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Usability of self-guided mixed reality fall risk assessment for older adults

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Abstract

Background: Fall risk assessments are critical to identify those at risk of falling, but they are seldom performed due to time restrictions with clinicians and the need for trained expertise. Mixed-reality headsets offer potential to overcome these limitations and provide self-guided fall risk assessments through validated, clinical tasks. However, there is limited evidence of whether older adults are willing to use and accept self-guided technology.
Objective: The purpose of this study was to determine the usability of a mixed-reality fall risk application (app) for older adults.
Methods: A customized application was developed and deployed on a Microsoft HoloLens display to guide users through four mobility tasks: five times sit-to-stand, timed up and go, eyes open stance, and eyes closed stance. Ten older adults used the headset and completed a self-guided assessment, thinking their thoughts aloud. Participants were interviewed to ask about their likes, dislikes, and perceived usefulness with the app. Interviews were recorded, transcribed, and coded into themes. Participants also completed the System Usability Scale.
Results: Three themes were identified: comfort, learnability, and usefulness. Older adults reported that the headset was heavy to wear, they needed time to learn how to navigate through the app and found the app useful to understand their fall risk. Average SUS score was 71.9.
Conclusions: A self-guided mixed reality app has the potential to offer routine, fall risk assessment to older adults. Increasing knowledge of older adults' fall risk may improve fall risk screening and provide treatment strategies to reduce fall-related injuries.

Keywords: Older adults, falls prevention, technology use, headset

Introduction

Falls are a significant health concern for older adults. One in four older adults falls each year and falls lead to adverse consequences including fractures, activity curtailment, and death (Rubenstein, 2006). Falls also have a large societal impact, resulting in 50 billion dollars of direct medical costs (Florence et al., 2018). Due to the detrimental consequences of falls, research over the last several decades has focused on interventions that prevent falls and related injuries (Gillespie et al., 2012). Despite the effectiveness of targeted interventions, the number of falls in older adults continues to rise (Gillespie et al., 2012; Kramarow, Chen, Hedegaard, & Warner, 2015).

The first step to prevent falls is to identify those at risk for falling (Panel on Prevention of Falls in Older Persons & Society, 2011). However, fall risk assessments are seldom performed. Clinicians have time constraints, equipment (i.e., force plates, motion capture systems) is expensive, and assessments require trained expertise (Smith et al., 2015). Consequently, older adults are frequently not aware of their risk for falls, and therefore they do not seek out prevention strategies.

With advancements in technology, there is potential for self-guided fall risk assessments to guide older adults through validated, clinical tasks and inform older adults of their risk for falling (R. Sun & Sosnoff, 2018). Self-guided assessments can overcome constraints in fall screening by leveraging cost-efficient technology and reducing the need for clinicians' time (R. Sun & Sosnoff, 2018). For example, smartphone embedded inertial measurement unit (IMU) has been leveraged to measure balance and provide a fall risk score in home settings (Hsieh, Fanning, Rogers, Wood, & Sosnoff, 2018; Rasche et al., 2017). Camera-based depth-sensors have also been utilized to quantify fall risk in older adults (Clark et al., 2012; Garcia, Navarro, Schoene, Smith, & Pisan, 2012; Ruopeng Sun et al., 2018). However, there are also limitations to these technologies. Camera-based depth-sensors require significant space and are physically constrained. For smartphones, how individuals place and ori-

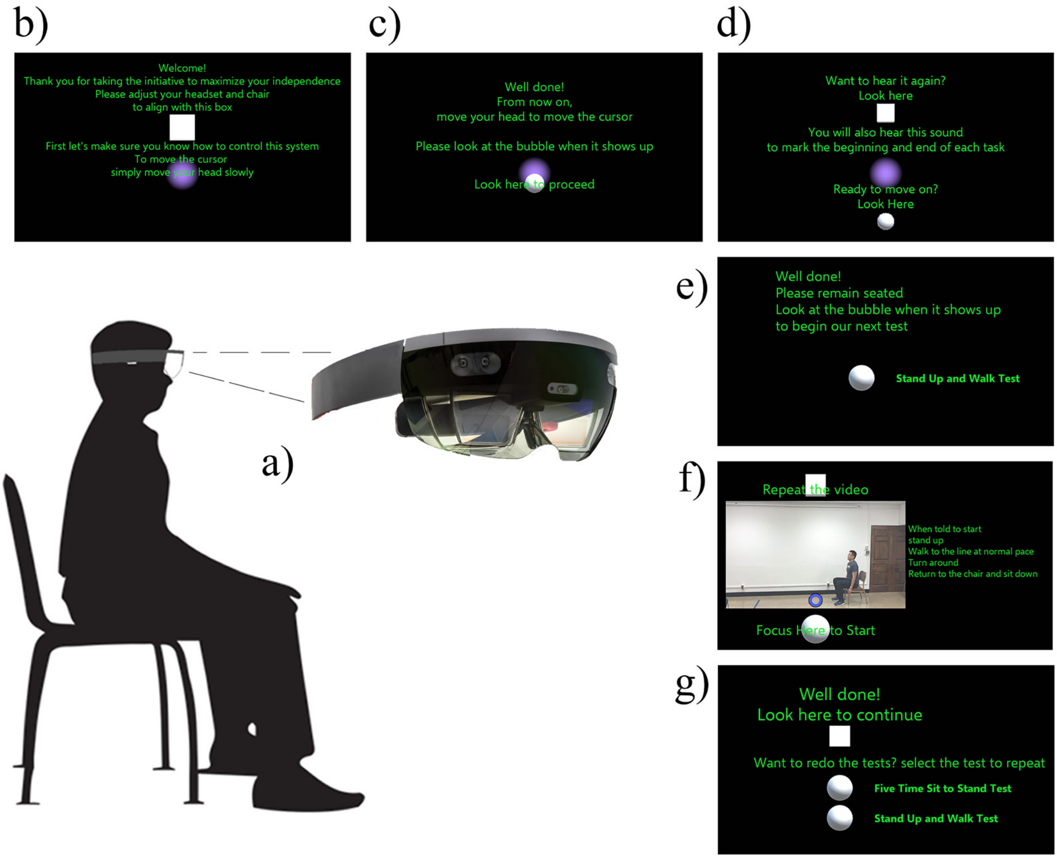

Figure 1. The Microsoft HoloLens was used as a mixed-reality headset device for self-guided fall risk assessment. Participants fitted the device to their head (a) and were guided to perform four mobility tasks. Users navigate through the system by fixating their gaze on a white control button (b-c). A sound was also used at the beginning and end of each task (d). Users were guided to perform each mobility task by watching an instructional video (e-f). After completing the task, participants had the option of repeating it or continuing to the next task (g).

ent a smartphone can influence IMU recordings. Smartphones also require that older adults can use a touchscreen device, but tactile function commonly declines with aging.

An additional technology that has the potential to afford self-guided fall risk assessment is mixed-reality headsets, such as the HoloLens (Microsoft, Redmond, WA, *Figure 1a*). This headset is embedded with an IMU that can measure movement during balance and walking tasks. It also contains multiple sensors to scan the environment which enables a hologram to be placed at a specific location in real-world (Kress & Cummings, 2017). The HoloLens is fitted in a standardized position on the head, reducing human error when interpreting IMU recordings. By using mixed-reality, individuals can receive instructions and visual demonstration, naturally interact with the virtual display through gesture control and gaze, and complete mobility tests with full visibility of the surrounding environments. Moreover, there is evidence that the HoloLens can accurately measure performance during clinical fall risk tasks such as the Timed Up and Go and sit-to-stand compared to inertial sensors (Ruopeng Sun, Aldunate, & Sosnoff, 2019).

Mixed-reality headsets offer several advantages to provide self-guided fall risk assessments for older adults. By undergoing self-guided assessments, older adults can understand their risk of falling and take part in prevention strategies. While self-guided fall assessments have the potential to overcome inadequate fall risk screening, there is limited evidence of whether older adults are willing to use and accept self-guided technology. A usable, self-guided tool must accommodate for age-related changes in perceptual, cognitive, and motor abilities and usability testing with older adults identifies additional challenges (Czaja, Rogers, Fisk, Charness, & Sharit, 2009). Determining if a self-guided application (app) in a mixed-realty headset is usable by older adults is an important step in the development of technology-based self-guided fall risk assessments. Therefore, the purpose of this exploratory study was to develop a self-guided fall risk app using mixed-reality and determine the usability of the app in older adults.

Methods

Application development

A customized Universal Windows Platform (UWP) application was developed under Unity (2018 2.6 personal) and Visual Studio (Microsoft Visual Studio 2017), and deployed on the Microsoft HoloLens head-mounted display operating under the Windows 10 system. Given the transparent display of the headset, the application was designed with a shadowed background and green/white display (*Figure 1b-1g*). The black background with light font allows older adults to clearly read and understand the app (Fisk, Czaja, Rogers, Charness, & Sharit, 2018). In order to simplify user interaction and allow intuitive control for older adult users, we chose to use gaze fixation to control the interface (i.e., users control the system by fixating their gaze on a control button for one to two seconds (*Figure 1b-1g*, purple shade/circle). To facilitate user onboarding, four stages of onboarding process was designed: (1) The user watched a tutorial video on a laptop explaining how to put on, adjust and control the headset (Supplementary Material), and was encouraged to ask questions before putting on the headset; (2) After putting on the headset, a welcome page was presented to guide the user to adjust the headset to maximize the field of view and to learn to control their gaze to proceed each task (*Figure 1b-1c*); (3) A sound beep was presented to familiarize the user with the starting cue (*Figure 1d*); 4) a menu was presented to remind the user to prepare for upcoming tests (*Figure 1e*).

The app consists of four mobility tasks based on Center for Disease Control guidelines. The tasks were performed in the following order: five times sit-to-stand, timed up and go (TUG), 30-second eyes open stand, and 30-second eyes closed stand (Stevens & Phelan, 2013). These tasks are valid, reliable fall risk tests that can be tested in clinical or community settings (Stevens & Phelan, 2013). Prior to each task, a video demonstration is displayed to demonstrate how to perform the task (*Figure 1f*). After completing each task, participants are given an option to repeat the task (*Figure 1g*).

Participants

Ten older adults participated in usability testing. Neilson has argued that small sample sizes (~5) are recommended to identify usability issues (J, 2012). Inclusion criteria included: (a) age 65 years or older, (b) capable of standing unaided, and c) normal or corrected to normal hearing and vision. Participants were excluded if they have history of: (a) cardiovascular disease, (b) neuromuscular disease, (c) motion sickness, (d) neck pain, or e) epilepsy or other seizure-related conditions. Participants were recruited from a local retirement community. All procedures were approved by the Institutional Review Board, and all participants completed written informed consent prior to participation.

Testing environment

Usability testing was performed at an apartment within a local retirement community. The retirement community includes both independent living and assisted living centers.

Procedures

A semi-structured, videoed interview process was used to determine the usability of the fall risk app and HoloLens device (Czaja et al., 2009). Participants watched a standardized video focusing on how to fit, adjust, and control the headset (Supplementary Material). Following the video, participants fitted the headset on, with help from research assistants only when necessary. Participants were then prompted to complete the four mobility tasks. During this process, participants were encouraged to think their thoughts out-loud as they navigate through the tasks. The participants' mixed-reality view was viewed from a laptop, to allow researchers to assist when needed.

After completing the mobility tasks, participants were interviewed about their usability of the headset. They were asked about their impressions, dislikes, and perceived benefits. Participants also completed the System Usability Scale (SUS) to quantify the usability of the headset (Brooke, 1996). The SUS contains ten questions on a five-point Likert scale and ranges from 0-100, with higher scores representing greater usability. Participants also completed questionnaires including the Mobility Device Proficiency Questionnaire (MDPQ) to determine their proficiency using technology and mobile apps for older adults (Roque & Boot, 2018), and the Activities Balance Confidence Scale (ABC) to determine their balance confidence. The MDPQ is a 16-item questionnaire that ranges from 0 to 40, with higher values indicating greater proficiency (Roque & Boot, 2018). The ABC is a 16-item questionnaire ranging from 0-100, which higher values indicating greater balance confidence (Powell & Myers, 1995). To assess for levels of fall risk, participants completed the Physiological Profile Assessment (PPA) which includes a test of contrast vision, reaction time, leg strength, proprioception, and balance on a foam surface

Table 1. Demographic information of all participants expressed in mean (standard deviation).

Age (years)	79.9 (6.4)
Gender	6 females; 4 males
Education (highest level)	1 High School Diploma 1 Bachelor's Degree 5 Master's Degree 3 PhD Degree or Equivalent
Activities balance confidence scale	85.7 (17.2)
Physiological profile assessment	1.2 (1.0)

(Lord, Menz, & Tiedemann, 2003).

Data and statistical analysis

All video recordings taken during the interview were transcribed verbatim by undergraduate research assistants and were verified by a member of the research team (RS). Qualitative data from the transcripts were reviewed to develop a coding system. Data was assigned with codes, and codes with similar content were grouped into thematic categories.

The SUS and MDPQ were used to provide quantitative data on usability and device proficiency. SUS and MDPQ scores were averaged across participants. Fall risk was quantified by the physiological profile assessment (PPA) based on established procedures (Lord et al., 2003).

Results

Participant characteristics

Participant characteristics are displayed in T*able 1*. Overall, age ranged from 72 to 91 years, education ranged from high school diploma to PhD or equivalent, balance confidence ranged from 47.5 to 99.1, and PPA scores ranged from 0.5 to 3.0. Three participants were at high fall risk (PPA>2), two at moderate fall risk (1<PPA<2), and five were at low fall risk (PPA<1) (Lord et al., 2003).

Usability interviews

Transcript and coding analysis revealed three distinct themes: comfort, learnability, and usefulness.

Comfort

Eight of the ten participants reported discomfort using the headset. They found the headset to be heavy and cumbersome. Although participants watched an instructional video on how to fit and adjust the headset, half of the participants needed assistance. Two participants complained that the headset applied too much pressure on their nose, while three participants were concerned about the headset slipping. Participants who wore glasses also found it uncomfortable to wear the headset with their glasses on.

"*I think for me the hardest part was getting the headset adjusted properly*" –Female, 82 years old
"*I feel a little more secure holding it. But that's only because it's heavy*" – Female, 84 years old
"*It would be nice if it was lighter*" -Male, 71 years old

Learnability

There were mixed results as to whether older adults felt they could learn to use the device on their own. Four participants reported that the mixed-reality app was not an intuitive tool to navigate. Participants needed extra practice to learn how to move their heads to navigate through the app. However, after going through a few practice trials, these participants were able to complete the mobility tasks on their own. For other participants, they reported that it was simple to use after introductory instruction was provided (*Figure 1*). Participants also found the instructional videos prior to teaching mobility tasks helped them understand how to perform them. Furthermore, they reported that the layout and format of the app were easy to follow and read.

"*I feel as if I could do it again, I could do it much quicker and steadier.*" -Male, 82 years old
"*Once you learn the criteria, it would be very easy to use*" -Female, 82 years old
"*I suppose the unfamiliarity with that and the fact that I am not used to using my eyes to follow a dot to be a cursor. If I did it again, the second time would be a whole lot easier. Maybe it takes a little practice.*" – Female, 73 years old

Usefulness

Overall, participants believed that using a self-guided fall risk assessment will be useful to understand their risk for falling. Participants find a perceived benefit of tracking their fall risk over time to observe changes. For instance, one participant reported that having objective fall risk results would help her track her fall risk over time, rather than relying on her personal, subjective judgment. Others reported that they would like their results to be shared with a physician to understand fall prevention resources. Overall, participants reported high usefulness in undergoing fall risk assessments and learning about their personal fall risk.

"*This would be a good thing for people to do every 6 months if people are progressing down the road to the tendency to fall. It would be good to know that*" -Female, 73 years old
"*I'd like to use it in my retirement facility if that could be passed on to my physician, or if I could use it before my appointment as a risk assessment*" – Female, 73 years old

Usability questionnaires

On average, participants rated the SUS of the self-guided assessment a 71.9, with a range from 37.5 to 92.5. The average SUS score for all technology use is 68, and a score of 80 or above indicates that users will recommend the device to others (Sauro, 2011). Our results suggest that the older adult users report average usability when using the self-guided assessment, but may not recommend the headset and app to friends. On the MDPQ, participants scored an average of 26.4, with a range from 9.5 to 35.5. A previous study reported average MDPQ scores for older adults was 20 suggesting that our sample had above-average technology proficiency (Roque & Boot, 2018).

Discussion

The aim of this study was to determine the usability of a self-guided fall risk app using a mixed-reality in older adults. After using a mixed-reality headset to perform four mobility tasks, participants reported moderate usability with the fall risk app. Overall, participants found the headset heavy and cumbersome, reported a needing time to practice using the app, and found the app useful to undergo an objective and validated fall risk tests. SUS score for the app was average compared to other technology, but below what older adults would recommend for others.

To the authors' knowledge, this is the first study to understand older adults' perceptions of a mixed-reality headset for fall risk assessment. This study suggests that while self-guided fall risk assessment may have the potential to improve screening in older adults, the development and design of the self-guided tool is important for its usability and adoption. Mixed-reality headsets have reported success for younger adult usage (Condino et al., 2018; Moosburner et al., 2018). However, during usability testing with older adults, 80% of participants reported discomfort when wearing the headset. The size and weight of headsets need to be further modified before being used by older adults. Half of the participants also reported needing additional practice before becoming proficient at independently using the app. While technology use in older adults is growing (Anderson & Perrin, 2017), novel technology may require more practice to learn (Czaja et al., 2006). When using fall risk technology for older adults, leveraging technology that older adults are familiar with may improve learnability, comfort, and adoption. Additionally, there is a need to develop lighter headsets for older adults' usage.

Older adults reported moderate usability with the headset, but they also reported high perceived usefulness in undergoing self-guided fall risk testing. Participants reported wanting to track their fall risk over time and have objective data to share with their physician. This underscores the need for routine, fall risk assessments to inform older adults of their risk for falling. Self-guided technology can provide older adults with routine, performance-based testing, and inform clinicians to make referrals for effective fall prevention interventions (Gell & Patel, 2019). Not only will effective treatments reduce fall risk, but our results suggest that older adults are eager to understand and reduce their risk.

Mixed-reality has been used in the past for fall prevention in older adults. Previous studies have used mixed reality to teach exercises and provide feedback to improve balance in older adults (Kouris, Sarafidis, Androutsou, & Koutsouris, 2018; Lee, Yoo, & Lee, 2017). However, these studies did not determine the usability of mixed reality devices for older adult users. Our results suggest that there is moderate usability using a mixed-reality fall risk app among older adults. Another self-guided fall screening technology has demonstrated higher usability. For instance, a previous study indicated high ease of use and high perceived usefulness for a smartphone app to measure fall risk (Hsieh et al., 2018). Older adults also reported high scores on the SUS when following a self-guided assessment from an avatar on a television monitor (Ruopeng Sun et al., 2018). Both studies included a similar sample of educated older adults, and this group of older adults may have greater ease of use with a device that they are familiar with (i.e., smartphone, television) than a new device. Therefore, while mixed-reality may offer the potential for self-guided fall risk assessments, leveraging technology that older adults already use may have greater potential.

The results of this study should be interpreted within its limitations. This study had a small, limited sample size due to its exploratory nature using a novel mixed-reality headset, and results cannot be generalized for all older adults. Future studies should include a larger sample size of older adults with mobility impairments. The participants in the study were also highly educated and had high mobile technology proficiency. This may influence their attitudes and ease of use with novel technology. Future iterations of a mixed-reality application should include older adults with less technology experience and lower levels of education. Because most observed usability challenges were related to the headset and not the custom-designed app as well as the fact that refinements to the hardware were not feasible, the second cycle of usability testing was not conducted. Testing with a newer version of the HoloLens may help identify improvements in usability, and the second cycle of testing with the same participants may determine the time it takes to learn how to use the app (Schulz et al., 2014). Last, while the HoloLens headset is more affordable than other wearable sensors, it is not commercially available. Its future availability to be used as a fall screening tool for older adults remains unknown. However, the fall risk app can be integrated with other mixed-reality devices, and future iterations of the HoloLens may be more affordable and available for older adults.

Conclusions

The purpose of this study was to develop a self-guided fall risk app through mixed-reality and test its usability with older adults. Because of difficulties learning and adapting to a new device, leveraging technology that older adults have experience with may improve usability with a self-guided fall screening tool. Older adults reported high perceived usefulness with the self-guided assessment, demonstrating the importance of informing older adults of their fall risk. Self-guided fall risk assessment has the potential to provide referrals to older adults of effective treatment interventions and using technology that older adults find usable can increase self-screening.

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Conflicts of Interest

There are no conflicts of interest to declare.

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