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Design Considerations for Technology Interventions to Support Social and Physical Wellness for Older Adults with Disability

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Abstract: Social and physical wellness are important considerations for maintaining one's health into older age and remaining independent. However, some segments of the older adult population, such as those aging with disability, are at increased risk for loneliness and reduced physical activity, which could result in negative health consequences. There is a critical need to understand how to deploy social and physical wellness interventions for people aging with disability. We provide an overview of constructs related to social and physical wellness, as well as evidence-based interventions effective with older populations. Our review yields considerations for how interventions may need to be developed or modified to be efficacious for this population segment. Technology may be a key component in adopting interventions, particularly tele-technologies, which we define and discuss in depth.

Keywords: Aging, disability, physical activity, social connectedness, technology support

Introduction

Worldwide, people are living longer [1]. Technology has tremendous potential to support successful aging – enabling people to remain healthy and socially engaged as they grow older. However, the needs of the older adult population are quite diverse. For example, many elders experience sensory, cognitive and physical changes that may influence their everyday activities [2]. Moreover, people with lifelong impairments (e.g., visual, hearing, motor) are also living longer and their unique needs must be accommodated as well. These individuals are often referred to as people "aging with a disability" but it is important to note that the true disability occurs only when their needs are not adequately met, through technology or otherwise.

Technology holds the promise of allowing older adults with disability to remain independent. However, for technological advances to be successful, we must first understand their specific needs and challenges, particularly those related to social and physical wellness. Many individuals with disabilities already use or have access to assistive technologies [3]. However, adoption may be hindered either because the technology does not meet their needs, or it is difficult to use, possibly due to age-related limitations. In addition, as a person with disability ages, his or her needs may also change due to age-related losses in sensation, perception, or movement control [2]. Therefore, it is imperative to determine how to best design and adapt technology interventions; yet there has been little research conducted on how technology interventions may be designed to meet the needs of this population segment.

This paper provides a review of social and physical activity definitions and interventions, with a focus on technology design considerations for persons with disability, particularly vision, hearing, and mobility disabilities, as those are most prevalent. We focus on both social and physical wellness for several reasons. First, social and physical wellness impact a person's long-term health, quality of life, and risk of mortality [4-8]. Thus, interventions that improve social and physical wellness can have dramatic positive health consequences. Second, as our review will highlight, despite prior research on social and physical wellness issues, these topics require

further study as they relate to older adults with disability. The growing number of older adults with disability raises potential for technology interventions that target this specific user group. Fourth, we posit that technology interventions, in particular, have the potential to meet the social and physical needs of older adults with disability. We do not focus on technology interventions for cognitive decline; such interventions are important for quality of life, however they lie outside the scope of this paper.

Because social and physical wellness issues have largely been researched separately, we first address each construct individually. For each, we provide a review of terminology and definitions. We also review evidence-based interventions for both social and physical wellness. We then close with a discussion about how technology can promote both social and physical wellness, because we believe many technology interventions have the potential to promote both. We highlight areas for which we believe additional research is needed.

Defining Older Adults with Disability

Defining disability is difficult; there is much debate surrounding the term, and it is often inappropriately used interchangeably with the term impairment. These terms imply different things and must be distinguished. Despite a lack of consistency in the literature, here we define impairment as an actual reduction in levels of physical or mental abilities (World Health Organization, 1980); more specifically the World Health Organization (WHO) in their International Classification of Functioning, Disability, and Health defined impairment as problems in body function or structure [9]. Disability may be defined as any restriction or lack of ability to perform an activity in the manner or within the range considered normal [10]. A similar definition from the Americans with Disabilities Act & Section 503 of the Rehabilitation Act of 1973, which defined disability as having a physical or mental impairment that substantially limits one or more "major life activities." Disability is an umbrella term, which encompasses impairment, limitations, and restrictions [11]. Thus, according to the WHO, disability is not just a health problem, but is rather a complex experience incorporating the interaction between a person's body, society, and environmental barriers [9, 10].

Older adults, typically defined at those 65 years of age and older, are a population segment that is expected to undergo dramatic growth in the next few decades. In 2013 older adults comprised 11.7% of the world's population, a proportion projected to rise to 21.1% by 2050 [1]. In the 2001 U.S. Census, 41.9% of the population aged 65 and older reported living with some form of disability [12]. Most of these individuals have challenges that result from normative changes that occur with age, however a subset of the older adult population has pre-existing disabilities.

Older adults have a unique set of capabilities and limitations because of normative age-related changes, as well as inter-individual differences. While some abilities tend to increase with age, such as vocabulary and general knowledge [13, 14], others have been shown to decline. Normative age-related changes include declines in motor speed, visual acuity, and hearing, particularly for higher-frequency sounds [15]. Aging is also associated with cognitive declines, including memory, attention, and decision making [15]. These declines can limit an individual's ability to independently engage in activities of daily living and fully participate in society. In this case, a person ages into disability, because an age-related change caused the disability (i.e., a limitation of one or more "major life activities").

However, some individuals 65 and older are aging *with* disability that was not caused by age-related changes. "Aging with a disability" has been defined as aging with an early onset of disability acquired at birth, childhood, or in early adulthood [16]. In the US, it is estimated that 29.5 million individuals aged 21-64 are growing older with a pre-existing disability [17, 18]. Furthermore, current and future trends of delayed mortality [19] are likely to result in an even greater number of individuals aging with a pre-existing disability. Age-associated declines may exacerbate existing disability. Similarly, some individuals suffer from impairment but may not experience disability until they encounter age-related changes. That is, compensatory mechanisms or tools allowed them to perform major life activities despite their impairment until they experienced added age-related limitations. These examples demonstrate how individuals with a pre-existing impairment are aging into disability or greater disability.

The CDC categories of disabilities include those that affect: hearing, vision, movement, thinking, remembering, learning, communicating, mental health, and social relationships [20]. In this paper we primarily focuses on older adults aging with hearing, vision, and/or mobility disabilities. From a large sample surveyed (n = 496,029; 217,920 males, 278,109 females), the 2011 American Community Survey reported rates of disabilities including visual (blind or has serious difficulty seeing even when wearing glasses), hearing (i.e., deaf or has serious difficulty hearing), and mobility (i.e., difficulty walking or climbing stairs) ([17];Table 1). Overall, mobility difficulties were reported most frequently by both men and women aged 65 and older.

	Male	***Female***
Visual Disability	6%	7.5%
Hearing Disability	18.8%	12.3%
Mobility Disability	19.4%	27%

Source:
Adapted from U.S. Census Bureau, American Community Survey (2012); retrieved www.disabilitystatistics.org
Table 1. Non-institutionalized older adults ages 65+ [17].

Maintaining the health and wellness of older adults with disability is critical for their ability to age-in-place successfully and independently. Decreases in social connectedness and physical activity are more prevalent in older adults with disability, and are thus associated with increased risk of mortality and morbidity. These risks could be mitigated through the use of technology. However, before we explore the potential benefits of technology interventions, we must first understand the social connectedness and physical activity needs and preferences for older adults. The following sections discuss each of these two constructs, both of which are important in maintaining wellness through old age.

Defining Social Connectedness, Social Participation, and Loneliness

Social connectedness, social participation, and loneliness are all related to a person's social wellness, and are important because together they help cover the breadth and richness of social interactions and a person's perceptions of their own social interactions. Social wellness is part of successful aging, which, among other components, includes engagement with life [21]. Engagement with life involves being actively involved with other persons and participating in activities such as volunteer work, church, or caring for others; it is encompassed by the concepts of social connectedness and social participation [21].

Because of their key role in successful aging, it is important to understand how these different aspects of a person's social interactions relate to one another. These three concepts – social connectedness, social participation, and loneliness – although related, are defined and measured differently. Designers of technology interventions must consider all of them because interventions have the potential to positively influence all aspects of social wellness. Figure 1 depicts how these terms are related.

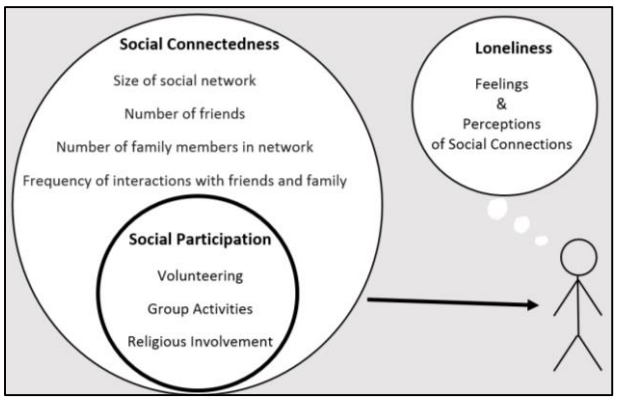

Figure 1. Social connectedness, social participation, and loneliness.

Social Connectedness

As defined by [22] "connectedness occurs when a person is actively involved with another person, object, group or environment, and that involvement promotes a sense of comfort, well-being, and anxiety reduction" (p. 293). Given this definition, one may think of social connectedness as the number of relationships an individual maintains, the frequency of interaction within those relationships, and the individual's level of involvement in community or groups.

The literature on social connectedness does not provide a standardized measurement, resulting in a high degree of variability in what is measured and how social connectedness is defined. To gauge social connectedness, various studies have measured social network size, [23, 24]; number of friends and number of family members in that network [23-25]; frequency of interactions with friends and family [23]; level of involvement in volunteering [23, 24, 26, 27]; and participation in organizations or recreational activities [26, 27]. Social connectedness has also been conceptualized as the breadth and depth of social interactions in both communal and personal settings [27]. Townsend and McWhirter emphasized the broad and changing definitions provided for social connectedness from paper to paper [28]. The various measurements of social connectedness are important for designers of technology interventions to consider. All of these conceptualizations should be considered when trying to design supports for social connectedness. Social connectedness is a multi-faceted construct, and various aspects are likely important to support via technology interventions to enhance feelings of connectedness for older adults.

Social connectedness has implications for both physical and psychological health. Social connectedness lowers anxiety [29] and helps sustain cognitive and physical well-being [23]. One study [7] found that older adults who had adequate social connectedness had a 50%

greater likelihood of survival compared to those with poor social connectedness.

Social Participation

Social participation is most commonly defined as a person's involvement in activities, such as volunteering, religious activities, or exercise classes [30, 31]. Similar to social connectedness, social participation also lacks a standardized scale for measurement, resulting in varying definitions in the literature. In some cases, it has been defined as a person's role in society [32]. Participation is distinguished from connectedness and loneliness in that it is only focused on a person's involvement in activities. However, most social connectedness scales measure a person's social participation even if it is not a comprehensive measurement [23, 24, 26, 27]. Types of activities that are typically measured are: volunteer work [30], shopping, attending a sports or cultural event, taking lessons, fitness [32, 33], visiting friends or family, and attending religious services [31]. One scale created to help measure social participation is the Assessment of Life Habits (LIFE-H). This measures daily life activities, such as personal care, as well as involvement in community [32, 33]. Similar to social connectedness, the definition and measurement of social participation is important for designers to consider because technology interventions have potential to enhance all of the reviewed aspects of social participation.

Loneliness

As stated by Beal [34] "Loneliness develops when there is a discrepancy between desired and actual social relations" (p. 799). Even people seemingly socially connected could still, in fact, be lonely or unsatisfied with the quantity or quality of their social connections [24]. Loneliness is not a direct measurement of social connectedness, or lack thereof [5]. One study found that although some older adults lived alone, it did not suggest that they were lonely [35]. Loneliness is the emotional *perception* of social interactions and connections, and is not directly linked to a person's actual social connectedness or participation. Unlike social connectedness and social participation, there is a greater use of one primary measure, namely, the UCLA loneliness scale [36]. This scale may thus be useful to measure the success of technology interventions.

Loneliness has been shown to be a predictor of transition to skilled nursing facilities in older age [37]. Lack of social connectedness can have negative consequences such as higher rates of morbidity/mortality, infection, depression, and cognitive decline [5, 7, 8]. Thus, it is well established that loneliness and/or the absence of social connectedness is problematic for older adults.

Older Adults' Risk of Loneliness

Increasing age alone is not significantly correlated with loneliness [24, 35]. Rather, other variables, such as age-related changes, disabilities, and life events, contribute to a person's social connectedness. For example, older adulthood is oftentimes accompanied by major life transitions, such as loss of family/friends, retirement, declines in health, or relocation. These events may contribute to changes, both positive and negative, in social connectedness or perceptions of loneliness. Furthermore, each life event is conceptualized and experienced differently by each individual experiencing it. However, it is clear that certain changes in one's lifespan may increase the need and importance of strong social connections. Thus, over the span of older adulthood, older adults are at higher risk of experiencing loneliness than other age groups, with 20-40% of older adults reported feeling lonely at any given time [8, 38].

Older adults with disability are at increased risk of loneliness and other negative social aspects. For example, challenges in mobility have been shown to be a predictor of loneliness [38-40]. An increase in mobility disability has been correlated with a decrease in social network and life satisfaction [35]. Mobility disability has been found to be correlated with reduced social contacts and social activity in older adults [41]. Even those simply at risk for disability have a decreased health-related quality of life (HRQOL) due to limited mobility, which was more strongly correlated than comorbidity to decreased HRQOL [6].

Loss of hearing also has negative effects on older adults' connectedness in the context of daily life activities such as shopping or using the telephone [42]. Importantly, hearing disability hinders communication [42-45] and the ability to sustain or develop social relations [45]. This hindrance to communication can lead to loneliness [40, 42, 44], depression, decreased self-esteem, and poorer functional status [42, 44, 46]; as a result, hearing disability has been linked to older adults experiencing severe social and emotional declines [47].

Visual disability has also been correlated with feelings of depression and a decrease in quality of mental health [48]. In study on vision disability, over 50% of people with vision loss reported a lack of social involvement [49]. Loss of vision has also been shown to reduce quality of life, which includes cognition, social relationships, and poorer moods [50]. In one study, over 50% of those with visual disability reported feelings of loneliness [51]. Furthermore, those with vision loss also have more difficulty in activities of daily living (ADLs) [48], making functional independence difficult to maintain and

increasing the likelihood of transitioning to institutionalized care.

Successful Evidence-Based Social Interventions

Social connectedness and loneliness have a well-established relationship with health risk, particularly for older adults with disability. Thus, it is crucial that researchers examine interventions that could support increased social wellness for older adults with disability. To date, many interventions have investigated the reduction of loneliness. Most successful interventions use an educational focus [52-57], such as social skill practice or social network development. For example, [53] tested an intervention with 177 older adults (aged 51-96) taught in small groups how to optimize their relationships with caregivers, resulting in a significant reduction of loneliness. Similarly, a health education program with an emphasis on social network development showed support for the reduction of loneliness, although this study lacked a control group [52].

Other effective or potentially effective interventions have encouraged older adults to participate in shared group activities/education, such as art, gardening, public performances, therapy, or writing [58-62]. In these studies older adults learned new skills, but also increased their social activity. These studies collectively indicate that interventions in groups could potentially benefit older adults at risk of loneliness.

Not surprisingly, social interventions for older adults aging with disability are few. However, of note, Fokkema and Knipscheer [63] tested a computer-focused intervention with a small group of older adults with physical disability living alone. The intervention used volunteers to teach the older adults how to use email and the internet, resulting in decreased loneliness. Similarly, older women with disability increased the breadth of their social networks by participating in a telephone support group [64] (for effectiveness of telephone support groups for persons without disability see [65]). In another study [66], older adults with hearing loss received hearing aids and kept a hearing diary in which they documented a moderate reduction of loneliness but not significantly so. Although not disabled, inactive older adults have also shown decreases in loneliness when introduced to a group exercise program and activities [55, 67]. These interventions address both social and physical needs of older individuals.

Conducting social interventions is challenging. First, it is difficult to recruit lonely individuals to participate in research. For many reasons, older adults who are either socially isolated or lonely may not be willing to participate in research, or may be difficult to find and recruit. Furthermore, few studies have focused on older adults with disability is overall not common in the literature. In addition, our review suggests that methodologies vary greatly in the development and testing of interventions. From small [63] to large [52] sample sizes, lack of control groups [63], and varying lengths of interventions (1.5 months [53] to 3 years [55, 63, 67]), it is difficult to draw general conclusions from the collective literature.

Educational and group interventions seem to generally have favorable results. Furthermore, the application of certain technologies shows promise in some interventions. Of the studies with a technology component, most interventions used common and simple technologies such as telephones, desktop computers, and video conferencing [56, 63, 68]. One study used assistive technology (hearing aids; [66]). These technology interventions illustrate the potential for technology innovations. However, the capabilities and limitations of older adults with disability need to be further researched to fully understand how technology-based interventions should be designed. The interventions described above were not technology design focused, per se. Thus, themes such as usability, integration, implementation, long-term adoption, and usefulness are currently not adequately researched.

Defining Physical Activity

Not only do older adults with disability face challenges in maintaining social wellness, they often also experience challenges in maintaining physical activity. Existing literature on the benefits of physical activity interchangeably uses terms such as exercise, physical fitness, and physical activity; however, there are differences in what these terms imply. The term physical activity is defined broadly as “any bodily movement produced by skeletal muscles that results in energy expenditure” [69]. To offer some distinction regarding specific activities associated with physical activity, some researchers have parsed physical activity into two distinct types: occupational and leisure-time [70]. Occupational physical activity is physical activity required to do work (e.g., household chores, lifting, bending) and leisure-time physical activity is recreational activity performed for health promotion and leisure (e.g., cycling, walking [70]). Physical exercise is a component of physical activity, and more specifically, is categorized as leisure-time physical activity [69]. Furthermore, exercise is defined as an organized and purposeful routine involving physical activity carried out with the intent to achieve better physical fitness [69]. Physical fitness is related to the ability to engage in various physical activities, with a

particular emphasis on aerobic capacity (i.e., endurance) and muscle strength (i.e., resistance [69, 71]). Better physical fitness leads to improved ability to perform both occupational and leisure-time physical activities [69]. Leisure-time physical activity in particular is associated with health benefits, therefore for the remainder of this paper the term 'physical activity' is used to refer specifically to leisure-time physical activity.

Older Adults' Need for Physical Activity

Physical activity is ranked as a leading health indicator for individuals of all ages [72]. The health benefits of physical activity are well known [73]. Physical activity not only increases average life expectancy and helps maintain a healthier body composition, but also reduces the risk of stroke, hypertension, cardiovascular disease, type 2 diabetes, obesity, osteoporosis, and several forms of cancer [73-75]. Moreover, regular engagement in leisure-time physical activity provides a multitude of physical health benefits, including increased endurance, muscle strength, and overall physical fitness [73, 75]. Other benefits include greater mobility, coordination, physical endurance, and better posture [74]. Physiological health benefits include better immune and cardiopulmonary function, better circulation, and weight control [73, 76].

As well as the many physical benefits, physical activity also has cognitive benefits. Memory, attention, cognitive performance, and reaction time improve with physical exercise [69]. Other benefits of physical activity include improved sleep and the prevention of cognitive impairments [77]. Engaging in regular physical activity can also reduce risk of dementia or cognitive decline [74]. In fact, there is more compelling evidence of physical exercise preserving cognitive capacity with age than there is for cognitive exercises [78, 79].

Regular physical activity also provides benefits to psychological well-being, including improved self-efficacy, self-image, self-satisfaction, self-esteem, body image, feelings of well-being, perceived health, and resilience [80]. Individuals who regularly engage in physical activity also tend to partake in other major life activities more frequently than those who do not participate in physical activity [81]. Exercise has been found to be effective in improving quality of life and lowering the risk of clinical depression and anxiety [68]. Other psychological benefits to regular physical activity include reduced stress and a greater sense of well-being [82].

Despite the numerous well-documented health benefits associated with maintaining an active lifestyle, older adults have low rates of physical activity [83, 84]. In fact, older adults are among the least physically active age group as compared to younger counterparts [85], with only about 25% of adults over the age of 65 engaging in regular physical activity, and this rate declines further to only 11% for older adults over the age of 75 [85]. This is especially problematic given that adults over age 65 are projected to be the most rapidly growing age group over the next forty years [86]. Hence, a growing proportion of the population may be deprived of potential physiological and cognitive health benefits attributed to engaging in physical activity [84]. These health benefits may be especially relevant for older adults due to the increased mortality rates associated with age.

Research from a national study conducted by the US Centers for Disease Control and Prevention [87] showed that only 28-34% of adults aged 65-74 engage in any physical activity. Furthermore, only 35-44% of adults over the age of 75 years reported being physically active [87]. Although there is a larger proportion of older adults beyond the age of 75 who report being physically active, it is important to underscore the positive relationship between physical health and longevity [87]. Consistent with previous research on positive health behaviors and longevity, those who engage in positive health behaviors, such as a healthy diet and exercise, have reduced risk for chronic health conditions and disability, and thus tend to live longer [85, 87, 88].

Older adults who have impairments or disabilities are even less likely to be physically active [81, 83]. Disability (e.g., from vision, hearing, cognitive or mobility impairment) has been shown to limit the amount and duration of physical activity that an individual is able to do, and to increase mortality [89]. Americans with mobility impairments are the least likely to participate in physical activity [81], less so than people with hearing or visual impairments [90]. Reasons people with mobility impairments cite for not engaging in physical activity include fear of falling, pain, and lack of energy [91, 92]. In general, poor health, lack of company, transport difficulties, lack of time, and lack of access to facilities are cited as reasons for older adults who have mobility limitations not engaging in physical activity [93]. People with severe mobility impairments also rate health related problems as a barrier more so than those with moderate or no impairments [93].

Fitness levels of individuals with visual impairments are generally lower than those of individuals with non-impaired vision [94, 95], but very little research has examined the physical activity rates of older adults with visual impairments [96]. One recent study involving 48 older adults with severe vision loss assessed potential barriers and facilitators related to engaging in a physical activity routine [96]. Findings from this study showed that visually impaired older adults cited their visual impairment as a barrier for engaging in regular activity,

especially walking. In addition, they reported concerns about accessibility and opportunity. One example of accessibility is the level of difficulty the individual has to endure to travel to a gym, which may make the gym inaccessible for someone with visual impairments [96]. An example of opportunity is that many existing aerobics or other exercise programs are not equipped to make necessary accommodations for people who have visual impairments [96]. Accessibility seems to be a major reason why individuals with visual impairments do not engage in physical activity [92].

It is likely that many formal physical activity settings are also not accessible to deaf or hearing-impaired individuals. For example, American Sign Language may not be offered to enable individuals with hearing loss to participate in the same activities as normal hearing individuals [97]. A gap in the literature also exists among empirical findings of the physical activity levels of deaf or hearing-impaired individuals. Because physical activities are highly visual, individuals may also be able to communicate through eye contact and gestures more easily [97]. A recent National Institutes of Health study included 760 participants over the age of 70 of which 68.9% had hearing loss [98]. Physical activity levels were assessed using accelerometers and self-report questionnaires. Compared to normal hearing individuals, activity levels among the hearing impaired were significantly low. In fact, those with hearing impairments had a 59% greater chance of self-reporting lower levels of physical activity, and a 70% chance of having lower levels of actual physical activity as measured by the accelerometer. More research is needed to assess how deafness and hearing disability may contribute to decreased levels of physical activity among older adults.

Regardless of disability type, older adults who have disabilities report that facilities lack proper accessibility and knowledgeable staff, and transportation and lack of information about accessible programs make it more difficult for them to effectively use such facilities [99]. There are also psychological barriers such as feeling self-conscious, fear of an unfriendly environment [99], and lack of company [93]. Many of the barriers identified for people with mobility disabilities are likely also barriers for those with hearing or vision disabilities. For example, barriers for people with any type of disability can include facilities lacking proper accessibility, knowledgeable staff, transportation and information about accessible programs, as well as self-consciousness, fear of an unfriendly environment, lack of company, and fear of falling [93, 99, 100]. To overcome these barriers, physical activity interventions must address the specific needs of older adults who have disabilities.

Successful Evidence-Based Physical Activity Interventions

Given the importance of physical activity for older adults and the significant barriers that exist in meeting the physical activity recommendations for individuals with mobility, vision, and hearing disabilities, interventions should focus on increasing physical activity rates for these populations. The literature on physical activity interventions with older adults (who are not described as having a disability) ranges from walking programs, targeted exercise instruction (individual and group [101-103], as well as Tai Chi [104-107]). The Otago exercise program has received considerable attention for its proven efficacy and it includes both muscle-strengthening and balance training exercises, in addition to a walking program [108]. In one randomized trial both Tai Chi and the Otago program were efficacious in improving mobility, although the Tai Chi group demonstrated more improvement in balance and the Otago group showed more improvement in lower extremity strength [109]. Many physical activity interventions have been developed or assessed in the context of falls prevention. Other studies have also shown that specifically targeted exercise programs, such as balance exercises, can reduce falls, and risk of frailty [100, 110-112].

Interventions developed for older adults may need to be modified for populations with disabilities, especially exercise programs that require lower body mobility. However, some programs have been developed specifically for individuals with mobility limitations. For example, recent randomized controlled trials have examined the efficacy of exercise interventions for wheelchair users [113, 114]. Studies of physical activity in older adults with mobility impairments show a reduction in risk for falling associated with participation in programs that include balance and muscle-strengthening exercises [73]. Physical activity has even been shown to improve mobility and physical function in older adults with mobility impairments [115], and may be related to reduced risk for hearing loss [116]. Many intervention studies have targeted specific subgroups (e.g., rheumatoid arthritis; chronic stroke, or multiple sclerosis patients) and it is unclear whether the results are generalizable to people with other disabilities.

Very little research has focused on activity interventions for individuals with vision or hearing disabilities. An exception is an intervention that used a modified Tai Chi program to improve balance in older adults with visual impairments [117]. Verbal instruction and physical guidance were used rather than visual instruction in three 1.5-hour weekly sessions for 16 weeks. The instruction emphasized weight shifting, head and

body rotation, and body alignment awareness. Participants in the Tai Chi group showed significant improvement in several aspects of balance control, as compared to the control group. Another example of a program that was modified for those with visual impairments is a dance intervention that used Tango dance classes to improve posture, balance, and lower body strength [118]. This study used a within subjects design, so that the improvements were found in pre-post assessments. Nevertheless, these indications of the efficacy of a physical activity intervention for people who have visual impairments are encouraging. There is clearly an opportunity here particularly for technologies that can make activity interventions more accessible to those with mobility, visual, and hearing disabilities.

Discussion

A significant proportion of the population is growing older with a disability [17, 18], and as people are living longer [19] it is expected that an even greater number of individuals will age with a pre-existing disability. This review suggests that older adults with disability could benefit greatly from interventions to promote social and physical wellness. Technology in particular has incredible potential to support this segment of the population to age successfully and remain healthy. However, this segment of the population has a variety of needs to manage long term impairment in vision, hearing, and mobility, in addition to age-related changes.

Interventions for social and physical wellness have been studied for older adults in general. Interventions involving education and group settings have been shown to be effective for the reduction of loneliness [52-57]. Interventions to encourage physical activity have included walking programs, targeted exercise instruction (individual and group) [101-103], as well as Tai Chi [104] [105-107]. However, many interventions have been studied with older adults without disability. It is critical to understand how to deploy social and physical wellness interventions for older adults with disability, because they have unique capabilities and limitations that will likely impact the accessibility and usability of current and future interventions. For example, more research is needed to understand if or how existing interventions might need to be modified, if additional training is needed, or even if they are efficacious for these individuals.

Technology in the form of desktop computers, video conferencing or telephones has been used in a variety of loneliness interventions [56, 63, 68]. We suggest that continued integration of technology into the design of future interventions has the potential to make them more applicable to older adults with disability. However there are specific considerations when designing technology interventions for older adults with disability, and much need for additional research.

Considerations for Technology Interventions for Older Adults with Disability

We propose a number of considerations below. Our discussion of this future research area focuses on *considerations*, rather than strict guidelines or parameters. We emphasize *considerations* because more research is needed. It is clear that technology interventions have much potential, however further clinical trials are needed to fully understand why and how such interventions positively influence physical and social wellness. Thus, based on our in-depth review, the following research and design considerations show promise of being impactful for older adults with disability. We encourage the design community to focus on the development of technology interventions for older adults with disability as a fruitful and meaningful endeavor.

Tele-technology for Communication and Exercise

First, consider the potential for tele-technology to promote both social and physical wellness. Tele-technology can be defined as technology that promotes communication *between* people, located remotely, typically via two-way video and/or audio. Successful social and physical interventions have had a “collaborative” component, oftentimes in group settings [52-57] [55, 67]. In other words, a potentially successful aspect of these interventions is the mere fact that other individuals (e.g., peers, instructors, therapists) are making direct contact with the older adult. Technology can enhance this communication by allowing individuals to connect more readily over long distances. Within the context of social interventions, use of videoconferencing and telephones has been researched [56, 63, 68], but emerging technologies such as telepresence robotics [69, 70] need further investigation. It is unclear whether telepresence is as beneficial as in-person support, a particularly important consideration for medical-related telecommunication such as physical rehabilitation and telehealth. Furthermore, many of these technology designs need to be reconsidered for older adults with disabilities [70]. For example, older adults with mobility disability may benefit from a telepresence robot with a telescoping spine (i.e., adjustable screen height) to adjust to an ideal viewing angle for older adults in wheelchairs. Other features such as voice command, larger screens, and multi-mode control (i.e., computer, tablet, smartphone) need usability assessments to meet the specific needs of older adults with mobile, visual, and auditory disability.

The use of tele-technology to increase physical activity and provide exercise holds much potential, but there is minimal empirical evidence to assess the efficacy of tele-technology physical activity interventions [119-121]. Future research is needed to understand what design modifications and/or training are required for older adults and those with impairments to use tele-technology. Moreover, research is needed to understand how to motivate individuals to adhere to tele-technology exercise programs.

Importance of Usable Design

The integration of any technology into social and physical interventions will require careful design to be usable by older adults with disability. Design recommendations for older adults are applicable [2]. However, these design specifications become increasingly important when considering disability, because the technology will need to be even more flexible and adaptable to meet the older adults' needs. For example, consider the use of multimodal input and feedback. An exercise game should provide instructions not only visually, but also via audio or physical feedback to be accessible to older adults with vision disability or impairment. Furthermore, hands-free or voice-activated input methods would be appropriate for individuals with visual impairment, and adjustable screen heights (e.g., for telepresence robots) would be more suitable for individuals in wheelchairs [70]. These are just a few of many design considerations, all of which need further research and user testing within specific use case interventions.

Measuring Intervention Success

It is important to test the short-term and long-term effects of an intervention with older adults with disability. However, as our review suggests, care should be taken when measuring the effectiveness of technology interventions. For example, the measurement should be based on what exactly the technology intervention aims to improve. As we discussed, social connectedness, social participation, loneliness, physical exercise, and PHYSICALDOI:activity are all terms that differ in definition and measurement. Therefore, a designer should carefully consider these terms and measures when determining – and assessing – the beneficial outcomes of any given technology intervention.

Closing

In summary, technology interventions to promote physical and social wellness for older adults with disability have the potential to address an important worldwide societal issue. However, it is first necessary to understand who the end users are; what are their unique capabilities and limitations; and what needs should be addressed via an intervention. Our review aims to offer preliminary answers to these questions by providing a detailed overview of social and physical wellness, and the complex definitions, measurements, and interventions involved in the study of each construct. Our goal is to provide insight to the multifaceted nature of social and physical wellness and to suggest opportunities for technology interventions to positively impact various aspects of promoting wellness. To that end, we highlight a variety of considerations for designing technology interventions; however, clearly much research is still needed in this problem space. Technology designers have an opportunity to make a positive impact. In focusing on technology interventions for older adults, it is critical to consider whether subjects are aging with a pre-existing disability, or have impairments and age-related changes that may lead to disabilities. Many challenges can potentially be mitigated through well-design technologies.

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