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User attitudes and implementation requirements of a tele-exercise intervention for people aging with lower body mobility impairment

Jenay M. Beer PhD[a,*], Taylor E. Mackin MSW[b], George Mois PhD[b], Lyndsie M. Koon PhD[c], Amber Datta[d], Tracy L. Mitzner PhD[e], Wendy A. Rogers PhD[f]

*[a]University of Georgia, Institute of Gerontology, Athens, Georgia, USA; [b]University of Georgia, School of Social Work, Athens, Georgia, USA; [c]University of Kansas, Life Span Institute, Lawrence, Kansas, USA; [d]University of Georgia, College of Public Health, Athens, Georgia, USA; [e]Georgia Institute of Technology, Center for Inclusive Design and Innovation, Atlanta, Georgia, USA; [f]University of Illinois Urbana Champaign, College of Applied Health Sciences, Champaign, Illinois, USA; *Corresponding author: Jenay.Beer@uga.edu*

Abstract

Background: Persons aging with mobility disabilities encounter barriers to exercise participation, such as lack of transportation, inaccessible facilities, and absence of tailored exercises programs. Tele-exercise lessens these barriers by enabling participation in remote exercise classes from home.
Objective: This study's goal was to assess the feasibility (user attitudes and implementation requirements) of a tele-exercise (Tai Chi) class for adults aging with mobility disabilities.
Method: This was a mixed-method feasibility study; participants (N=19; age M=61.2±10.81) aging with a mobility impairment participated in a seated Tai Chi exercise class via video-conferencing software. User attitudes and usability were assessed using questionnaires and a semi-structured interview, while implementation requirements were assessed using a semi-structured interview and observational methods.
Results: Participants expressed positive attitudes toward the tele-exercise class, specifically the physical, emotional, and social benefits. Age- and disability-specific requirements to implement a tele-exercise intervention were identified, including large font size, adjustable volume, tailored exercises, and environmental design.
Conclusion: Findings provide guidance for the implementation and deployment of remote tele-exercise classes and interventions for persons aging with mobility disabilities.

Keywords: self-care, technology, exercise, disability

Introduction
Background

The world's population over 60 years of age will rise to an estimated 22%, or 2 billion people, by 2050 (World Health Organization, 2018). In the United States alone, 35.2% of older adults are aging with disabilities, the most prevalent being mobility disability (Kraus et al., 2018). Older adults often experience ambulatory disability due to an inability to perform or participate in activities as a result of a lower-body impairment over an extensive period of time (Mpofu & Oakland, 2009). Other age-related functional and cognitive declines can compound the difficulty experienced in their participation in everyday activities. Mobility disability can develop in multiple ways: early in life, gradually over many years, or suddenly due to a catastrophic event (e.g., fall-related injuries) (Rosenberg et al., 2011). Physical capability predicts the onset of many adverse health outcomes, such as decreased well-being and quality of life, decrease in social participation, cognitive decline, hospitalization, disability in activities of daily living, admission to nursing homes, multimorbidity, and earlier mortality (Cooper et al., 2011; Fried & Guralnik, 1997; Groessl et al., 2007; James et al., 2011; Weinberger et al., 2009). Given these risk factors and the growing prevalence of older adults with mobility disabilities in the population, it is crucial that supports are developed to optimize their health and independence.

Tai Chi has been extensively studied over the past several decades, with a 2004 systematic review pointing to both physiological and psychosocial health benefits for persons managing chronic conditions (Wang, Collet, & Lau, 2004). More recent studies have confirmed these early findings. Broadly, Tai Chi has been shown to positively influence balance, functional performance, muscle strength, and cardiovascular function (Day et al., 2012), as well as pain management (Yau & Packer, 2002), quality of sleep, lower body flexibility, and cardiorespiratory function (Chen, Li, et al., 2007). Emotional, cognitive, and social benefits of engaging in Tai Chi include improvements in self-esteem and well-being, increased quality of life (Shem et al., 2016), decreased symptoms of depression (Chi et al., 2013), broadening social networks, decreasing loneliness, and increasing satisfaction with perceived social support (Yau & Packer, 2002).

In particular, Tai Chi is well-known as an effective exercise modality for aging adults (Day et al., 2012; Hsu et al., 2016; Mortimer et al., 2012; Wang et al., 2016; Wu et al., 2010). In fact, extensive literature suggests that Tai Chi exercise can have a significant reduction in fall risk among older adults (for a recent systematic review, see Hu et al., 2016; odds ratio = 0.70, 95% confidence interval, 0.59 to 0.84). For those with mobility disabilities, Tai Chi typically utilizes a variety of slow, extensive upper-body movements (Y. Wang et al., 2015), and can be used with individuals who have mobility disabilities as it allows for seated participation of the movements. In fact, participation in physical activity and exercise can reduce the risk of falls, injury from falls, and prevent further declines in functional limitations and mobility loss (Froehlich-Grobe et al., 2012; Rosenberg et al., 2011). A recent systematic review on patients with Parkinson's Disease (many of which were aging) showed that Tai Chi/Qigong was associated with statistically significant improvement on motor outcomes, balance, fall risk reduction, and depression (ES range -.225 to .544, $p < .001$ to .06; Song et al., 2017). This finding is in line with an earlier systematic review (Leung et al., 2011), concluding that tai chi improves older adult balance compared to no treatment groups and reduces fall incidence in nonfrail older adults (24-week interventions, pooled effect size OR = 0.85, 95% CI = 0.63, 1.17).

Despite the value of Tai Chi and other types of exercise, persons aging with disabilities face barriers to adopt and maintain regular exercise (Malone et al., 2012). In fact, half of all adults with disabilities do not participate in any aerobic physical activity (Carroll et al., 2014). Barriers may include functional limitations, such as pain or discomfort, and physical safety concerns, as well as contextual barriers such as minimal social support, inaccessible exercise facilities, environments, or equipment, and lack of access to transportation (Martin, 2013; Rimmer et al., 2004). Persons aging with mobility disabilities are more likely to consider exercise programs as effective if those programs are inexpensive, convenient, able to be performed independently with some instruction and tailored to their needs and capabilities (Rosenberg et al., 2011).

Technology-facilitated exercise programs, such as those offered through tele-technologies may be viable solutions to facilitate exercise participation for people aging with mobility disabilities. The use of tele-technologies such as Skype, Facetime, and other software programs show potential to deliver remote exercise programs to those aging with mobility disabilities. More specifically, "*tele-exercise*" is exercise facilitated through video-conferencing technology (Wu et al., 2010). Video-conferencing allows an individual to meet with an instructor for a one-on-one class or a group of individuals to meet for a group class, thereby also promoting social interaction.

However, as technologies are increasingly being developed to support the aging market, many are not designed to support older adults' needs, particularly those who have pre-existing mobility disabilities. The TechSAge Technology Intervention Model (Mitzner et al., 2018) illustrates the value of technology interventions to support persons aging with pre-existing impairments. Specifically, this model illustrates how a person's capacity (body structures and functions) combined with context (environmental/personal facilitators or barriers) impact performance outcomes related to functional ability (activity and participation). With appropriate contextual support, an individual with a pre-existing impairment may not experience disability. For example, consider an individual who has had a lower-body mobility impairment for most of their life, but that impairment did not negatively affect their activity and participation (e.g., they can access, attend, and participate in their daily activities, such as exercise classes). However, consider the addition of age-related arthritis which results in wheelchair use. If this individual with pre-existing impairment experiences contextual barriers (e.g., lack of wheelchair accessible transportation), their ability to participate in an activity, such as an exercise class, will be reduced and therefore they will experience disability (negative impact to activity and participation). The TechSAge Technology Intervention Model highlights the need for proper contextual supports, such as technology, to increase functional ability by maximizing facilitators and minimizing barriers, enabling successful participation in a given activity. Tele-exercise holds much potential to reduce contextual barriers by eliminating the need for transportation, allowing participation in an exercise class from home, and enabling access to instruction tailored to their needs and capabilities.

Exercise programs utilizing technology have been tested previously and successfully with special aging populations including those at risk of mobility decline (Bean et al., 2019), pre-frail older adults (Dekker-van Weering et al., 2017), and those living in geographically rural areas (Elder et al., 2016). Tele-exercise may also facilitate access to exercise programs for those aging with mobility disabilities within their own homes, while also providing individualized and professional exercise instruction. Previous findings indicate that adults aging with mobility disabilities hold positive attitudes toward tele-exercise classes and show interest in long-term adoption (Mitzner et al., 2017; Wu & Keyes, 2006; Wu et al., 2016). Moreover, there is some evidence that technology-facilitated exercise programs are effective for improving levels of physical function and reducing emergency department visits of older adults with mobility disabilities, as compared to a control group (Bean et al., 2019). While there is scant literature on wellness applications of tele-exercise for adults aging with mobility limitations, these studies show some of the potential applications of tele-technology in the domains of health and wellness.

Goals of the study

Previous work has investigated tele-exercise needs, design requirements, and usability for adults aging with mobility disabilities (Mitzner et al., 2017; Wu et al., 2016). Older adults with mobility disabilities and exercise instructors with experience teaching this population both expressed positive attitudes and perceptions of usefulness for tele-exercise. However, the specific implementation requirements to develop a successful long-term tele-exercise intervention for persons aging with mobility disabilities are not known, including the amount of space needed in the user's home, visual/audio specifications, and technical requirements for the participants' home and instructor's studio (e.g., software/hardware, and network/wifi components). Using the TechSAge Technology Intervention Model (Mitzner et al., 2018) as a framework, the goal of the current research was (1) to investigate user attitudes and (2) identify implementation requirements to determine the feasibility of a Tai Chi inspired tele-exercise intervention for persons aging with mobility disability. Our aim was to guide the design of remote tele-exercise classes for adults aging with mobility disabilities.

Methods

Participants

Our mixed-methods feasibility study was conducted at two research sites located in the Southeast and Midwestern regions of the United States. Participants were recruited from local social agencies, healthcare settings, and community centers. We used a brief telephone interview to evaluate eligibility according to the following inclusion criteria: (a) self-identified as having lower body impairment for 5+ years; (b) no upper body impairment; and (c) able to participate in gentle movement exercise. All participants answered the survey and participated in the semi-structured interview.

Study methods and protocol

Prior to the study, we mailed participants a packet with the consent agreement and a demographics survey to complete at home. The remainder of the protocol took place in a research laboratory. Upon arrival, the participant was first met by the primary researcher and was led to a private interviewing room. The participant received an overview of the tele-exercise project including funding sources, goals, and background information.

Participants were administered the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005), and completed questionnaires to assess technology acceptance (adapted from Technology Acceptance Model (Davis, 1989; Venkatesh & Bala, 2008), self-efficacy for exercise (Resnick & Jenkins, 2000), and physical activity affect (Lox et al., 2000). The primary researcher then set up the hardware and video-conferencing software (OneClick.chat), obtaining a connection with the secondary researcher, who was located in a remote location to act as the exercise instructor. The exercise instructor and the participant never had in-person contact during the study. The primary researcher guided the participant to a chair that was placed several feet from the laptop and webcam (*Figure 1*). The researcher configured the technology until the participant was centered in the webcam view, visible from the knees up. The exercise instructor was positioned the same way within the webcam view. The participant and exercise instructor were seated in chairs with armrests and without wheels and positioned in front of solid background to increase visibility. During the session, the primary experimenter logged implementation facilitators and barriers they observed. This included a custom note-taking document, which categorized observed implementation challenges (i.e., situations where users were having observed difficulty interacting with the technology or task) into high-level categories: visual, audio, environmental.

The remote exercise instructor then proceeded to show the participant a demonstration of the Tai Chi inspired exercise training. Common Tai Chi exercise interventions require multiple sessions spanning weeks and even months to learn and perform correctly (Fox et al., 2011). Given that our investigation was for feasibility purposes, participants only attended a single 15-minute exercise session. We used a simple, seated Tai Chi inspired gentle movement series that our participants could learn and perform safely in the short exercise session, described in *Table 1*.

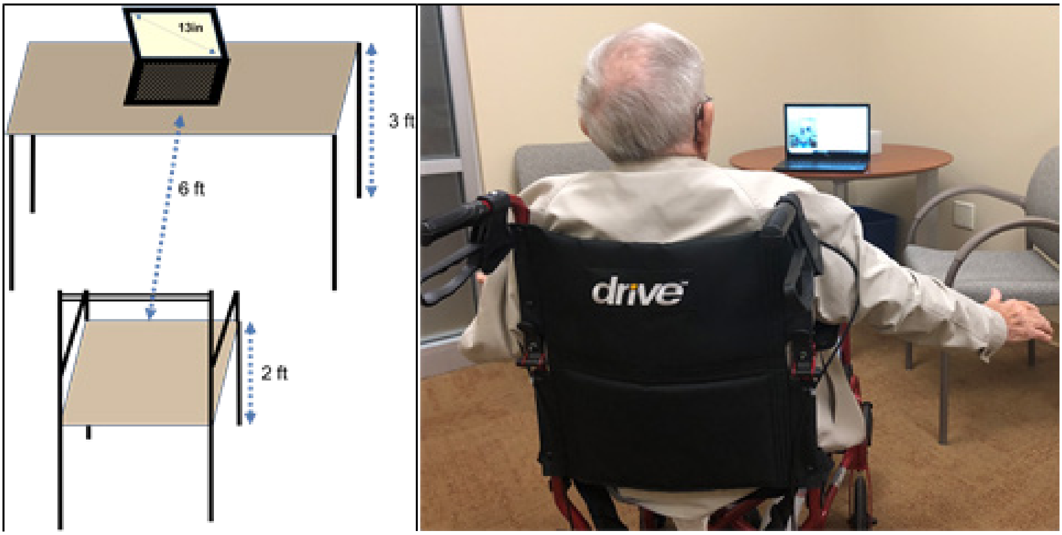

Figure 1. Tele-Exercise set up for study participant (Note: Consent for photo publication was obtained)

Following the demonstration, the participant completed the second set of questionnaires: NASA TLX (Hart, 2006; Hart & Staveland, 1988) and Physical Activity Affect questionnaires (Lox et al., 2000; Craig et al., 2003), followed by an audio-recorded 60 min semi-structured interview. Interview questions assessed participants' thoughts and opinions of the tele-exercise demonstration. After the interview was completed, the participant completed the final set of questionnaires which included: Self-Efficacy for Exercise (Resnick & Jenkins, 2000), Technology Acceptance (Davis, 1989; Venkatesh & Bala, 2008), and System Usability Scale questionnaire (Brooke, 1996). All participants were debriefed and compensated $40.

Questionnaire measures

Demographics

At the beginning of the study, demographics and health information was collected via the TechSAge Minimum Battery (Gonzalez et al., 2016).

Cognition measures

The Telephone Interview for Cognitive Status (TICS; Brandt et al., 1988) was used during screening to confirm participants did not have cognitive impairment (scored 24+). The Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005) was administered upon arrival to the study to confirm cognitive status.

Physical activity measures

All participants passed the gentle movement readiness scale (a variation of the Physical Activity Readiness Questionnaire; PAR-Q; Thomas et al., 1992) while screened for eligibility for the study. Additionally, physical activity affect (Lox et al., 2000; Craig et al., 2003) and self-efficacy for exercise (Resnick & Jenkins, 2000) were administered pre-post demonstration.

Workload measures

The NASA TLX is a multi-dimensional assessment of workload, extensively used in a variety of domains with high validity and reliability (Hart & Staveland, 1988; Hart, 2006). It was administered immediately after the tele-exercise demonstration to measure workload across six domains (0 = very low; 100 = very high; raw scores): mental demand, physical demand, temporal demand, effort, frustration, and performance.

Technology acceptance and usability measures

The Technology Acceptance Model (Davis, 1989; Venkatesh & Bala, 2008) (pre-post demonstration) has over the decades become a valid, reliable, key model in understanding behavioral acceptance and adoption of technology (for review of application, validity, and reliability, see Marangunic & Garanic, 2015). The questionnaire (Davis, 1989; Venkatesh & Bala, 2008) was administered both pre-and post-demonstration. This survey (1=extremely unlikely, 4=neither, 7=extremely likely) measured acceptance across multiple subscale domains, and composite scores were calculated for each domain. Finally, the System Usability Scale (SUS; Brooke, 1996) was administered post-demonstration and is scored by converting each question to a new number, adding them together, and then multiplying by 2.5 to convert the original scores from a scale of 0-40 to 0-100. Past research has shown SUS to consistently have reliabilities at or above .90, and it is industry standard to consider a score higher than 68.0 as above average (above 50th percentile) (for review see Brooke, 2013; Lewis & Sauro, 2018).

Table 1. Tai Chi inspired exercise demonstrations

Exercise	Description	Depiction
Deep breathing (warm-up) (Li et al., 2003; Sandlund & Norlander, 2000; Wolf et al., 1997)	1. Inhale through nose four-second count 2. Hold breathe at the top four-second count 3. Exhale through the mouth four-second count 4. Repeat for 4 repetitions	--
Carrying the Ball (Lavretsky et al., 2011; Motivala et al., 2006; Schaller, 1996; Shem et al., 2016; Wong et al., 2001)	1. Position hands at the center of the body as if holding a ball 2. One hand moves above head palm facing the ceiling, other hand moves down to side palm facing the floor 3. Bring hands back to center; top hand stays on the top of the ball and another hand to the bottom of the ball 4. Repeat for 4 repetitions	
Wild flying goose (A. W. Chan et al., 2017; A. W. K. Chan et al., 2010; Lee et al., 2009; Leung & Tsang, 2008; Song et al., 2017)	1. Hands positioned palm facing down outside of armrests 2. Inhale, moving arms up above shoulder palms facing out 3. Exhale bringing arms back down 4. Arms back in the original position with palms down 5. Repeat for 4 repetitions	
Wave hands(Fox et al., 2011; Fuzhong et al., 2001; Li et al., 2003; Taylor-Piliae & Coull, 2012; Y. Wang et al., 2015)	1. One arm tucked with an elbow to the side, the other extended 2. Hand closest to body moves in a gentle curve towards the opposite elbow 3. Hands switch positions 4. Torso twists moving hands to the opposite side of the body 5. Repeat for 4 repetitions	
Tense and relax (cool-down) (Baird & Sands, 2004)	1. Hands resting on a lap with palms facing the ceiling 2. Inhale and clench hands into a fist tightly 3. Hold at the top count of four 4. Exhale and relax hands allowing fingers to relax 5. Repeat for 4 repetitions	--

Note: Consent for photo publication was obtained.

Qualitative data analysis protocol

We analyzed the qualitative data from the semi-structured interviews of 17 participants (2 missing due to technical issues). All interview audio recordings were professionally transcribed verbatim. Transcripts were segmented into meaningful data units, defined as any attitudinal statements that participants made about tele-exercise. A coding scheme was developed through the use of thematic analysis, using a qualitative data analysis software, MAXQDA (Verbi Software, 2010). Our qualitative analysis utilized two theoretical frameworks. First, the Technology Acceptance Model (Davis, 1989; Venkatesh & Bala, 2008) informed coding themes related to attitudes (e.g., perceived usefulness, perceived ease of use) that predict intentional acceptance of the technology. Second, the TechSAge Technology Intervention Model (Mitzner et al., 2018) informed coding themes related to how technology could reduce contextual barriers to the successful performance of exercise (e.g., reducing the need for accessible transportation, allowing for customization/tailoring of exercises). Two transcripts were coded by two researchers with an intercoder agreement of 84% (Saldaña, 2009). All remaining inconsistencies were discussed, and the coding scheme was revised until consensus was reached. This final coding scheme was utilized to analyze all remaining transcripts, which were divided equally and coded by the two researchers.

Implementation / Observation analysis protocol
Data from the participant interviews and experimenters' logs of observed implementation facilitators and barriers were analyzed. The data from this log were evaluated and compared across sites. The in-depth data provided a length list of implementation challenges and considerations – crucial for making a tele-exercise intervention successful. These findings were then categorized, based on the TechSAge Technology Intervention Model (Mitzner et al., 2018), into implementation requirements.

Results

Participant demographics
In total, 19 community-dwelling adults (M = 61.2 ± 10.81 years of age, range = 43-86, 8 males and 11 females) aging with self-reported lower-body impairment participated. All participants passed the gentle movement readiness scale (a variation of the Physical Activity Readiness Questionnaire; PAR-Q; Thomas et al., 1992), and scored 24+ on the Telephone Interview for Cognitive Status (TICS; Brandt et al., 1988). Most, 68%, of participants identified as Caucasian, 21% as African American, and 11% as Asian. Participants reported using a variety of mobility aids, including canes, wheelchairs, walkers, and scooters. Overall, participants reported their general health as "good" (scale: 1=poor, 5=excellent; M = 3.21 ± .98).

User attitudes: Questionnaires
Given the goal of determining feasibility for this intervention, we focus here questionnaires directly related to user attitudes regarding usability, perceived workload, and technology acceptance, which were completed after the exercise demonstration. All questionnaires were analyzed using descriptive statistics. The mean normalized System Usability Scale (SUS; Brooke, 1996) score was passing (i.e., above average usability) 80.13 ± 15.49. For the NASA TLX (Hart & Staveland, 1988), participants reported low average levels of mental demand (M = 37.50 ± 27.39, n = 19), physical demand (M = 31.94 ± 28.68, n = 19), temporal demand (M = 26.67 ± 23.57, n = 19), effort (M = 33.33 ± 27.65, n = 19), and frustration (M = 21.88 ± 17.67, n = 17). Participants reported a high rate of performance (0 = failure, 100 = perfect; M = 73.33 ± 31.06, n = 19).

The technology acceptance questionnaire scores did not differ significantly between pre- and post-demonstration. The post demonstration acceptance scores provide insightful descriptive trends – for all subscales, means were above neutral (>4.00). Wilcoxon signed rank test were used to compare post-acceptance subscale scores to the neutral score. These tests indicated that participants perceived the tele-exercise technology as useful (M = 5.95 ± .77, Mdn = 6.00, Z = -3.82, p < .001), easy to use (M = 6.18 ± .81, Mdn = 6.25, Z = -3.82, p < .001), and enjoyable (M = 6.03 ± .74, Mdn = 6.00, Z = -3.82, p < .001). Participants also reported having positive perceptions supportive facilitating conditions (i.e., degree to which an individual believes that an organizational/technical infrastructure exists to support system) (M = 5.12 ± 1,85, Mdn = 6.00, Z = -2.03, p <.05), and positive perceptions of the privacy/security of the technology (M = 5.01 ± 1.20, Mdn = 5.00, Z = -2.89, p < .01). Participants indicated intentional acceptance (i.e., plan to use the technology in the future) (M = 5.08 ± 0.79, Mdn = 5.00, Z = 3.46, p < .001). Participants reported only moderate social influence (i.e., degree to which an individual perceives that important others believe they should use technology; M = 4.37 ± 1.16, Mdn = 4.75, Z = -1.81, p = .07).

User attitudes: Interview themes
Usability and implementation themes
Participants expressed that they would be comfortable with using a computer, webcam, and video-conferencing software to participate in a tele-exercise class. Nearly all participants indicated that they had access to the other requirements: a chair, Wi-Fi, and webcam. However, nearly a third of the participants expressed that they might have difficulty setting up these technology components or troubleshooting during technical difficulties. Only a few participants commented on visual difficulty due to the size of the computer displays, as well as the software split-screen design. One participant noted, "*What I disliked about it was the split-screen was hard [to see]. And it was small. It was not large. So, someone that has a vision problem would not be able to see as clear as if the screen was larger.*" Nearly half of the participants encountered difficulty hearing the instructor. This was due to background noise (e.g., street noise, air conditioning vents), as well as poor-quality laptop microphones. One participant said, "*[I didn't like] the muffling sound, because it kept interrupting, and when you're trying to focus on exercising and it keeps muffling, you lose your train of thought.*"

Perceptions of privacy themes
Four participants did comment on privacy concerns related to sharing video, noting discomfort about class members or an instructor being able

Table 2. Intervention implementation requirements

Technology support characteristics	
Challenges	**Suggested solutions**
Depth perception limitations – participant and instructor had difficulty with depth perception during the demonstration as the three-dimensional exercise was being displayed two-dimensionally.	Multiple external web cameras (e.g., offer front and side views of instructor movements). 3D cameras. Depth sensors. Virtual reality.
Visual limitations – video conferencing software used a split-screen design, which divided the webcam views into two halves. The software also incorporated a chat-box feature. Participants had mixed input, some had difficulty seeing the instructor whereas others enjoyed being able to see themselves exercise.	Use of a larger display. Allow for user customization, thus giving the user the ability to modify between a full and split-screen interface. Option to remove chat-box.
Auditory limitations – participants reported difficulty hearing the instructor.	Utilize external microphones for the instructors. Utilize external speakers.
Connectivity limitations – occasional lag and pixelation disrupted video experience.	Assist participants in-home network diagnosis and troubleshooting/ Test participant home network speed to determine eligibility for intervention.
Participant capacity	
Challenges	**Suggested solutions**
Participant functional ability – range of participant physical capabilities and perceptions of workload.	Seated Tai Chi is an appropriate exercise intervention for the target population. Allow for tailored or customized movements.
Environmental context	
Challenges	**Suggested solution**
Adequate lighting – visualization can vary based on environmental lighting or even time of day.	Participants and instructors should face a primary light source (or have multiple light sources). Utilize soft lighting.
Background noise – laptop microphones picked up background air-conditioning, traffic, etc.	Reduce external noise sources - encourage participants to exercise in a closed room or reduce background home noise. The instructor should be in a controlled studio with adequate acoustics (e.g., insulated room, sound-absorbing paneling, flooring with minimal reverberation).
Visual clutter – the instructor/participant should be the focal point in the video framing.	Situate the exercise chair with a solid colored wall behind the instructor/ participant. This reduces visual clutter and allows the instructor and participant to see each other's movements more clearly.
Video framing and space requirements – the front-facing camera should capture the instructor/participant at eye level, capture participant movements.	Consider adjustable desk or camera height to keep the frame at eye level. A 6-10 ft distance from the camera to the table allowed for a full shot (e.g., capturing participant from head to toes in a seated position).
Chair design – participants needed room to move arms, but aging participants also needed assistance getting in/out of the chair.	While an armless chair allows for most arm movement, for safety some participants needed arms to support getting in/out of the chair. Thus, consider user capabilities when recommending a chair. If a participant is a wheelchair user, consider a wheelchair where foot rests can fold out of the way.

to see inside their home. One participant stated, *"if you're not sure who the other participants are, I think they would also not be comfortable because we might not have met face to face."* Although participants were open to the idea tele-exercise, more than half of the participants held mixed opinions on how comfortable they were with the instructor being remotely located. Specifically, participants wanted assurance that the remote instructors could adequately provide tailored or customized exercises, help when needed, and be attentive to their individual needs.

Perceptions of usefulness and enjoyment themes
Despite these concerns, nearly all participants indicated that they would attend a tele-exercise class on a weekly basis if it were available to them. The one participant who had mixed opinions suggested they would use it during occasions where they were unable to attend an in-person class. When prompted to discuss attitudes toward tele-exercise, study participants

discussed, on average, twice as many positive perceptions than negative. Importantly, all participants indicated that they felt like active, rather than passive, participants in the tele-exercise class. Participants recognized the physical, social, and emotional benefits exercise could offer them. One participant noted benefits to their wellbeing, while another stated *"it would be nice to meet people in other remote locations or other homebound people."* Many participants mentioned the benefit of convenience. As one participant stated, *"I think it's time-saving. You don't have to go and leave your home and rush to go to the exercise center."* Another participant stated, *"I could be at home, so this would be more readily available."*

Implementation evaluation

The researcher observation notes (i.e., notes taken during the study in situations where usability challenges were observed) provided insight into implementation challenges, and possible solutions. Based on the TechSAge Technology Intervention Model, we organized our summary of implementation requirements findings into three broad categories (*Table 2*).

Technology support characteristics refer to design specifications that would allow the technology to best facilitate a successful intervention. For example, challenges associated with depth perception or audio limitations can be addressed through careful selection of technology type (e.g., multi-camera views, or virtual reality) and ability (e.g., adjustable volume). Participant capacity refers to the physical and mental potential of an individual based on their body structures and functions. We identified a range of participant perceptions of workload and the need for tailored exercises to match the exercise to the participant's capabilities. Finally, environmental context refers to facilitators and barriers that lead to more successful performance than disability in terms of the user's functional ability for activity and participation. For example careful selection of chair design, environmental lighting, and background noise is important to maximize participation in the tele-exercise intervention.

Discussion

This feasibility study is important because, to our knowledge, it is the first to investigate specific implementation facilitators and barriers to develop a successful tele-exercise intervention specifically for persons aging with mobility disabilities. The aim of this study was to assess the feasibility of a Tai Chi inspired tele-exercise class with an emphasis on understanding user attitudes and implementation requirements. We identified challenges and recommended solutions to those challenges using the TechSAge Technology Intervention Model (Mitzner et al., 2018) as the theoretical framework for this formative work.

Confirming previous research (Mitzner et al., 2017; Wu et al., 2016), the current findings suggest that tele-exercise holds great potential in helping to address contextual barriers to engaging in physical activity that is experienced by persons aging with mobility disabilities. Our technology acceptance and SUS questionnaire data revealed positive attitudes about tele-exercise; specifically, the tele-exercise was useful, easy to use, and enjoyable. The NASA-TLX suggested that the tele-exercise Tai Chi inspired demonstration was not perceived as high workload, it is important to note the NASA TLX had high standard deviations. This indicates variability in participant perceptions of workload. It is possible that participants' diverse physical capabilities made the exercises more difficult for some than others. Nonetheless, participants felt successful in completing the demonstration. These findings point to the need for tailored and customized exercises for older adults with different capabilities.

The interview data revealed generally positive attitudes about tele-exercise, confirming the questionnaire findings (specifically our technology acceptance and SUS questionnaires). Participant interviews specifically confirmed technology acceptance findings that the technology was perceived as useful, easy to use, and enjoyable. However, the qualitative interviews did provide greater nuance in user opinions and considerations for implementation. Specifically, participants recognized the physical, emotional, and social benefits of the Tai Chi inspired tele-exercise (Chen, Hsu, et al., 2007; Chen, Li, et al., 2007; Day et al., 2012; Shem et al., 2016) and indicated that they have the technical and support resources available to participate in remote exercise from their home. Some participants had mixed opinions about whether an instructor should always be remote; these data suggest that a hybrid course (i.e., a mix of in-person and remote) may be preferable in some cases. However, all participants reported that they felt like an active participant in the tele-exercise demo, rather than a bystander. This qualitative finding supports our NASA-TLX finding that participants felt successful in performing the task. Whether an exercise course is offered in person or remote, participants did note the importance of tailored exercises, with direct, timely, and tailored instructor feedback. Such feedback is crucial, considering participants' variability in their NASA-TLX workload survey. This finding also supports a recent systematic review (Geraedts et al., 2013), which posits that direct remote contact seems a particularly good alternative to supervised onsite exercising. Such direct feedback even offered remotely through the tele-exercise software, may positively influence adherence and self-efficacy.

This feasibility study exposed implementation considerations for a tele-exercise intervention. Our intervention design recommendations are useful for the implementation of tele-exercise interventions, but also telecommunication design in general. As the TechSAge Technology Intervention Model (Mitzner et al., 2018) highlights, it is crucial to consider design considerations at the intersection of age-related changes (e.g., changes in vision and hearing, thus a need for large font and volume control) as well as functional capability due to pre-existing conditions (e.g., tailored exercises due to variations in perceptions of workload). Some of these implementation suggestions may not be feasible in homes, where space may be limited, there are no large computer screens, or network speeds may be slow.

This feasibility assessment was the first step in building a full-scale intervention tele-exercise program. This study had several limitations. First, because this was a feasibility study, the sample size is relatively small, and the interaction with the technology took place at a single time point in a laboratory setting. Therefore, the generalizability of our findings may not apply to individuals aging with other types of impairments or disabilities (e.g., cognitive or perceptual decline). Furthermore, our inclusion criteria included persons with self-reported impairment; we did not conduct in-depth functional assessments with our participants. Thus, future research should investigate longer-term interventions, with larger sample sizes and pre-/post-assessment to evaluate the effectiveness of tele-exercise across age and functionality. Nonetheless, the results of the current study provide encouraging support for the feasibility of tele-exercise interventions for persons aging with mobility disabilities and provide in-depth implementation requirements to improve the deployment of a tele-exercise intervention.

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Previously published conference abstract (preliminary data only, presented as a poster)
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