issues. In addition, hand-held devices equipped with tilt and acceleration sensors similar to the famous "Wii" game console are also considered too costly and complex for our purpose [13, 14].

Considering all the aforementioned, new smart home technologies should provide comprehensible operating possibilities, which are simple, small, inexpensive and lightweight, in order to ensure a smooth human-technology interaction. The research and development project "SmartPointer", pursues this goal.

1.2 "SmartPointer" (SP)

"SmartPointer" is a collaborative project funded by the Federal Ministry of Education and Research (BMBF) in the KMU-Innovative-Announcement Human-Technology Interaction program. As part of the project, a universal system with a simple quasi-intuitive operating structure is to be developed. By means of a buttonless gesture-controlled handheld remote device with a long battery lifetime, elderly people will be able to control various household appliances such as lights, heating, blinds, windows or TV in their living environment.

Technology
The new "SmartPointer" system consists of:

(1) a handheld battery-operated and buttonless "SmartPointer", similar to a small flashlight, which emits visible light to select a particular device and spatially structured, invisible infrared (IR) light to operate the device (see Fig. 1),
(2) an optoelectronic receiving unit (photosensors) in, on or near the device to be remotely controlled and
(3) a decoding and communication unit for reconstruction and recognition of the performed gestures and their conversion into the respective device-specific control commands, together with connection to the device to be operated.

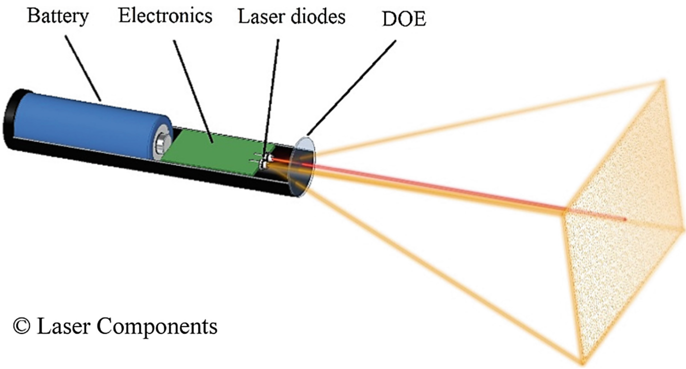


Fig. 1. Schematic view of the SmartPointer (own illustration: Laser Components, 2019)

Functionality
With a handheld, buttonless and particularly user-friendly light pointer ("SmartPointer"), the user carries out typical intuitive pointing and operating gestures in the direction of the device to be operated, in order to select and switch it or adjust it continuously. A light-sensitive receiver on the device detects the trajectory of the emitted, specially structured light in the invisible IR wavelength range and converts the identified gesture into device-specific control signals. Preliminary studies by Ruser et al. [35] showed the feasibility and potential of this approach. Throughout all development phases, the user perspective of elderly and mobility-impaired people will be consistently considered. The intuitive, buttonless remote is intended to make a significant contribution to supporting independent living.

1.3 Tremor Symptoms

Essential tremor is a symptom that occurs in about 1% of the total population and about 5% of the population over 60 years. As prevalence increases with age, as many as 10–15% of those over 70 and 50% of those over 90 suffer from more or less severe tremor, which can significantly reduce the quality of life of those concerned. Routine activities such as writing, holding an object, dealing with buttons and drinking are usually affected at a very early stage and may no longer be possible with serious forms of the disease. This can have a negative influence on the social life of those affected, and they may withdraw more and more, due to shame and inability to manage their daily lives successfully [15, 16].

Against a background of tremor symptoms causing problems with the accuracy of gestures, we consider the question of how the SP system can overcome these problems. In order to be able to deduce conclusions for the system development, this group of people was included in the study. The evaluations of the reproduced trajectories will be used to determine whether certain algorithms can be developed to enable smooth gesture recognition, even with the disturbance variable "tremor". Although this question is essential for the project and the development of the system, it cannot yet be answered as only the requirements analysis has so far been undertaken.

1.4 Aim of the Study

Many studies in the field of gesture control in the past have concentrated on the target group of younger people. In contrast, the "SmartPointer" project focuses on seniors over the age of 60. The aim of the study was to determine the age-related requirements of older people and people with tremor for an SP system, using qualitative and quantitative methods. Furthermore, the study participants were asked about their concerns about, and expectations towards an SP system, in order to assess the level of acceptance for such an innovative system among the target group.

2 Methodology

In order to answer the questions, a mixed-method design consisting of a guideline-based interview, a task-based part and a questionnaire using a gesture catalog, was used. The survey was conducted once in individual interviews with 20 seniors over 60 years of age. A total of 16 subjects consisting of 10 healthy elderly persons and six elderly persons with tremor, completed the study. In the cases of four of the participants, we performed only the assessments, the task-based part and the gesture catalog. The interviews were conducted in German. All the described investigations were carried out with the approval of the responsible ethics committee (EA4/134/18). A declaration of consent was obtained from all involved persons.

2.1 Study Procedure

The study covered a survey period of two months (October to November 2018). In advance, interested respondents were informed and educated about the study via a telephone interview, and checked against inclusion and exclusion criteria. After signing the agreement on the survey day, the seniors completed three assessments.

1. To test their cognitive abilities, the subjects performed the Mini-Mental State Examination (MMSE) with 30 items, in a digital version. This test was also used as a screening test to exclude persons with cognitive impairments from the study (MMSE < 25). With regard to statistical quality criteria, this instrument has good to very good results (reliability coefficient .96 and retest reliability .89; validity .78) [17].
2. The hand force of the dominant hand was measured using a hand dynamometer. This was mainly used to highlight differences between healthy subjects and subjects with tremor. In this test, reliability coefficients of .89 to .96 are considered very good [18]. The content and construct validity can be assumed to be given [19].
3. The Grooved Pegboard Test was used to determine the coordinative abilities or fine-motor abilities of the dominant hand, in order to investigate the influence of tremor on gestures (test-retest reliability .69 to .76 for the dominant hand) [20].

Subsequently, the interviews and the analysis of the requirements for the SP system were conducted. The interview guideline was divided into five phases. In the first interview phase, the topics of sociodemographic data, domesticity, use of technical devices in the household and handling of technical devices and associated problems were covered. In the second part of the interview, a short explanatory video clip was shown to the test participants for a better understanding of the SP system. The subsequent survey focused on the requirements for the handheld device to be developed (design) and the associated gestures (desired functions of the devices to be controlled). In the third phase, the task-based investigation took place. Here, the test participants were asked to use their imaginations to demonstrate 32 intuitive gestures for particular operating functions of various technical devices (see Table 1).

Table 1. Devices and functions of the demonstrate gestures

Devices	Functions
TV	On/off Volume higher/lower Program forward/back Program selection
Music system/radio	On/off Volume higher/lower Song forward/back Function selection
Telephone	Answer/finish phone call Volume higher/lower
Heating	On/off Warmer/colder
Light	On/off Brighter/darker
Blinds	Up/down
Door	Open/close Unlock/lock

The intuitive gestures were demonstrated on a screen (1.20 × 1.50 m) using a standard laser pointer in sitting position. The distance to the screen was 1.50 m. Both the point projections of the pointer on the screen (see Fig. 2) and the arm or hand movements (see Fig. 3) were filmed. In these first experiments we used a video camera (frame rate 30 fps) with a resolution of 850 × 480 pixels.

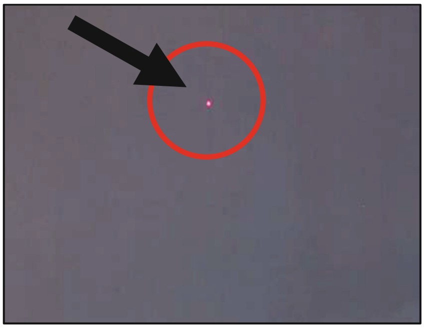


Fig. 2. Pointer on the canvas

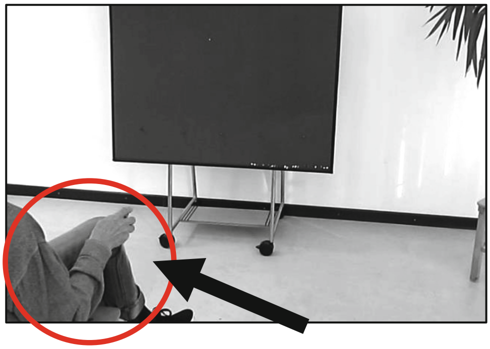


Fig. 3. Gesture

The video material was subsequently evaluated with special software, which makes it possible to reconstruct the trajectories and derive the gesture recognition from them. Two examples are shown in Figs. 4 and 5, which also clarify the differences between the two groups.

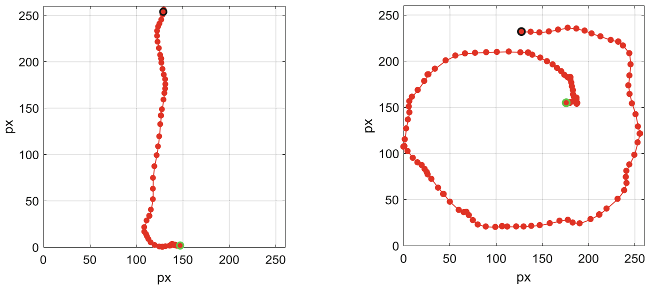


Fig. 4. Examples for recorded gesture trajectories. Participant P01 without tremor, gestures “UP” (left), “CIRCLE LEFT” (right)

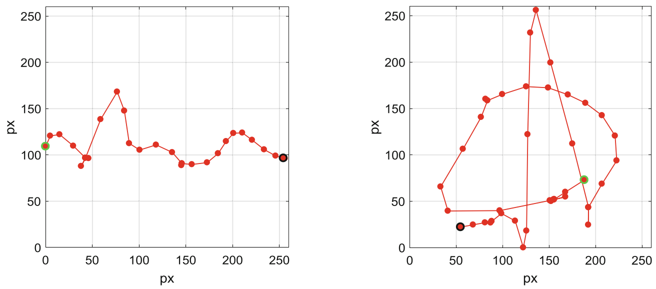


Fig. 5. Examples for recorded gesture trajectories. Participants T01 with tremor, gestures "RIGHT" (left), "CIRCLE RIGHT" (right)

In the fourth phase, the same devices with the corresponding functions were assessed using a gesture catalog. This time, the participants received suggestions and were asked to tick the gesture they thought appropriate for controlling the respective device or function. The gestures to be selected from were full circle, "A", "X", tick, swipe right/left, swipe up/down, clockwise/counterclockwise circle, wave and number. In the last part, the participants were asked about the requirements for the overall system (receiver unit, gestures and concerns).

2.2 Sample

The entire sample comprised 20 seniors aged 60 and over. Among them were 14 healthy seniors (seven male and seven female) aged 74.8 ± 3.3 years and six seniors (three male and three female) with tremor, aged 74.5 ± 8.7 years. The results are presented in Table 2. Based on the results of the MMSE, all recruited subjects were able to participate in the study (MMSE $\geq$ 25 points). The values showed only a small difference between healthy subjects (MMSE: 29.07 ± 1.12 points) and subjects with tremor (MMSE: 28.83 ± 1.17 points). In addition, finger coordination was measured using the Grooved Pegboard Test. The results show significant differences between the two groups in this test (U-test, $p = 0.011$). When measuring the hand force with a hand dynamometer, there are appreciable differences of approximately 9 kg between the groups, but no relevance could be determined when testing for significance (U-test, $p = 0.117$).

Table 2. Assessment results

	N	$\bar{x}$	SD	Sig.
MMSE_points	**20**	**29.00**	**1.124**	
Healthy	14	29.07	1.141	$p = 0.600$
Tremor	6	28.83	1.169	
Pegboard_min.	**20**	**01:45**	**00:54**	
Healthy	14	01:24	00:15	$p = 0.011$*
Tremor	6	02:34	01:21	
Hand force_kg	**20**	**25.415**	**10.576**	
Healthy	14	28.129	9.375	$p = 0.117$
Tremor	6	19.083	11.304	

Base: Mann-Whitney U-test, * $p < 0.05$

2.3 Data Analysis

The qualitative content analysis of the interviews was conducted by the moderators based on a systematic protocol. In order to ensure the correctness of the evaluation, the four-eyes principle was applied. The protocols for all 16 test participants were subsequently digitized and subjected to computer-aided evaluation using ATLAS.ti. The aim of the content analysis was to reduce the material from the interviews and to create an overview through abstractions. Therefore, the analysis was based on a category system of 42 codes. These codes were strongly oriented to the guidelines of the interview. For the final evaluation of the results, the contents of the codes were checked for similarities, from which the reduction was formulated in the form of requirements. For illustration purposes in the results evaluation, important requirements were documented with transcribed quotations from the tape recordings. Quantitative methods (descriptive and inductive) using Excel and IBM SPSS Statistics 25 were used to evaluate the sociodemographic data, the assessments, the task-based part and the gesture catalog.

3 Results

3.1 Qualitative Results

The following paragraph presents the results from the qualitative part of the study, using quotations from the interviews for illustration.

Use of Technology
The results of the qualitative part of the study show that technical devices within the households of seniors mainly consist of entertainments electronics. The most commonly used devices were PCs or laptops, TVs and radios.

Technology Operating Issues
The questioned seniors identified two main issues relating to system operation: firstly, the large number of choices within the operating menu and secondly, the large selection of buttons with unclear functionalities, constituting a high potential for operation errors. *"There is the potential that I hit the wrong button" (P01, female, 79y).*[1]

The long periods required for adaptation to new operation systems were mentioned and described as being problematic. Here, seniors mainly referred to the wiping gestures for smartphones or tablets. Seniors with tremor symptoms especially criticized small buttons, as their accuracy in pressing buttons is considerably reduced, and this leads to operating errors. *"Yes, sometimes it hardly works. The smaller the buttons, the worse the situation, because my hands, because they shake a lot" (T02, female, 84y).* In addition, seniors with tremor mentioned their problems with holding things. *"When I'm shaking badly, I could just throw it into the corner, because absolutely nothing works then" (T06, female, 60y).*

[1] All quotations were translated from German into English. A "P" stands for a healthy senior, a "T" stands for a senior with tremor symptoms.

Desired Devices for Gesture Control

Gesture control for TVs (n = 13), lights (n = 6), hi-fi systems/radios (n = 5) and doors (front door and room doors) (n = 3) were the most frequently desired by the interviewees. The majority of the study participants rejected gesture-based control of devices within close proximity of the user for reasons of pointlessness. Examples were washing machines and stoves or ovens. *"Perhaps an automatic system for automatically switching off the device, but otherwise you have to stand in front of the oven anyway" (P04, male, 76y).*

Apart from the control of devices, the seniors expressed requirements regarding the operation of functionalities for each device. Desired functionalities included, but were not limited to, switching the device on and off, adjusting the volume, switching TV and radio channels and directly choosing the channel, dimming the lights and opening/closing and locking/unlocking doors. Additional features were selected for heating, window blinds, telephones and mobile phones, TV media libraries and Internet boxes.

Receiver Unit

The study participants made diverse statements regarding the system setup. For the array and location of the receiver units especially, no general statements could be derived from the interviews. However, the seniors described two main possible concepts: (1) a central receiver unit combining all operable devices or (2) one receiver unit per device. According to the participants, a central receiver unit makes sense when a user wants to control devices outside the room that he or she currently occupies. *"A central receiver unit which can be extended to a random number of devices" (P08, male, 78y).* However, a central unit was also associated with complex handling. Therefore, many participants preferred one unit per device. *"Definitely one receiver unit per device. Otherwise, I would need a whole lot of different gestures" (P01, female, 79y).* One unit per device additionally offers safety-related benefits. *"It [the device control] is more direct, […] maybe I cannot slip and trigger something [an action or function] I don't want to" (T04, female, 72y).*

Gestures

The interviewed seniors made clear statements regarding the gesture-control of various household devices. To some extent, these statements were linked to the participants' experiences with their current technology use and showed their great need for security and safety. The seniors asked for the use of consistent and uniform gestures for the same functionalities, regardless of the device. For example, the same gesture for volume control of TV and radio. *"It should be easy, clear, always the same. It may be boring for young people, but here it absolutely makes sense" (P09, male, 71y).* A great concern among the seniors was the possibility of forgetting the control gestures and consequently losing the power to control their devices. A catalog listing the gestures and corresponding functions was perceived as helpful by the majority of participants. *"Well, […] if you forget that [gesture] – you forget things when you are old – then you can look it up" (T02, female, 84y).* The choice of whether to use their own invented gestures or gestures provided by the developing company, was dependent on the participants' trust in technology and their own perceived technical understanding. Seniors who rated their own perceived technology understanding rather high would prefer to invent their own gestures. In contrast, participants who stated they preferred gestures provided by the developing company also stated that they trusted the developing company to choose appropriate gestures, rather than themselves. *“No, I would rather trust the provided gestures because they have been evaluated and I would adapt myself, but I would also like to have a catalog listing the gestures” (P02, female, 81y).*

Feedback

All interviewed participants required feedback from the system indicating a successful or unsuccessful connection between the remote and the device. Two main types of feedback requirements could be derived from the interviews: (1) audible feedback and (2) visual feedback. According to the seniors, audible feedback should be unique and clearly assigned to a function and visual feedback should be clearly visible and differentiable from other light sources. Another idea from the participants was to have audible feedback via voice output. However, the best solution, according to the study participants, was a combination of visual and audible feedback, in order to allow distinct feedback for persons with either visual or hearing impairments. *“Well, I would prefer a visual feedback. For the time when I cannot see very well anymore, then an audible feedback should be implemented” (T04, female, 72y).* The seniors rejected a tactile feedback such as vibration, due to a potentially negative impact on the operation and handling of the system. Participants with tremor symptoms especially, expressed skepticism, but healthy seniors were also concerned about the potential impact. *“Well, […] especially as vibrations or similar are present in various diseases anyway, and maybe affected persons experience it [a tactile feedback] as unpleasant or maybe it even triggers or amplifies symptoms. So maybe it would be helpful for a specific group of users, e.g., visually impaired people, but not in general for all users” (P02, female, 81y).*

Safety and Security

Many statements from the interviews revealed a high level of safety and security needs among the participating seniors. Their concerns included data protection, safety of people and potential operating errors. The interviewees frequently discussed the potential risk of system access by third parties. In the context of data transfer in the system, the participants wondered whether unauthorized third parties might be able to control devices from outside if, for example, neighbors owned the same system. They discussed whether they could control, for example, the unlocking mechanisms of a front door and gain access to the living environment. *“Well, I have that concern, that my neighbor or somebody with malicious intent, if he has access to my system […], he could do anything with it: he could switch on my oven and when I am not home, he could wreak havoc, so it must be ensured that security programs similar to my computer program prevent access from outside” (P08, male, 78y).* An additional concern expressed by the seniors was related to people’s safety in the context of the infrared lamps in the system. *“I have a great-grandson, he just turned six, and what if a child like him gets his hands on the remote and fumbles with it, what happens then? […] You can see how I fumble around with that remote and what if my great-grandson is sitting there and the infrared lamps meet his face or his body, maybe you need to take that into consideration” (T03, male, 82y).*

3.2 Quantitative Results

The following paragraph presents the results from the quantitative part of the study.

Use of Technology
In the quantitative evaluation, the use of various technical devices such as TVs, radios, telephones, smartphones, mobile phones or PCs/notebooks/tablets was also evaluated (n = 16). The following results were determined for the use of smartphones. In the group of healthy seniors, two thirds of the respondents used their smartphones regularly, but in the group with tremor symptoms only half did so. Four of the test participants still used a conventional mobile phone (two seniors from each group). It was surprising that 14 out of 16 subjects owned a PC. Only six seniors had a Notebook and four had a tablet. Use of a television or the telephone was reported by all the respondents.

Evaluation of Task-Based Investigation and Gesture Catalog
The task-based part and the gesture catalog were also quantitatively evaluated (n = 20) for a comparison between gestures invented by participants and given gestures. The frequency of used gestures was examined as a priority. Altogether, 417 gestures invented by participants and 330 gestures from the gesture catalog were evaluated. Gestures that occurred only rarely or were mentioned or shown only once were not taken into account. As shown in Fig. 6, gestures such as horizontal (right/left) or vertical (up/down) lines and circular movements (circle, either clockwise or counterclockwise) were the most frequently used gestures of the interviewed participants.

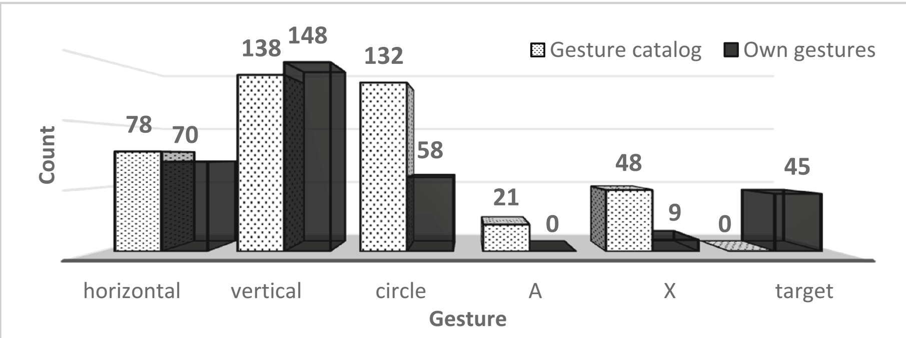


Fig. 6. Comparison between gesture catalog and participants' gestures for the most frequently used gestures for all functions

A comparison between healthy seniors and seniors with tremor showed clear differences in the task-based investigation for the gesture denoted "targeting" or "pointing to the device". Almost exclusively, tremor patients indicated this gesture as a control option (see Fig. 7). Almost 50% of healthy volunteers, on the contrary, preferred vertical pointing patterns.

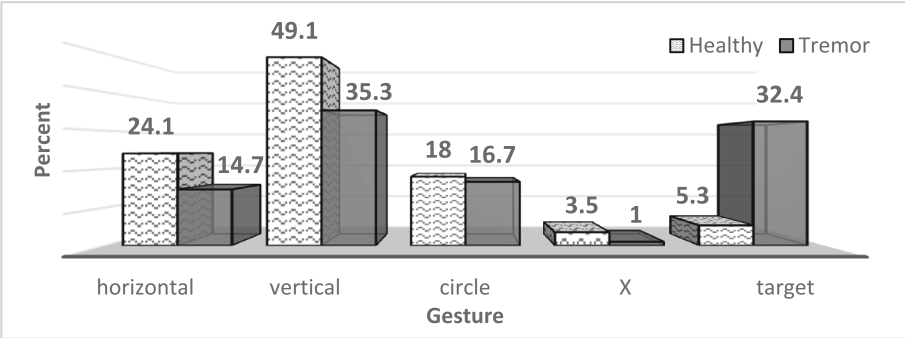


Fig. 7. Task based investigation: comparison of participants' invented gestures for healthy seniors and seniors with tremor

From the overall survey of the gestures used in the gesture catalog, it can be seen that there are only minor differences (approximately 5%) between the two groups (see Fig. 8), except that circular movement patterns seem to play a greater role in healthy seniors.

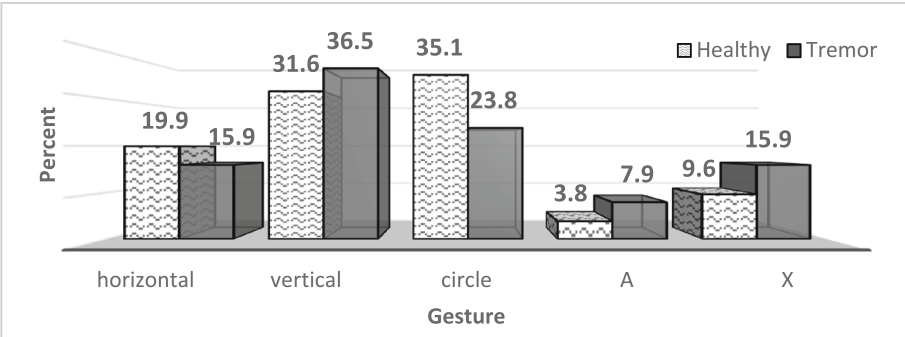


Fig. 8. Gesture catalog: Comparison of the indicated gestures between healthy seniors and seniors with tremor

In general, it could be observed that the gestures are oriented to existing patterns and that there are tendencies towards the use of certain gestures. As there were no serious differences in the gestures used between the two groups, the same functions for the different technical devices for all seniors were combined and are illustrated below.

Switching on and off occurs in the following devices: televisions, music systems, telephones, heating and lights. From the gesture catalog, it emerged that circular movements (60%) are the preferred gestures for switching on devices or systems (see Fig. 10). With regard to the participants' own gestures, the targeting gesture is somewhat favored (26%), although the circle pattern (20%) is also a relevant gesture (see Fig. 9).

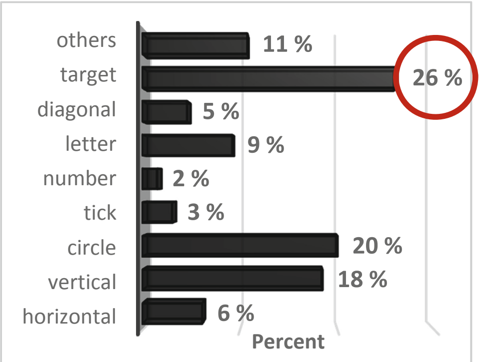


Fig. 9. Participants' own gestures – switch on

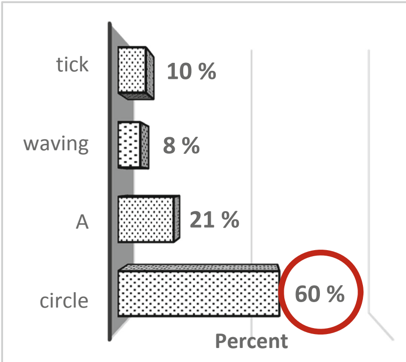


Fig. 10. Gesture catalog – switch on

The results for the switch off function are very similar. Seniors also prefer targeting (25%) for this function (see Fig. 11). Regarding the gesture catalog, the questioned participants disagreed. The gestures "circle" and "X" show an almost identical result, at 50% and 49% respectively (see Fig. 12).

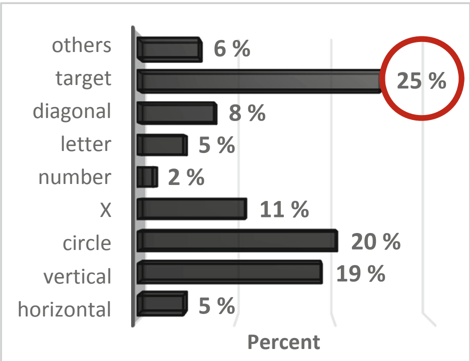


Fig. 11. Participants' own gestures – switch off

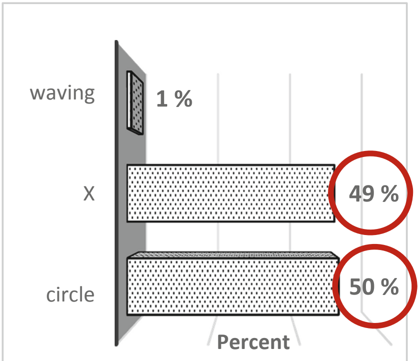
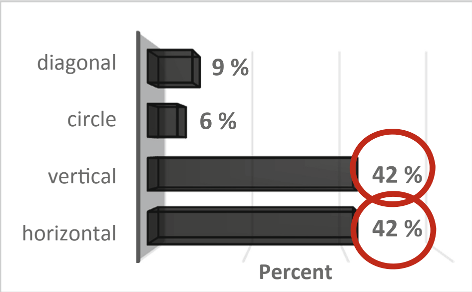


Fig. 12. Gesture catalog – switch off

The function for increasing or reducing volume was requested for televisions, telephones and music systems. Concerning this function, the participants were also divided in their opinion about whether vertical or horizontal gestures were more appropriate (see Fig. 13). The interviewed persons did not agree with regard to the gesture catalog, but the tendency towards vertical or horizontal patterns is still discernible (see Fig. 14).



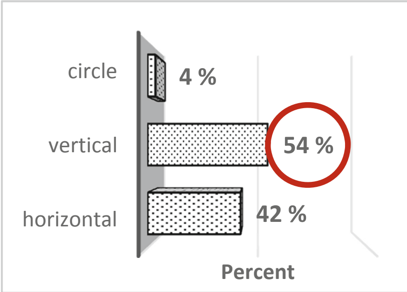
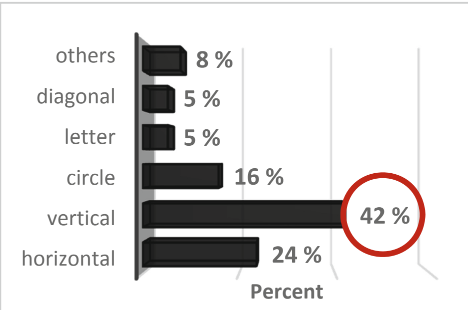


Fig. 13. Participants' gestures – volume up/down **Fig. 14.** Gesture catalog – volume up/down

Back and forth were functions that occurred either for the television, in switching programs back and forth or for music systems, in switching songs/channels back and forth. Interestingly, for this function there were different opinions for individual gestures and catalog gestures. For individual gestures, the preference was for vertical movements, i.e., upwards or downwards (see Fig. 15), whereas for the gesture catalog, the preference was for horizontal movements to the right and left (see Fig. 16).

In contrast to the back and forth function, the test participants agreed on the up and down function for controlling the temperature, the dimmer or the blinds. In this case, the majority voted for vertical up and down movement patterns both in their own gestures and in the gesture catalog (Figs. 17 and 18).



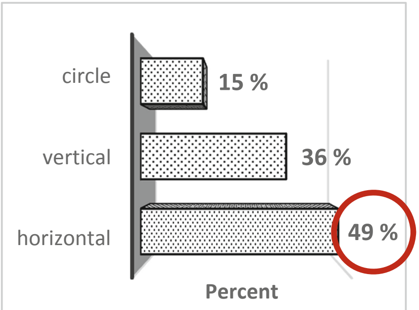


Fig. 15. Participants' own gestures – forward/back **Fig. 16.** Gesture catalog – forward/back

The last function evaluated was opening and closing doors and windows. As shown in Figs. 19, 20, 21 and 22, the majority of the participants' own gestures were different from those taken from the gesture catalog. On the one hand, vertical movements were dominant in the participants' own gestures, and on the other hand, circular movements were preferred from the gesture catalog. The large number of gesture variations indicates a rather inconsistent opinion.

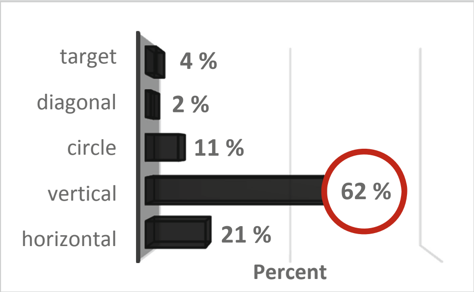


Fig. 17. Participants' own gestures – up/down

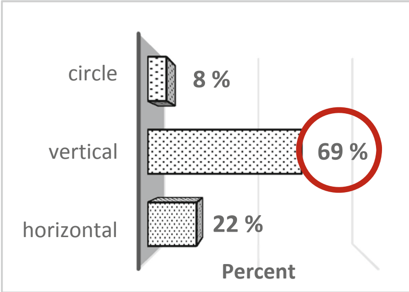


Fig. 18. Gesture catalog – up/down

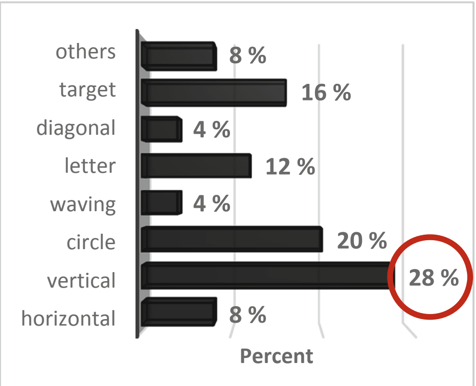


Fig. 19. Participants' own gestures – open

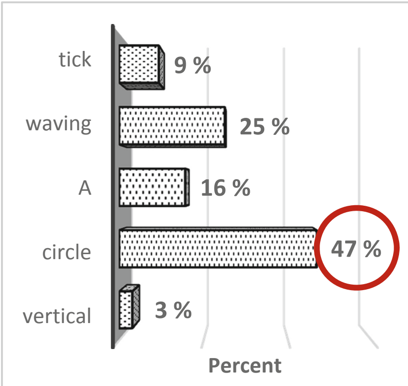


Fig. 20. Gesture catalog – open

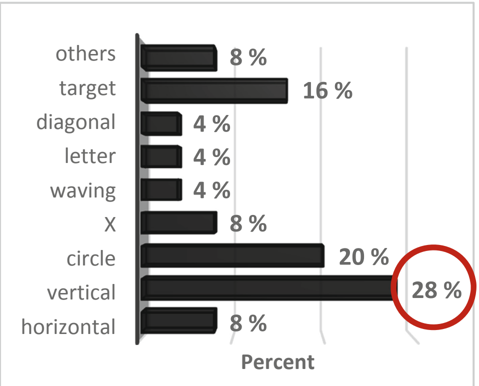


Fig. 21. Participants' own gestures – close

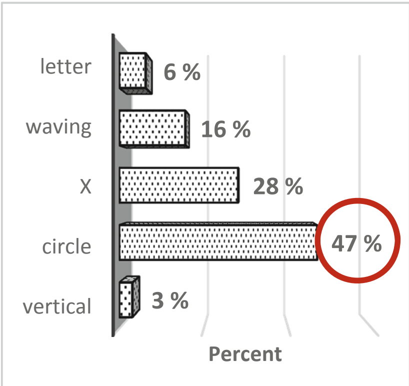


Fig. 22. Gesture catalog – close

4 Discussion

New human-technology interactions, which should contribute to an independent life into advanced age, increase the need for corresponding research in the geriatric field [21]. However, a review by Kühnel et al. in 2011 [22] concluded that only very few studies include age-specific user opinions in the design process for gesture-based interactions. This observation is still valid today. Therefore, this project has the goal of developing a technical solution especially for seniors. The emphasis was on older people and older people with tremor who were actively involved in the development process in order to identify requirements as well as expectations and concerns about an SP system. Through the 16 qualitative interviews, a multitude of age-appropriate requirements for the development of the SP system could be identified. These will be discussed in detail below. They are of central importance in the entire development process. Furthermore, studies prove the high importance of user-centered approaches, as there is a large gap between the requirements of younger and older people [21]. The use of technology constitutes an evidence of the solemn differences between the generations. Whereas over 90% of people in the age group up to 50 use a smartphone, only 41% of people over 65 do so [23]. Although the results of this study show that the interviewed persons used smartphones (60%) or tablets (25%), problems occurred with regard to device operation. According to the respondents with tremor, this difficulty can increase many times over, as the accuracy of gesture execution becomes impaired. Nevertheless, more complex tasks such as rotating or zooming, are also a challenge for healthy elderly people [24]. Against this background, gesture-in-mid-air systems can be a real relief for elderly people. The results of the present study also show that they are interested in the new gesture-based operating system. This type of system is especially popular since small buttons or applications such as those on a smartphone or tablet do not have to be hit accurately. These results were also confirmed in a study by Bobeth et al. [25]. Gesture-in-mid-air operation requires more practice in this age group, but study participants showed a higher interest in this compared to a control with mobile devices. Gerling et al. [26] also pointed out that handheld control devices such as controllers or remote controls facilitate the execution of a gesture, compared to hands-free control. This represents a further advantage for the SP system.

According to the test participants, visual or acoustic feedback or a combination of both would increase operating safety. The necessity for optical, acoustic or tactile feedback in gesture control has also been confirmed in various studies [27, 28]. Most of the surveyed seniors were in agreement about the doubtful usefulness of tactile feedback. They supported the opinion of Hwangbo et al. [28], that acoustic feedback makes more sense than haptic feedback, especially for older people. Sáenz-de-Urturi et al. [29] also recommended acoustic feedback, especially for gesture-in-mid-air systems.

The interviewed seniors mentioned concerns about forgetting operating gestures and operating the system incorrectly. According to Pages [30], operating errors are the result of lack of knowledge and experience in technology use, as well as cognitive impairment. Considering this, it is essential to prevent concerns about avoiding operating errors. According to the literature, a clear and easy operation procedure as well as intuitive and simple gestures, can counteract concerns about operating errors [25, 31–

33]. Additionally, users should receive a comprehensive training on the system. Seniors especially, could benefit from relevant information about the quality of safety-related measures intended to ensure personal and data protection.

As shown in the quantitative results, there were only a few differences between the two groups in terms of chosen gestures. With regard to one gesture, i.e., “targeting”, there was an evident difference between the two groups and between the task-based investigation and the gesture catalog. The reason for the discrepancy might be explained by tremor symptoms. People with tremor might automatically choose gestures requiring little physical effort, in order to minimize movements. The gesture catalog did not list the “targeting” gesture. However, it listed a circle, which was interpreted by the seniors to be a pointing gesture and therefore chosen more frequently. A further outcome of the study was that the participants repeatedly chose the same, mainly simple, gestures, for the same functionality, regardless of the type of device. Generally, the chosen gestures were similar to the gestures defined for household technology in a study by Ouchi et al. [34], namely, straight up and down, straight left and right and a clockwise and counterclockwise circle.

5 Conclusion

In conclusion, it was shown that older people were highly interested in, and receptive to, the SP system. Existing problems with conventional technical devices, such as buttons which are too small and too numerous, often generate an overload for seniors, which can be minimized by an intuitive gesture-controlled and buttonless interaction. Although the seniors recognized the benefits of the system for themselves and for the most part could exactly describe the desired functionalities, they also expressed concerns regarding malfunctioning, system failure, forgetting gestures and data and personal security. A comparison of the requirements of healthy older persons and persons with tremor showed only a few differences in the types of gestures, feedback and concerns. However, the gestures of participants with tremor were performed less clearly. Preliminary studies by Ruser et al. [35] have already shown that a satisfactory performance of this innovative approach based on test trajectories with 29 gestures was achieved in healthy participants, with an average recognition rate of almost 94%. Considering only six fundamental quasi-intuitive gesture (‘UP’, ‘DOWN’, ‘LEFT’, ‘RIGHT’, ‘CIRCLE LEFT’, ‘CIRCLE RIGHT’), the average recognition rate was above 98%. In this respect, it will be important in the further course of the project to determine the suitability of the system for people with tremor, and to develop technical solutions for gesture recognition in cases of tremor.

References

1. Statistisches Bundesamt: 13th Coordinated Population Projection for Germany (2015). https://service.destatis.de/bevoelkerungspyramide/index.html#!y=2030&l=en&b=1948. Accessed 26 Feb 2019
2. RKI: Health in Germany – the most important developments (2015). https://www.rki.de/EN/Content/Health_Monitoring/Health_Reporting/HealthInGermany/health_germany_node.html. Accessed 27 Feb 2019
3. Kremer-Preiß, U.: Aktuelle und zukunftsträchtige Wohnformen für das Alter. In: Wahl, H.-W., Tesch-Römer, C., Ziegelmann, J. (eds.) Angewandte Gerontologie: Interventionen für ein gutes Altern in 100 Schlüsselbegriffen, pp. 554–561. Kohlhammer, Stuttgart (2012)
4. Oswald, F., Wahl, H.-W.: Alte und neue Umwelten des Alterns – Zur Bedeutung von Wohnen und Technologie für Teilhabe in der späten Lebensphase. In: Naegele, G., et al. (eds.) Teilhabe im Alter gestalten – Aktuelle Themen der sozialen Gerontologie, pp. 113–129. Springer VS. Wiesbaden (2016)
5. Strese, H., Seidel, U., Knape, T., Botthof, A.: Smart Home in Deutschland – Untersuchung im Rahmen der wissenschaftlichen Begleitung zum Programm Next Generation Media (NGM) des Bundesministeriums für Wirtschaft und Technologie (2010). Institut für Innovation und Technik (iit). https://www.iit-berlin.de/de/publikationen/smart-home-in-deutschland. Accessed 08 Feb 2019
6. Meyer, S.: Technische Unterstützung im Alter - was ist möglich, was ist sinnvoll? Expertise zum Siebten Altenbericht der Bundesregierung (2016). Deutsches Zentrum für Altersfragen. https://nbn-resolving.org/urn:nbn:de:0168-ssoar-49980-9. Accessed 07 Feb 2019
7. Statista: Share of Internet users in Germany from 2014 to 2018, by age (2019). https://www.statista.com/statistics/790407/internet-usage-by-age-germany/. Accessed 27 Feb 2019
8. Statista: Anteil der Internetnutzer nach Endgeräten und Altersgruppen in Deutschland im Jahr 2016 (2019). https://de.statista.com/statistik/daten/studie/222917/umfrage/genutzte-internetzugaenge-in-deutschland-nach-alter/. Accessed 12 Feb 2019
9. Frees, B., Koch, W.: ARD/ZDF-Onlinestudie 2018: Zuwachs bei medialer Internetnutzung und Kommunikation. Media Perspektiven **9**, 398–413 (2018)
10. Al-Shamayleh, A., Ahmad, R., Abushariah, M., et al.: A systematic literature review on vision based gesture recognition techniques. J. Multimed. Tools Appl. **77**(21), 28121–28184 (2018)
11. Rautaray, S., Agrawal, A.: Vision based hand gesture recognition for human computer interaction: a survey. Artif. Intell. Rev. **43**(1), 1–54 (2015)
12. Bachmann, D., Weichert, F., Rinkenauer, G.: Review of three-dimensional human-computer interaction with focus on the leap motion controller. Sensors **18**(7), 2194 (2018)
13. Liu, H., Wang, L.: Gesture recognition for human-robot collaboration: a review. Int. J. Ind. Ergon. **68**, 355–367 (2018)
14. Schlömer, T., Poppinga, B., Henze, N., Boll, S.: Gesture recognition with a Wii controller. In: Proceedings of the 2nd International Conference on Tangible and Embedded Interaction (TEI 2008), pp. 11–14 (2008)
15. Louis, E.D., Ottman, R.: How Many People in the USA Have Essential Tremor? Deriving a Population Estimate Based on Epidemiological Data. Tremor and Other Hyperkinetic Movements, 4 (2014). https://doi.org/10.7916/D8TT4P4B. Accessed 27 Feb 2019
16. Deuschl, G., Berg, D.: Essenzieller Tremor: State of the Art der Nervenarzt **4**(89), 394–399 (2018)
17. McDowell, I.: Measuring Health - A Guide to Rating Scales and Questionnaires. Oxford University Press, New York (2006)
18. Fetz, F., Kornexl, E.: Sportmotorische Tests: praktische Anleitung zu sportmotorischen Tests in Schule und Verein. ÖBV, Wien (1993)

19. Bös, K.: Handbuch Motorische Tests - Sportmotorische Tets, Motorische Funktionstests, Fragebögen zur körperlich-sportlichen Aktivität und sportpsychologische Diagnoseverfahren (3. überarbeitete und erweiterte Ausg.). Hogrefe Verlag GmbH & Co. KG., Göttingen (2017)
20. Ruff, R.M., Parker, S.B.: Gender- and age-specific changes in motor speed and eye-hand coordination in adults: normative values for the finger tapping and grooved pegboard tests. Percept. Motor Skills, **76**(3_Suppl.), 1219–1230 (1993). https://doi.org/10.2466/pms.1993.76.3c.1219. Accessed 08 Feb 2019
21. Chen, W.: Gesture-based applications for elderly people. In: Kurosu, M. (ed.) HCI 2013. LNCS, vol. 8007, pp. 186–195. Springer, Heidelberg (2013). https://doi.org/10.1007/978-3-642-39330-3_20
22. Kühnel, C., Westermann, T., Hemmert, F., Kratz, S., Müller, A., Möller, S.: I'm home: defining and evaluating a gesture set for smart-home control. Int. J. Hum Comput Stud. **69**, 693–704 (2011)
23. Statista: Share of smartphone users in Germany in 2017, by age group (2019). https://www.statista.com/statistics/469969/share-of-smartphone-users-in-germany-by-age-group/. Accessed 27 Feb 2019
24. Liang, S.-F.M., Lee, Y.-J.B.: Control with hand gestures by older users: a review. In: Zhou, J., Salvendy, G. (eds.) ITAP 2016. LNCS, vol. 9754, pp. 350–359. Springer, Cham (2016). https://doi.org/10.1007/978-3-319-39943-0_34
25. Bobeth, J., et al.: Tablet, gestures, remote control? Influence of age on performance and user experience with iTV applications. In: Proceedings of 2014 ACM International Conference on Interactive Experiences for TV and Online Video, Newcastle Upon Tyne, United Kingdom, 25–27 June, pp. 139–146 (2014)
26. Gerling, K.M., Dergousoff, K.K., Mandryk, R.L.: Is movement better? Comparing sedentary and motion-based game controls for older adults. In: Proceedings of Graphics Interface 2013, pp. 133–140. Canadian Information Processing Society (2013)
27. Chung, M.K., Kim, D., Na, S., Lee, D.: Usability evaluation of numeric entry tasks on keypad type and age. Int. J. Ind. Ergon. **40**(1), 97–105 (2010)
28. Hwangbo, H., Yoon, S.H., Jin, B.S., Han, Y.S., Ji, Y.G.: A study of pointing performance of elderly users on smartphones. Int. J. Hum.-Comput. Interact. **29**(9), 604–618 (2013)
29. Sáenz-de-Urturi, Z., García Zapirain, B., Méndez Zorrilla, A.: Elderly user experience to improve a Kinect-based game playability. Behav. Inf. Technol. **34**(11), 1040–1051 (2015)
30. Page, T.: Touchscreen mobile devices and older adults: a usability study. Int. J. Hum. Factors Ergon. **3**(1), 65–85 (2014)
31. Bobeth, J., Schmehl, S., Kruijff, E., Deutsch, S., Tscheligi, M.: Evaluating performance and acceptance of older adults using freehand gestures for TV menu control. In: Proceedings of 10th European conference on Interactive TV and Video, Berlin, Germany, 04–06 July, pp. 35–44. ACM (2012)
32. Gerling, K., Livingston, I., Nacke, L., Mandryk, R.: Full-body motion-based game interaction for older adults. In: Proceedings of SIGCHI Conference on Human Factors in Computing Systems, Austin, TX, USA, 05–10 May, pp. 1873–1882. ACM (2012)
33. Ferron, M., Mana, N., Mich, O.: Mobile for older adults: towards designing multimodal interaction. In: Proceedings of 14th International Conference on Mobile and Ubiquitous Multimedia, Linz, Austria, 30 November–02 December, pp. 373–378. ACM (2015)
34. Ouchi, K., Esaka, N., Tamura, Y., Hirahara, M., Doi, M.: Magic wand: an intuitive gesture remote control for home appliances. In: International Conference on Active Media Technology, Kagawa, Japan, 19–21 May (2005)
35. Ruser, H., Kosterski, Sz., Kargel, Ch.: Gesture-based universal optical remote control: concept, reconstruction principle and recognition results. In: IEEE International Instrumentation and Measurement Technology Conference (I2MTC), Pisa (2015)