RERC TechSAge: Making a Difference to the Lives of Older Adults with Disability Through Design and Technology

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Abstract. As with people who are experiencing normal aging, there is great potential for technology to provide supportive solutions for people aging with disability. Yet, while little is known about the needs and abilities of people aging with disability, universal design (UD), which is an approach that promotes usability for all, regardless of ability or impairment promising, offers great promise in developing effective technologies for people aging with disability. The *Rehabilitation Engineering Research Center on Technologies to Support Successful Aging with Disability* (RERC TechSAge) takes the unique approach of applying UD principles to rehab engineering research and the development of new technologies for older adults. This paper will provide an overview of TechSAge's mission and conceptual framework and highlight three projects: User Needs research, the App for Locational Intelligence and Geospatial Navigation project (ALIGN) and the SmartBathroom. These and other TechSAge projects provide exemplars of how incorporating UD in front-end research and development, versus accommodating specific limitations after the fact, can extend usability of technology and environments for broad use, and particularly people aging with disability.

Keywords: Universal design · Aging with disability · Technologies for aging

1 Introduction

People with disabilities are living longer than ever before. For individuals with long-term impairments, the addition of normal age-related declines, such as loss of vision or hearing, can present unique challenges that can further inhibit their ability to carry out daily living activities and live independently. Historically, research in disability and aging has emphasized the impact of either increasing levels of chronic illness and functional losses in late life (aging into disability) or aging and congenital or acquired impairments from early to middle life (aging with a disability). The former has been primarily the purview of geriatrics/gerontology (e.g., U.S. National Institute on Aging), and has an aging research approach (i.e., understand and control factors that affect aging) more than a disability research approach (i.e., understand and compensate for factors that affect disability). In contrast, the latter, which has been the interest and focus

J. Zhou and G. Salvendy (Eds.): ITAP 2016, Part I, LNCS 9754, pp. 82–91, 2016.
DOI: 10.1007/978-3-319-39943-0_9

of rehabilitation engineering under the National Institute on Disability, Independent Living and Rehabilitation Research (NIDILRR) priorities, has focused primarily on understanding the consequences of life-long impairments in old age and early-onset of aging due to disability.

Although both approaches are important, each only addresses half of the aging problem in that they both overlook the 29.5 million Americans aged 21–64 who are now growing older with a long-term impairment or disability [1] and who will likely experience newly acquired and pervasive age-related functional losses, comorbidities and secondary conditions [2–7]. For these individuals, the additive effects of age-related conditions may mean the difference between their current impairment or disability and aging into disability or multiple disabilities, respectively.

There are few published studies about the effects of rehab interventions for people with age-related deficits in function among the population of people aging with impairment or disability. Evaluation of existing rehabilitation engineering interventions, usability testing, and research devoted to increasing the availability of technologies for this population is lacking; therefore, little scientific evidence exists with which to inform practice. Thus, despite comprising the majority of the population of seniors with disabilities, individuals who are experiencing age-related limitations beyond their primary impairment/disability are also the most underserved and understudied target population. Although many older adults with long-term impairments already use (or have access to) assistive technologies (AT), it is crucial to determine how to adapt and integrate technology as the both the user and their devices age [8].

2 TechSAge Overview

To address this need, the mission of the Rehabilitation Engineering Research Center on Technologies to Support Successful Aging with Disability (RERC TechSAge) is to support people with chronic conditions and long-term impairments who are at risk of disability or increased disability due to comorbid age-related losses; by empowering these individuals to sustain independence; maintain health; engage safely in basic activities at home and in the community; and fully participate in society; through increasing knowledge about, availability of, and access to effective, universally-designed technologies. Working within a universal design paradigm that drives all RERC activities, RERC TechSAge serves as a catalyst for a major shift in the understanding and design of home and community technologies for people aging with impairment and disability in order to achieve the goal of influencing rehabilitation engineering practice by assessing the impact of age-related changes on the activity and participation needs and outcomes of people growing older with impairments and/or disabilities.

2.1 Theoretical Framework

RERC TechSAge is grounded in the idea that disability is not an inevitable outcome for people with impairments. The Person-Environment Fit model suggests that disability occurs when the demands of one's environment exceeds their abilities [9].

Integrating this framework within the World Health Organization's International Classification of Functioning, Disability and Health (ICF) paradigm [10], TechSAge projects focus on understanding the environmental impact of pre-existing and age-related impairments and addressing needs through the development of supportive technologies. While an impairment does not necessarily lead to disability, the potential interaction of multiple comorbidities and impairments on top of a pre-existing impairment will compound the effects of environmental demands. As such, people aging with disability are more likely to encounter barriers in the home and community than they did prior to the onset of age-related declines. As with people who are experiencing normal aging, there is great potential for technology to provide supportive solutions for people aging with disability.

Figure 1 demonstrates the differences in environmental interaction and performance outcomes between individuals with age-related changes and existing impairment compared to those with either age-related changes or impairment. Even when the environment is held constant, when age-related deficits (e.g., loss of strength) are added to one's existing condition (e.g., uses a wheelchair), environmental factors that were previously facilitators (e.g., the slope of a ramp), can become barriers (e.g., slope is too steep). As a result, people aging with a disability are more likely to encounter more environmental challenges than individuals with either an impairment or an age-related change. In comparison to be people with an impairment OR and age-related decline (top row), those with an impairment AND an age-related decline (bottom row) are more likely to encounter barriers (Bs) and less likely to find facilitators (Fs), increasing their risk of disability and decreasing their likelihood of achieving successful performance. Headers at the top represent the integration of Person-Environment Fit constructs (i.e., person, context and performance) with those within the ICF (i.e., body structure and function, contextual barriers and facilitators, and activity and participation). For example, an age-related decline alone, such as hearing loss, can create barriers that prevent an individual from participating or fully participating in an activity. However, this barrier can be overcome with the appropriate support, or facilitator, such as a hearing aid, to perform the activity. Imagine a person who has been blind since childhood. They have become accustomed to using assistive devices with sound based cues, such as screen readers and white canes, to navigate their environment and carryout everyday activities. As an older adult, they are now experiencing age-related hearing loss. The combination of impairments is likely to result in more, and perhaps larger, barriers in their environment. Moreover, the facilitators that previously worked for them are no longer working and have, in essence, become barriers, decreasing the likelihood of successful performance and increasing the likelihood of disability.

2.2 R&D Activities

Currently in year 3, the RERC TechSAge has already made important strides in setting the foundation for strategic research and development (R&D) projects to achieve the goals and mission of the center. Research activities are underway to provide converging evidence necessary to design integrated technology supports for seniors aging with disability. Specifically, RERC TechSAge is developing an evidence-based taxonomy

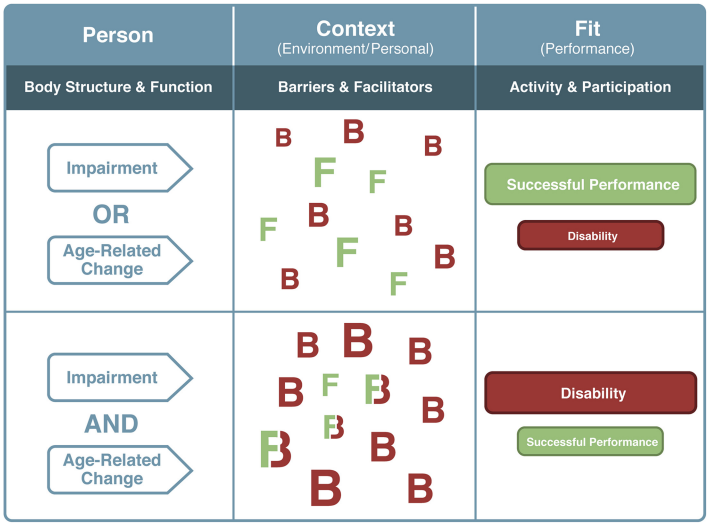

Fig. 1. Differences in person-environment fit and task performance between people with age related changes OR impairment compared to those with age-related changes AND impairment (TechSAge target population).

of user needs, stratified by functional loss, identifying needs and predictors of interventions for home-based tasks, and demonstrating feasibility of using functional performance data to predict task performance within and across activities. The RERC has developed a participant registry of people aging with disability to provide efficient, study-specific recruitment for projects as well as the Minimum Battery assessment to standardize measures across all TechSAge participants. A large-scale database has been developed to integrate both assessment and project-specific data to identify patterns of ability, performance, and technology needs. These are described in greater detail below.

Development activities, including mobile applications and smart technologies have short-term and longer-term outputs and outcomes, respectively. Two projects, representing each of these activities are described in this paper. The ALIGN project, which is a route planning application for people with mobility limitations who are experiencing comorbid vision loss, is intended to advance the rapid and cost-effective deployment of software development and evaluation. In addition, for individuals with unstable abilities due to variable conditions (e.g. arthritis, multiple sclerosis), the SmartBathroom project, will create a context-aware, fully automated bathroom with continuous monitoring of a user's functional status (e.g., gait, balance, posture) and task performance (e.g., toilet and tub transfers) that will synchronously adjust environmental features (e.g., grab bars, fixtures) based on a user's needs at any point in time.

3 User Needs Research

To ensure relevance, all TechSAge activities have a basis in user needs. Projects take a comprehensive approach to real problems, including activities of daily living (ADLs), mobility and transfer, medication management, and technology needs, experienced by people with disabilities as they age. The User Needs Research project serves as a foundation of the center, intended to provide evidence necessary to design supportive technology solutions addressing the needs of constituents, including adults with disabilities who are aging into secondary and co-morbid conditions and their caregivers, rehabilitation professionals, and healthcare practitioners.

3.1 Taxonomy of Everyday Support Needs

An archival analysis of existing literature and relevant data from public aging and disability databases revealed that despite the prevalence of vision, hearing and mobility impairments among older adults, very little is known about older adults with pre-existing impairments specifically [11]. Available statistics and resources were limited to the broader population of older adults with impairments and did not differentiate between individuals with a pre-existing impairment vs those who acquired an impairment in older age. Moreover, the sparse information regarding difficulty in task performance and use of assistive technology among older adults with impairments typically focused on select Activities of Daily Living (ADLs) and Instrumental Activities of Daily Living (IADLs) and failed to capture Enhanced Activities of Daily Living, such as leisure, in which older adults spend a large proportion of their time [12]. Findings confirmed the research gap and the need to comprehensively explore everyday task challenges, what makes these tasks difficult, current strategies and solution, and ultimately unmet support needs for this understudied population of older adults aging with disability.

Addressing this need, TechSAge researchers are currently developing a comprehensive User Needs assessment tool for older adult participants with long-term vision, hearing, and mobility impairments. Specific emphasis will be placed on capturing how the individual responds to task challenges with daily activities in relation to the Selection Optimization and Compensation framework [13]. The User Needs assessment incorporates findings from an interview study wherein subject matter experts with a range of professional and/or personal experiences and roles with older adults with these specific impairments (e.g., caregivers, family members, medical professionals) gave their perspectives on challenges experienced by these populations [14]. Focusing on three domains, including technology use, access to community resources, and housing, this study revealed themes of challenges that were specific to certain impairment groups as well as cross-cutting. For instance, one technology challenge specific to visually impaired older adults was difficulty adapting to popular touch screen devices, as they are used to relying on devices with buttons that provide tactile cues. Across impairment groups, subject matter experts discussed that the small size of phones created operational challenges. Findings from this study and other related studies in the User Needs Project are driving the content and specific questions of the assessment, which will be administered to approximately sixty participants in each target population, stratified by age.

3.2 Home-Based User Needs

In addition to investigating everyday support needs via interviews and survey data, TechSAge investigators are working to establish ground truth by exploring user needs in the home. The Home-Based User Needs project is geared toward understanding how individuals with pre-existing impairments who are experiencing age-related losses co-morbidly carry out activities in the home related to home mobility and medication management, often essential for maintaining independence and aging in place. For the first in-home study researchers interviewed older adults with long-term mobility impairments about their process for select activities of daily living, such as bathing and toileting, in context and documented photos of barriers and supportive solutions in their environment [15]. Researchers continue to analyze the rich interview and photo data, which is driving a follow-up study with participants to gauge longitudinal changes in needs and assistive technology use. The Home-Based User Needs team also conducted an in-home interview with older adults with vision, hearing and mobility impairments focused specifically on issues with medication adherence and current strategies. Through further analysis, researchers hope to identify which strategies or technological solutions are associated with higher rates of adherence for specific combinations of primary impairment and secondary functional loss and the underlying human factors at play.

4 ALIGN

The App for Locational Intelligence and Geospatial Navigation project, or ALIGN, entails the development and evaluation of a mobile app to inform outdoor route planning for people aging with ambulatory impairments who are experiencing additional age-related declines in vision. People aging with long-term mobility impairments generally use familiar outdoor routes that accommodate their functional abilities and assistive technologies (AT). For these individuals, the addition of age-related declines (e.g., vision loss, hearing loss) create a new set of environmental challenges that often exceed the abilities of these individuals, even on long-used routes [16, 17]. Despite these challenges, the real barrier to outdoor mobility is the lack of information with which to plan safe and appropriate alternative routes.

4.1 App Functionality and User Interface

To effectively promote community mobility among the target population, the ALIGN app not only incorporates a range of environmental factors that impact accessibility and safe mobility, but also take into account personal and social preferences of the user. Unlike other accessibility applications that identify predetermined “accessible” routes based on a few “standard” features (e.g., 1:12 slope, smooth sidewalks and curb cuts), ALIGN will include critical information about accessibility factors both static (e.g., land uses, vegetation, street connectivity) and dynamic (e.g., traffic volumes, timing of lights) that can be uploaded (as needed) close to real time. This will enable users to determine for themselves what routes are accessible and acceptable to them based on their own abilities, the demands of the situation, and what they prefer.

An online survey of older adults with mobility impairment was undertaken to identify important parameters for the app. The survey yielded priority factors, such as presence of sidewalks, types of intersections, and obstructions/lanscape overgrowth, which will be incorporated in the app. A weighting system was applied to each factor based on an Analytical Hierarchy Process (AHP) in order to generate mobility scores for route segments, and ultimately develop and implement a routing algorithm.

To address the variety of abilities in the senior population, the ALIGN user interface (Fig. 2) was designed to accommodate a range of abilities. The interface continues to be iteratively refined with upgrades such as featuring more intuitive icons and providing alternative and redundant forms of guidance (e.g., voice and visual) for mapped routes and turn-by-turn directions.

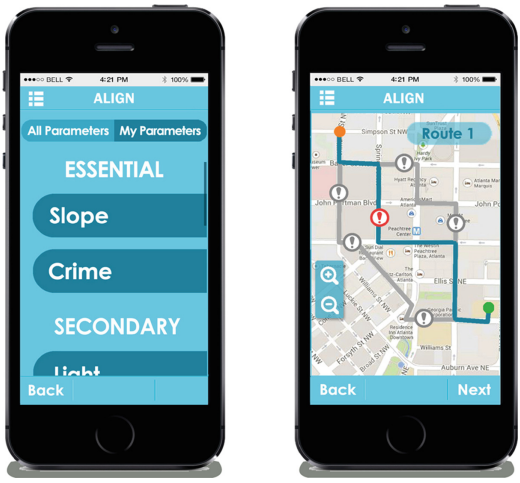

Fig. 2. Screenshots of the ALIGN route planning app show how the user can create pedestrian routes that best suit their needs based on desired environmental characteristics.

4.2 Data Acquistion

Integrating a wide range of environmental information, the development of the ALIGN app's functional capabilities required creative data sourcing strategies. Where possible, relevant public datasets were obtained from national and local organizations, such as the U.S. Census Bureau, Georgia Department of Transportation (DOT), Atlanta Regional Commission, and Atlanta Police Department. In some cases, real time data, such as pedestrian volumes and timing of crossing signals, could not be found with the possibility that such data is not publically available or doesn't yet exist. For these data alternative solutions, including crowd sourcing, are being explored. Data has been acquired to create a working prototype for a small area of Georgia Tech's campus. The prototype is currently being evaluated under conditions of actual use to determine feasibility and practicality.

5 SmartBathroom

Historically, toilet accessibility has primarily consisted of a set of fixed grab bars and raised toilets that are based on the abilities of young male wheelchair users with good upper body strength [18]. However, as people with disabilities grow older, their functional limitations are exacerbated by age-related decrements. Increasingly, existing transfer solutions cannot compensate for age-related frailty. To compound the problem, functional abilities not only vary both across individuals, but also within individuals over time due to progressive chronic conditions, such as arthritis. As a result, fixed transfer systems are only able to support some abilities some of the time.

A number of studies have been undertaken to determine the optimum design for toilet transfer; however only one study has evaluated a flexible system [19] with a user adjustable height and tilt toilet. Although the adjustable toilet was effective, the lack of an adjustable grab bar was problematic. Moreover, user control of the adjustments may not be effective for individuals who are not aware of the specific adjustments they need at a particular time. To provide a more flexible environment that will accommodate a range of abilities at any time, the SmartBathroom project will to develop a bathroom environment capable of assessing an individual's abilities at any point in time and spontaneously adjusting supportive environmental features to accommodate those abilities.

5.1 Lab Construction

An existing bathroom in the Georgia Tech Aware Home Laboratory is being renovated to create a fully functional modular and motorized environment that will provide the flexibility for fixtures (i.e., toilet, tub and sink), supportive devices (e.g., grab bars) lighting and cabinetry to be rearranged or removed. An array of sensing technologies will be embedded in the environment (e.g., floor, walls, ceiling fixtures) to measure biomechanical data (e.g., gait, balance, posture, grip strength and speed, accuracy, and efficiency of movement), forces exerted on the toilet, bathtub, sink, and grab bars, and locations where fixtures and grab bars are used. A vision system (e.g. Kinect) and smart floor sensors will track movement and gait. In addition, motorized hardware will make adjustment to the various fixtures.

5.2 Next Steps and Long-Term Goals

To develop the predictive algorithms that will control the environment, 25 individuals with a mobility impairment will participate in two test sessions at Time 1 (T1) and Time 2 (T2). Functional measures of static and dynamic stability, posture, balance, gait speed, forward and side reaches, grip strength and range of motion will be taken using standardized instruments. Participants will transfer on/off or in/out of the fixtures. In T1 subjects will perform the tasks with the fixtures set up in the same locations and positions (e.g., height, distance from walls) as in their own bathroom. At T2, an occupational therapist (OT) will help subjects adjust the fixtures and grab bars to set up their optimum configuration. The configuration will then be tested, followed by a post-trial rating to determine if any of the dimensions require further adjustment. If so, the dimensions will

be reset and the trial repeated. These procedures will be repeated until no adjustments are made.

Given the general absence of integrative technologies in the design of bathroom products, we anticipate that the smart technologies developed in this project are at least 10 years from commercialization. However, within the 5-year project we expect to develop and market, a range of interim, "smarter" technologies that will provide a more universal design system through feedback that will enable users to adjust their transfer behaviors to optimize use of a fixed environment.

6 Discussion

The goal of the RERC is to develop new knowledge and tools that can promote and increase community mobility, health, safety, and independence of people with disabilities even as the onset of new functional limitations result in new and pervasive barriers. However, the RERC's efforts are only beginning to scratch the surface of understanding the problems and developing solutions for our target populations. In fact, the premise of much of the basic research undertaken by the RERC is to identify the set of questions to be addressed by future efforts in this space.

The current RERC development projects have been designed to test usability and utility with pilot data on effectiveness. Longer term there is a need for translational research of these evidence-based interventions to identify intervention efficacy on health, activity and participation of people aging with disability. In research there is the need to examine the use of technology supports and changes in adoption strategies over time as older adults with impairments and some disability age into either disability or greater disability. Because much of the RERC's target audience has historically been underserved by traditional technology interventions, it is important to examine indigenous, individualized solutions that will scale up to customizable universal design solutions. Finally, there is need to understand and develop universally designed, smart interventions that not only compensate for disability, but are capable of effecting behavior change that enhances the acceptance and effectiveness of the interventions.

Acknowledgements. This research was supported in part by a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (Department of Health & Human Services, Administration for Community Living) Grant 90RE5016-01-00 under the auspices of the Rehabilitation and Engineering Research Center on Technologies to Support Successful Aging with Disability (TechSAge; www.techsage.gatech.edu). The authors would like to Amy Lambeth, HCI graduate student at Georgia Tech, for her assistance creating a visual depiction of differential environmental barriers and performance outcomes between individuals with age-related changes and existing impairment compared to those with either age-related changes or impairment (Fig. 1).

References

1. Brault, M.W.: Americans with disabilities: 2010, U.S. Census Bureau, U.S. Department of Commerce (2012)

2. Freid, V.M., Bernstein, A.B., Bush, M.A.: Multiple chronic conditions among adults aged 45 and over: trends over the past 10 years. National Center for Health Statistics, Hyattsville, MD (2012)
3. Institute of Medicine: Secondary conditions and aging with disability. In: Field, M.J., Jette, A.M. (eds.) The Future of Disability in America. The National Academies Press, Washington, D.C. (2007)
4. Jensen, M.P., Molton, I.R., Groah, S.L., Campbell, M.L., Charlifue, S., Chiodo, A., Forchheimer, M., Krause, J.S., Tate, D.: Secondary health conditions in individuals aging with SCI: terminology, concepts, and analytic approaches. Spinal Cord **50**(5), 373–378 (2011)
5. Kailes, J.I.: A user's perspective on midlife (ages 18–65) aging with disability. In: Workshop on Disability in America: A New Look, pp. 194–204. The National Academies Press, Washington, D.C. (2006)
6. Kemp, B.J., Mosqueda, L. (eds.): Aging with a Disability: What the Clinician Needs to Know. The Johns Hopkins University Press, Baltimore (2004)
7. Kinne, S., Patrick, D.L., Doyle, D.L.: Prevalence of secondary conditions among people with disabilities. Am. J. Public Health **94**(3), 443–445 (2004)
8. Agree, E.: The potential for technology to enhance independence for those aging with a disability. Disabil. Health J. **7**(S), 33–39 (2014)
9. Lawton, M.P., Nahemow, L.: Ecology and the aging process. In: Eisdorfer, C., Lawton, M.P. (eds.) Psychology of Adult Development and Aging. American Psychological Association, Washington, D.C. (1973)
10. World Health Organization (WHO): International Classification of Functioning, Disability and Health. World Health, Organization, Geneva (2001)
11. Harrington, C.N., Mitzner, T.L., Rogers, W.A.: Understanding the role of technology for meeting the support needs of older adults in the USA with functional limitations. Gerontechnology **14**, 21–31 (2015)
12. Rogers, W.A., Meyer, B., Walker, N., Fisk, A.D.: Functional limitations to daily living tasks in the aged: a focus group analysis. Hum. Factors **40**(1), 111–125 (1998)
13. Baltes, P.B., Baltes, M.M.: Psychological perspectives on successful aging: the model of selective optimization with compensation. In: Baltes, P.B., Baltes, M.M. (eds.) Successful Aging: Perspectives from the Behavioral Sciences, pp. 1–34. Cambridge University Press, New York (1990)
14. Preusse, K.C., Gonzalez, E., Singleton, J., Mitzner, T.L., Rogers, W.A.: Needs assessment of individuals aging with impairment: findings from Subject Matter Expert Interviews. In: Proceedings of the Human Factors and Ergonomics Society Europe (HFES Europe) (2015)
15. Gonzalez, E., Fausset, C.B., Foster, A., Cha, G., Fain, W.B.: Moving in, out and around the home: solutions from older adults with long-term mobility impairments. In: Proceedings of the Rehabilitation Engineering Society of North America (RESNA) 2015 Annual Meeting (2015)
16. Rantakokko, M., Iwarsson, S., Mänty, M., Leinonen, R., Rantanen, T.: Perceived barriers in the outdoor environment and development of walking difficulties in older people. Age Ageing **41**(1), 118–121 (2012)
17. Rosso, A.L., Auchincloss, A.H., Michael, Y.L.: The urban built environment and mobility in older adults: a comprehensive review. J. Aging Res., Article ID 816106, 10 (2011). doi: 10.4061/2011/816106
18. Sanford, J.A.: Design for the Ages: Universal Design as a Rehabilitation Strategy. Springer, New York (2012)
19. Gentile, N., Edelmayer, G.: FRR-field-test (2005). http://www.is.tuwien.ac.at/fortec/reha.e/projects/frr/conference/1555_Real_life_test_at_a_day_care_centre_en.pdf. Accessed 24 Mar 2014