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Peer-Reviewed Paper

Acceptance of seniors towards automatic in home fall detection devices

Introduction:

Increasing longevity in most western countries puts a burden on their economies and presents their healthcare systems with new challenges (Schmidt et al. 2013). In addition to age-related diseases, falls are amongst the main risk factors for chronic disabilities, a major contributor to medical expenditures (Murray et al. 1996) and the leading cause for fatalities in senior citizens. To reduce some of the negative effects of falls for older adults, various approaches to fall detection are available. Personal alarm systems that rely on manual activation by the user after a fall are in widespread use for geriatric fall detection in North America and Europe (Fleming et al. 2008). However, these systems fail to raise alarms if the user is unconscious. Furthermore, Heinbucher et al. (2010) found that personal alarm systems were not used at all by 27% of the subjects and only 14% wore the button all the time. Therefore, more recent investigations have looked into ways of automatic fall detection. The most commonly used approaches can be divided into three categories: wearable devices (mostly accelerometers), ambient sensors and optical sensors (Igual et al. 2013). Various studies have investigated the effectiveness of these fall-detection technologies in laboratory conditions (Lindemann et al. 2005, Chen et al. 2005, Bianchi et al. 2010, Yuwona et al. 2012) but only few of them were conducted with seniors under real life conditions and suffer from reliability problems (Bourke et al. 2008, Bourke et al. 2010, Bagala et al. 2012, Feldwieser et al. 2014).

Kangas et al. (2008) compared different low-complexity fall detection algorithms. The reports of the study state excellent impact detection with a head-worn accelerometer but, due to stigmatization of the user, suggests that a waist-worn triaxial accelerometer is optimal for fall detection. Browsell et al. (2004) equipped 34 subjects with a waist-worn accelerometer for a mean period of 17 weeks; 85% of the subjects stated the accelerometer improved their feeling of safety, 72% felt more confident, 58% thought it improved their independence and 90% were pleased they had a fall detector. However, 38% of users reported problems attaching or wearing the belt. Ferrari et al. (2011) examined the acceptance of five hospitalized older adults while performing everyday activities, such as sitting and getting in and out of bed. The authors report a high acceptance of a chest-worn accelerometer in five hospitalized seniors, however, the subjects only wore the fall detector for a period of four hours which narrows the possibility of generalizing the results.

Bloch et al. (2011) investigated the acceptability of a body-worn accelerometer on 10 hospitalized seniors in a geriatric ward, for an average of 21 days. After the initial investigation, subjects were instructed to wear the accelerometer permanently for the duration of the study. One subject reported itchy sensations related to the sensor but no other adverse events or functional impairments were recorded. The acceptability of the system was rated as excellent and no dropouts occurred during the investigation. Giansantini et al. (2009) developed a video-based tool for use in home assessment of the fall risk of older adults. The study was performed by inertial measurement units with accelerometers and rate gyroscopes. One subject was equipped with the device for a period of 20 days. The authors found high acceptance of a waist-worn accelerometer; however, with one subject the sample size was low.

A number of studies analyzed seniors' acceptance of automatic fall detection devices. For example, Londei et al. (2009) investigated the perception and receptivity of older adults regarding the introduction of intelligent video monitoring at home. Ten of the 50 recruited subjects refused to participate and 25 subjects could be included in the investigation. Brownsell et al. (2000) found, that steps taken to improve privacy protection like the ability to turn video monitoring off were welcomed by the subjects. Demiris et al. (2012) interviewed 15 subjects, who stated they would only agree to be videotaped by cameras used for fall detection purposes if the pictures were anonymized. Despite the interesting findings of these studies, it has to be mentioned that the results are only based on the theoretical perceptions of seniors during interviews or focus groups.

Justification:

Despite the widespread use of personal alarm systems, the literature shows these systems are hardly used in the event of a fall and not worn by subjects in the majority of cases. There are several studies that investigate the acceptance of automated fall detection devices of older adults with a predefined risk of falling. These investigations found clear acceptance problems with fall detection devices. However, most studies did not actually install fall detection devices in the homes of older adults and installment or wearing time of the devices was short. Additional qualitative research is needed to understand older adults' perceptions of the acceptability of various types of fall detection technology already in use before additional resources are invested in developing technical fall detection systems for the domestic environment. For this purpose, this study investigated the acceptance of fall detection technology among 14 seniors with a predefined risk of falling over a prolonged period of time (eight weeks) within their community dwellings during everyday conditions. The primary goal was to find out the acceptance of community-dwelling senior citizens with a predefined risk of falling towards automated fall detection devices. Secondary goals were the evaluation of physical and mental health status, fear of falling, as well as attitude towards technology in general and technology commitment.

Methods:

The following section describes the methods that were used during this study.

Procedure:

The following section contains information about the study's procedure. Seniors were recruited through announcements displayed on boards in senior community dwellings. Leaflets about the study were displayed in local pharmacies, physiotherapist clinics, doctors' offices, activity centers for seniors and board and care homes.

In visit 0 potential subjects from a Berlin city population were screened for inclusion and exclusion criteria. Persons were eligible for the study if they were aged 65 years or older, experienced at least one fall in the last 12 month and a Timed up and Go test result above 15 seconds (a predefined risk of falling). A timed up to go test (TUG), (Podsiadlo & Richardson 1991) with results of over 13.5 seconds was found to have the predictability to classify people who were at risk of falling. Since the TUG does not seem be a reliable predictor on its own (Barry et al. 2014), only subjects that experienced at least one fall in the last

12 months and had a TUG result above 15 seconds were included in the study. Persons with existing immobility were excluded from the trial. All subjects gave their written informed consent.

After informed consent was signed, examination of admission and a safety report were assessed and the feasibility of sensor installation in the dwelling was checked. Medical geriatric assessments TUG, the Tinetti test (Tinetti 1986), Functional Reach Test (Duncan et al. 1990), STRATIFY Oliver at al. 1997), the Barthel index (Masud & Morris 2001) and the mini mental state examination (MMSE) (Folstein 1975) were performed. The TUG is a clinical test for evaluating mobility and fall risk in older adults. Patients have to get up from a chair from a sitting position, walk a distance of three meters, turn around and return to a sitting position again, when the time for the process is stopped. The Tinetti test assesses the mobility and fall risk of seniors by evaluating various tasks related to balance and gait. The Functional Reach Test is used to assess the functional balance of older adults in a standing position. The STRATIFY test consists of a six-item questionnaire that commonly is used for classifying fall risk. The Barthel index is a questionnaire for the systematic assessment of basic functions of everyday life. The MMSE test is a questionnaire that is commonly used for the assessment of cognitive deficits. Furthermore instructions on handling the waist-worn accelerometer (SHIMMER® Rev 1.3) and the visual and acoustic Microsoft® Kinect sensor which was installed in the homes of subjects that agreed to the installation were given.

This study was performed within the private homes of elderly adults living independently and self-sufficiently. All subjects received an accelerometer with the corresponding belt. Three of the 14 subjects were also equipped with the video and acoustic fall detection system. The reason for only equipping a sub-group with the additional video and audio was that this system required elaborate installation measures and was more cost intensive compared to accelerometric fall detection. The subjects were instructed to wear the accelerometer during the daytime for at least eight hours. When fully charged, the accelerometer had a battery life of five to seven days. For comfort reasons the accelerometer was not worn during the night. The subjects were encouraged the wear the accelerometer during all activities such as sport classes, vacation, bike rides, housework etc. The sensor had to be worn in the frontal pelvis region of the subjects' body, in a special belt, that fitted the exact dimensions of the sensor to assure the high quality of recorded data. The sensor had to be charged every five to seven days; an indicator for the status of the battery was not available. Charging was either performed by the subjects themselves, or the latest at each visit of the study personnel. A subgroup (n=3) of the study population additionally received one video and audio monitoring system (1 camera) which could manually be turned off by the subjects in case of discomfort or privacy concerns. Subjects were instructed to keep visual and audio recording running 24 h a day during the study duration. For this purpose, a Microsoft Kinect sensor with an integrated microphone was used. Visual and audio data were stored on a Dell Laptop Computer. Due to the large amount of data collected by the system, an external hard disk drive had to be used for data storage. Before installation it was demonstrated that the collected video data would make it impossible to draw conclusions about the subject's actual identity

A self-developed questionnaire consisting of open and closed questions was carried out on the first and last days of the study to obtain information on general subjective wellbeing, acceptance and attitude towards the used sensor equipment as well as the overall attitude towards technology, subjects had the option to rate each system as either "very acceptable", acceptable", "rather not acceptable" or "not acceptable". The collected data from the questionnaire were then analyzed; findings are presented in the results section. The questionnaire was pre-tested with five seniors before it was applied to the study population and consisted of general questions on demographics, self-rated health status and technical acceptance on a five-item Likert scale, with open questions regarding technical acceptance and a validated questionnaire by Neyer et al. (2012) on technology commitment. The researchers also took field notes.

The study duration was eight weeks with a maximum of nine visits. The study was approved by the ethics committee of the Charité Universitätsmedizin, Berlin (EA4/005/12). This study is part of a larger study that investigated the capabilities of fall detection devices in the homes of 28 older adults (Feldwieser et al. 2014), due to organizational issues it was only possible to investigate 14 of the 28 subjects on the acceptance issues related to fall detection devices. Subjects were recruited from a Berlin city population though flyers and leaflets in hospitals, senior activity centers, pharmacies, physiotherapist clinics and the university for the elderly in Berlin. The current sample only represents a subsection of 14 participants from the previously mentioned study.

Results:

Fourteen subjects (nine female, five male), mean height 157.80±45.8 cm, mean weight 75±10.9 kg, mean age 75.1 ± SD 7.5 years, aged from 69 years to 88 years completed the pre-post questionnaire. Since no significant correlations were found in the statistical analysis, only the results from the field notes and a frequency analysis of the questionnaire date will be presented. In general, recruiting of the subjects was difficult and many people who were contacted refused to participate in the study. Frequently stated reasons were that the study duration was too long, concerns about privacy or unwillingness to have technical equipment installed at home were expressed. Sixty-one seniors were screened and 14 were included in the study.

All subjects rated the accelerometer as either very acceptable or acceptable before and after the study, with identical results for the camera and microphone. The subjects were not worried about their data being recorded before or after the study. However, the subjects stated in the questionnaire that they were worried about data being recorded while family and friends were present. While it was positively noted by the subjects that the accelerometer could be worn underneath clothing, female subjects frequently mentioned that it was visible to other persons by leaving a “bump” (♀, 84) in the area where it was worn. This was perceived as unattractive and three subjects worried that it would stigmatize them and make them look like “there is something wrong with me” (♀, 88). There was no indicator of the charging status of the accelerometer’s battery. Subjects therefore frequently expressed concern and did not know if the device was still operating. The availability of the privacy button and the fact that subjects were not personally recognizable on the video recordings was welcomed by all subjects, during recruitment as well as throughout the study duration. Installation of the visual and acoustic equipment was often difficult due to the size of the equipment, need for wiring and availability of power sources. Flickering or blinking lights on any device was disturbing to all subjects and was either taped or shut off to reduce subject disruption. All subjects refused to be recorded in private areas like the bedroom or bathroom.

Technology commitment:

The subjects were very curious about technical innovations. Overall, they were confident and interested in using technological innovations and felt they were in control of the outcomes. They found the technology appealing and confident in their ability to use technological innovations. Subjects stated that they were less likely to be overwhelmed by technical innovations after the study (n=2) compared to before (n=5), as well as less afraid to handle or break technical innovation after the study (n=2) than before (n=4). Before and after the study subjects showed a high level of interest in the results of the study “I would like to see what the benefit of it is” (♂, 69 years), “well, I want to know why I am falling down” (♀, 79 years), “I am very curious about the results” (♀, 70 years), “that there will be some results” (♂, 70 years). Before the study three subjects feared that the fall detection technology would lead to a change in their everyday life. This number noticeably decreased to only one subject after the study. .

Health:

After the medical geriatric assessment, the subjects showed no signs of cognitive impairment (assessed by MMSE), a moderate risk of falls (Tinetti, STRATIFY), no limitations in functional balance abilities (Functional Reach), minimal locomotors functional restrictions (Barthel Index) and a functional relevant reduction in mobility (TUG). Fear of falling also decreased towards the end of the study. Self-rated general health of subjects was reduced after the study duration. Initially, 35% of the subjects rated their health status as good to very good, while at the end of the study this number decreased to 14%.

Fall detection:

This investigation was part of a larger study that investigated 28 patients. The results of the fall detection capabilities are reported elsewhere (Feldwieser et al. 2014) but are briefly stated. The study was able to collect a large amount of sensor data, overall 1,023 days of data were recorded. No falls were recorded in front of the microphone or the camera. There were 15 falls during the study, in 12 of these cases the accelerometer was worn and 10 falls were detected correctly. However, the defined algorithm that was used for fall detection recognized 3.75 falls per day, which equals 4,592 falls.

Discussion:

Because of infrequent use of technology, older people often perform worse than younger adults in the handling of technology, become more upset and often blame it on themselves when something goes wrong and are more easily confused when using technology (Esposito 2012). This is a potential reason why senior citizens are often skeptical when asked to use technical innovations and have a tendency to reject it (Route Perez 2014). These findings are contrary to the results of the current study. Possible reasons could be that the subjects in this study showed good technical commitment and were comfortable using the technology. Additionally, the fall detection devices in this study were very easy to use, with only minimal interaction of the subjects. Sample sizes in most studies on acceptance of automatic fall detection devices are small and long-term studies in the dwellings of seniors with a predefined risk of falling are rare. Despite the seniors' high acceptance of automatic fall detection devices in this study, it was possible to identify several barriers to their use, which could help increase the acceptance of these systems. Furthermore, the observations from previous studies on this subject should be brought in context with the current findings.

Accelerometer:

The acceptance of the accelerometer was generally high. The relatively small size of the accelerometer and the adjustable belt used in the current study could be a reason for this observation. These findings were confirmed by another study that also provided a special belt for housing the sensor (Marschollek et al. 2014). Subjects reported fewer problems (27%) with the accelerometer with the belt than without it (38%). While the belt for the accelerometer was generally perceived as comfortable, women found the size of the accelerometer bulky and unappealing. Despite the relatively small size of the accelerometer, it was still visible as a small bump underneath the clothes which was perceived as especially since it was found "not attractive" and stigmatizing. Future studies should take up these usability issues and incorporate them in the design of accelerometric fall detection devices, so that gender-specific acceptance problems can be resolved. Male users in this study did not express any aesthetic concerns. The missing indication of the accelerometer's battery status was a concern for a majority of subjects. While Brownsell et al. (2004) reported that subjects actually felt and increased sense of security and more confident when wearing fall detection devices, issues that actually decrease the subjects' confidence in fall detection devices should be avoided. Future studies that investigate battery-operated accelerometers should implement an indicator for battery life, keeping in mind that blinking lights are likely to be unsuitable for this purpose.

Visual and acoustic fall detectors:

The subjects for the video fall detection expressed some concern about privacy issues. Further steps taken in the research to maximize privacy such as the use of the "privacy button", not recording actual conversations and taking videos that will not identify the person might have eliminated acceptance issues in this investigation. Subjects were concerned about privacy issues especially when friends and family came to visit and if this was a cause for discomfort to visitors, it would potentially reduce subjects' social contacts. Subjects were also happy about the fact that there was just one camera installed in their dwelling and instalments in the bathroom and bedroom were generally denied. These observations are also confirmed by Lodi et al. (2009) and Brownsell et al. (2000). Flickering lights of the hardware were generally perceived as disturbing by all subjects. In this study flickering lights were only present on the visual and acoustic fall detection system and not on the accelerometric sensor. Subjects requested that flickering or permanent lights should either be switched off or taped off. The size of the equipment was still quite large and required quite a large amount of wiring, which presented problems in the installation process; the large amount of wires presented a particular problem. Wires had to be laid carefully so they did not act as another risk factor for falling in the seniors' dwellings. If feasible, wireless connections should be used as much as possible to reduce any additional risk of falling and to not disturb the overall architectural impression of the subject's home. Future investigations should also use smaller devices that are easier to install and versatile mounts for the camera system are required to find the right spot to provide the best field of vision.

The reported difficulties in recruiting subjects suggests that automatic fall detection devices cannot be applied to the broad general population. As with the use of social media, some people seem to be more concerned about privacy issues than others. In particular, the visual fall detection was seen as invasive to the privacy of the subjects. Similar observations were made by Lodi et al. (2009) and Demiris et al. (2012). Therefore it is likely that only a specific part of the senior population would be willing to actually use automated fall-detecting devices in the domestic environment. The reasons why seniors are not willing to accept this technology need to be evaluated in more detail, so that potential barriers can be identified and fall detection systems can be adapted to the desires of this population.

During recruitment it was easier to find subjects for the accelerometer. This observation was also made by Kurniawan et al. (2008). Accelerometers benefit from the fact that they can also be carried outside the home and therefore seem to be more suitable for seniors who are more active and have good cognitive abilities. Since battery-operated accelerometers need regular charging, an indicator on battery status is recommended. Optical and acoustic fall detection systems can operate autonomously and do not require any interference; however, these systems only operate inside the home and therefore are more suitable for less mobile seniors with cognitive impairments. Investigations on which devices are most suitable to monitor sensitive areas like the bathroom or the bedroom still need to be conducted, since there is a high resistance in the literature to using cameras in these spaces.

Limitations:

It has to be mentioned that it was difficult to recruit seniors who agreed to participate in this study due to concerns about privacy issues. This might have led to some selection bias; subjects in this study generally showed high values of technology commitment and were open towards technical innovation and less concerned about privacy issues. The results of this study cannot be generalized due to the small sample size and the experiences from this population might not apply to subjects with varying degrees of technological experience or different physical and mental limitations. The study population was also in good physical and mental health, seniors with more severe health conditions might show different degrees of acceptance towards fall-detection devices. Future research is needed to identify other potential target groups with a high acceptance towards automatic fall detection systems.

Subjects showed a strong personal interest in the circumstances and reasons for their falls and were keen to receive results about their personal fall risk. This was not the purpose of this investigation and no immediate results could be presented to the study population. Only future research that will provide subjects with direct benefit of a fall detection service can further clarify this point and might additionally improve the perceived usefulness and acceptance of such systems. In the light of the high false alarm rate of the accelerometer in this study, the acceptance rate towards the accelerometer would be likely to have changed if an alarm was raised each time a fall was detected.

Conclusion:

Future research on larger study populations with varying degrees of fitness and under real-life conditions is needed. The usability issues of current systems need to be addressed. In particular, an indicator that shows the charging power of the battery was perceived as useful by the participants and could lead to an increased feeling of safety. The study showed gender-specific usability issues regarding the size of the accelerometer. Women perceived the size of the accelerometer as not aesthetic and bulky, while male users did not have any concerns on that matter. Therefore, future studies should aim at a sensor design that is slim and not visible from the outside to increase acceptance of such systems for females.

Optical and acoustic fall-detection sensors are an opportunity to compensate for the deficits of current accelerometer systems. Nevertheless the acceptance is generally lower than for accelerometer-based systems due to concerns about privacy of subjects. This study employed a privacy button which enabled the subjects to deactivate the optic and acoustic sensors at any given time. This feature was perceived as a very positive by all subjects who were equipped with the optic and acoustic sensor. These findings suggest that embedding devices that maximize the privacy protection of users increase the subjects' acceptance of those devices.

While a battery indicator light on the accelerometer was a lacking feature for many subjects, flickering light of the recording devices like the laptop, optical sensor or the external hard drive were a reason for frequent complaints of the subjects and should be avoided in future investigations. It remains unclear if the current findings can be transferred to a broader population of senior citizens, especially in the light of the small sample size.

Falls, fall-related costs and the effects on an individual person's heath still present a highly relevant topic in healthcare and the senior population. Fall-detection systems could be used to address some the negative effects of falls. However, these systems require constant monitoring and in-home installation of specific sensors. Despite the overall positively perceived benefits of fall-detection systems, future investigations on larger populations are required to determine if such systems will be generally accepted for fall detection purposes in the domestic environment of senior citizens.

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	Age	**Height (cm)**	**Weight (kg)**	**MMSE (points)**	**Tinetti (points)**	**Stratify (points)**	**functReach (points)**	**Barthel (points)**	**Timed up (sec)**
Mean	75.1	157.80	75.0	27.9	20.1	2.2	31.7	88.5	26.2
SD	7.5	47,6	11.4	2.5	6.6	1.4	6.1	15.2	26.3
Median	73	172	76	29	21	2	32.4	95	17

Table 1. Descriptive Data and geriatric assessments

Table 2. Technical acceptance and Health status

	Overwhelmed by technical innovations	Afraid to break equipment	Health status (very good/good)
Before	39%	32%	35%
After	14%	14%	14%

Figure 1 Waist worn accelerometer

Figure 2 Microsoft Kinect Sensor

Figure 3 Accelerometer belt

Figure 5 Privacy Button

Figure 4 Unidentifiable subject in video recording