EXAMINING THE EFFECTS OF A HOME USABILITY INTERVENTION ON COMMUNITY AND HOME PARTICIPATION

By

Kelsey Shinnick Goddard

Submitted to the graduate degree program in The Department of Applied Behavioral Science and the Graduate Faculty of the University of Kansas in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

_____

Chair: Jean P. Hall, Ph.D.

_____

Vincent T. Francisco, Ph.D.

_____

David P. Jarmolowicz, Ph.D.

_____

Derek D. Reed, Ph.D.

_____

Sherrie Tucker, Ph.D.

Date Defended: 21 January 2021

The Dissertation Committee for Kelsey Shinnick Goddard
certifies that this is the approved version of the following dissertation:

EXAMINING THE EFFECTS OF A HOME USABILITY INTERVENTION ON

COMMUNITY AND HOME PARTICIPATION

_____

Chair: Jean P. Hall, Ph.D.

Date Approved: 21 January 2021

Abstract

The usability of a person's home is central to community living. In order to participate in the community, a person must be able to first bathe, dress, and leave home (Stineman et al., 2007). Unfortunately, however, the majority of people with mobility impairments live in housing that is not accessible to them (Bo'sher et al., 2015). To address accessibility concerns, home modifications offer a solution to make a person's home more usable to them. Although previous studies have examined the effects of home modification interventions on functional performance, fall risk, and caregiver demand (Stark et al., 2017), no known studies have examined the effects of an interior home modification on community or home participation. Thus, the purpose of this study is to evaluate the effects of a home modification intervention on community and home participation. These data are analyzed as part of a larger study conducted under the Research and Training Center on Promoting Interventions for Community Living (RTC/PICL). Survey measures in the current analyses included a demographics questionnaire, home characteristics questionnaire, home safety measure, and Ecological Momentary Assessment (EMA) in which participants completed a week of daily smartphone surveys to report if they were in their community or at home. If participants reported they were at home, they were asked to report which areas in their home they had visited since the last survey prompt. First, a Randomized Controlled Trial (RCT) design was used to assess changes in community participation, home participation, and perceptions of home safety among participants who did and did not receive a home modification intervention. Results from the RCT design show that no statistically significant differences in community and home participation exist between the intervention and control groups. Second, a cross-sectional design was used to assess differences among participants who do and do not report (a) accessibility features within their home, (b) feeling safe

in specified areas of their home, and (c) using a mobility aid. Results from the cross-sectional design show that participants who report (a) adequate kitchen light were more likely to spend time in their kitchen; (b) feeling safe entering their home, using their bedroom, and using their kitchen were respectively more likely to spend time in their community, bedroom, and kitchen; (c) using a mobility aid were more likely to spend time in their bathroom and bedroom; and (d) using a wheelchair were less likely to spend time in their basement. Finally, barriers to conducting research related to home modification interventions and community participation are discussed and potential solutions for future research are identified.

Keywords: home modification, community living, mobility impairment, disability

Acknowledgements

As Stephen Hawking famously said, “Intelligence is the ability to adapt to change.” The year of 2020 was a historical year that tested the ability of many to adapt to change. Brick-and-mortar educational systems were demolished, advancing research studies were abruptly halted, and cultivated ideas became uprooted. Although we had never experienced such degrees of physical distance or isolation, these challenges brought us closer than ever before. Soon, shared resilience taught us new ways to rebuild, move forward, and grow – *together*.

I am thankful to have a mentor that has equipped me with many of the traits needed to adapt – Dr. Jean Hall has taught me the importance of patience, persistence, and perseverance throughout even the most challenging of times. Jean took a chance on me when I was very close to quitting for perhaps one of the first times in my life. Jean taught and challenged me in new ways, and I will forever be grateful to her for where I am today and where I know I am going.

I am also indebted to my brilliant committee members, Drs. Vincent Francisco, David Jarmolowicz, Derek Reed, and Sherrie Tucker. I am thankful for your flexibility and the grace that you have shown me as I have learned to adapt to these unprecedented circumstances.

This project would not have been possible without funding, and I am very thankful for the many scholars and advocates who have come before me. Thus, I would like to acknowledge that the contents of this manuscript were developed under a grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR grant number 90RT5043). NIDILRR is a Center within the Administration for Community Living (ACL), Department of Health and Human Services (HHS). However, the contents of this manuscript do not necessarily represent the policy of NIDILRR, ACL, HHS, and you should not assume endorsement by the Federal Government.

Finally, as my friend and colleague Noelle Kurth once noted, people with disabilities are some of the most resilient people you will ever meet because many are forced to regularly adapt to change in order to survive. I want to acknowledge the support of one of my dearest friends, Tucker McKiven, who continues to teach me that, not only must we adapt to change, but we must also change the things we cannot accept. I am grateful for our friendship, and I am confident that we will continue to grow stronger together. Ad astra per aspera, my friend – to the stars through difficulties.

Table of Contents

List of Illustrative Materials

Appendix Index

Examining the Effects of a Home Usability Intervention on Community and Home Participation

For people with mobility impairments, "life starts at home" (Greiman et al., 2018). The usability of the home environment is central to maintaining independence in the completion of activities of daily living (ADLs) such as dressing, toileting, or eating (Stineman et al., 2007). If a person's home is not usable to them, however, they may exert additional energy completing ADLs or choose not to complete ADLs (Greiman et al., 2018). This lack of usability may further exacerbate secondary conditions such as pain, fatigue, or depression, which can impact a person's decision to leave their home or participate in their community (Ravesloot et al., 2016). Fortunately, however, this lack of usability can often be addressed by modifications to a person's home.

Commonly reported components of home modification interventions for community-dwelling adults with health conditions are summarized in a systematic review conducted by Stark et al. (2017). Results of Stark et al. (2017) show that components of home modification interventions often include (a) assessment of the person completing ADLs, (b) assessment of the home environment, (c) action planning for the implementation of the home modification, (d) implementation of the home modification, (e) follow-up consultation/training, and (f) professional (e.g., occupational therapist) expertise throughout assessment and follow-up training components. Additionally, the authors conclude that multi-component home modification interventions are more effective (i.e., improved functional performance, reduced fall risk, and reduced demands on caregivers) than less comprehensive approaches.

A systematic scoping review conducted by Carnemolla & Bridge (2018) examined commonly reported outcome measures assessing the effects of home modification interventions

for people with mobility impairments. Categories of outcome measures commonly include (a) falls-related evidence, (b) self-care and independence, (c) physical health and well-being, (d) caregiving, (e) economic effectiveness, (f) aging process, and (g) social participation. Although these outcomes are important to study, no known research has examined the effects of an interior home modification on community and home participation. Given these gaps in the literature, the purpose of the current study is to evaluate the effects of a home modification intervention using Randomized Controlled Trial (RCT) and cross-sectional designs to examine changes in community and home participation.

Background

In the past century, disability rights advocates have sought to expand community supports and services to people with disabilities, while decreasing reliance on segregated institutional settings. Initial legislation important to the community integration and inclusion of people with disabilities included the Vocational Rehabilitation Amendments of 1954, which expanded rehabilitation services to people with disabilities, and the Rehabilitation Act of 1973, which prohibits discrimination on the basis of disability within all programs receiving federal funding. Congress expanded the protection of the rights of people with disabilities to the private sector upon passing the Americans with Disabilities Act (ADA) of 1990, which prohibits discrimination on the basis of disability in all areas of public life, including employment, education, and transportation. In 1999, the U.S. Supreme Court ruled in *Olmstead v. L.C.* that the unjustified segregation of people with disabilities is a form of unlawful discrimination under the ADA and that people with disabilities must receive services in the most integrated settings possible. This landmark decision paved the way for many people with disabilities to receive supports and services in the community rather than in institutional settings.

Although the social and political zeitgeist may have been primed for this shift to community living, the physical infrastructure of the community was not. Many people with disabilities quickly became segregated in their communities due to the inaccessibility of the environment, specifically with respect to housing (White et al., 2010). Finding affordable and accessible housing is paramount to the integration of people with disabilities into society. Even prior to the implementation of the Fair Housing Amendments Act of 1988, disability scholars emphasized the importance of housing as a foundation to people with disabilities being able to utilize services and supports in the community (Carling, 1989). Without affordable and accessible housing, these scholars recognized that "most rehabilitation interventions are simply not productive" (Carling, 1989, p. 6).

Prior to the implementation of the Fair Housing Amendments Act, many federal and state mandates for accessibility requirements were based on the American National Standards Institute (ANSI, 1986) "Specifications for Making Buildings and Facilities Accessible to, and Usable by, the Physically Handicapped." Although mandates based on the ANSI standards required a certain percentage (5-10%) of new construction to be made fully accessible to wheelchair users, these accessible dwelling units often had high levels of vacancies (Bostrom, 1987). This phenomenon was partially due to the fact that, because mandates applied only to new construction, newly developed dwellings typically had high rent that many people with disabilities could not afford (Bostrom, 1987). Additionally, mandates did not specify the residency capacity of accessible dwelling units, so many accessible dwelling units were built as one-bedroom units and could not support people with disabilities with families or live-in attendants (Bostrom, 1987). Building owners also had trouble renting these units to nondisabled tenants due to their institutional appearance and because nondisabled renters found certain

accessibility features (e.g., lowered kitchen surfaces) inconvenient. As a result, many building owners felt that they were losing money and began lobbying to have accessibility mandates reduced or removed (Bostrom, 1987).

In response to the lobbying efforts of building owners, a new paradigm emerged to focus on "adaptable housing" in lieu of "accessible housing" (Bostrom, 1987). With the switch to "adaptable housing," a dwelling unit was no longer required to be made accessible to a person with a disability, but instead required dwelling units to be "primed" to be made accessible if a person with a disability wanted to modify the dwelling unit to fit their individualized needs. As stated by the U.S. Department of Housing and Urban Development (HUD), "Adaptability solves the problem of making accessible housing attractive and marketable to people who do not need or want some of the accessible features that look different or might be inconvenient, while making it possible for the adaptable features, such as clear knee space and grab bars, to be available when a tenant requires them" (Bostrom, 1987, p. 8).

The shift to "adaptable housing" is evident in the requirements of the Fair Housing Amendments Act of 1988, which (a) prohibits discrimination based on disability status when a person is buying, renting, or securing finances for a home; (b) outlines accessibility design and construction requirements; and (c) requires the allowance of reasonable accommodations and modifications in housing. Although the Fair Housing Amendments Act outlines design and construction requirements for new dwelling units, it is important to note that the Act did not intend to make units fully accessible. Instead, the Fair Housing Amendments Act is intended to place "modest requirements" that avoid any conditions that would "impose an unreasonable burden on builders, and significantly increase the cost of new multifamily construction" (Fair Housing Accessibility Guidelines, 1991). For example, although the Fair Housing Amendments

Act requires buildings to have reinforced walls for grab bars, it does not require building owners to actually install these grab bars. It is important to note, however, that these "modest requirements" would render these dwelling units unusable to any resident with a disability requiring grab bars without their actual installation. Additionally, many people with mobility impairments have individualized home usability needs that may not be included within the "adaptable" design and construction requirements. For example, although a dwelling may be constructed to be "adaptable" by offering a 60 in. pivoting turn space in bathrooms and kitchens, the dwelling may not be "usable" to an electric wheelchair user requiring a 94 in. pivoting turn space.

The Fair Housing Amendments Act does offer some protection against usability concerns by requiring that the housing landlord allow people with disabilities to make reasonable modifications to their dwelling units, regardless of date of first occupancy. However, the landlord is not required to pay for these reasonable modifications and may require that the resident restore the dwelling unit to its original condition when leaving. Thus, the financial burden of making an apartment "usable" often falls on people with disabilities and their families. A recent report published by the U.S. Department of Health and Human Services shows that most people who have received a home modification report spending at least $100 on the modification and that only a very low percentage (approximately 6%) report receiving any type of insurance payment or government subsidies for these modifications (Freedman & Agree, 2008). Given that people with disabilities are more likely to live in poverty, many are not able to afford expensive home modifications to make their dwelling more usable to them and may have to endure suboptimal or inaccessible living conditions (Tabbarah et al., 2000).

Although the Fair Housing Amendments Act offers adaptable housing requirements for new multifamily construction and reasonable modifications for existing multifamily residences, it is important to note that privately owned or leased single-family, two-family, and three-family homes are exempt from these requirements. As a result, very few single-family homes offer any type of accessibility features, although single-family homes account for approximately 40% of all rental properties (Joint Center for Housing Studies, 2017). Henning-Smith and Gimm (2018) analyzed data from the 2014 American Community Survey and found that people with disabilities are more likely to report living in a single-family residence (66.0%) compared to a multifamily (23.9%) or mobile residence (10.1%) and are more likely to report owning a home (58.0%) compared to renting (42.0%). Thus, although the Fair Housing Amendments Act requires adaptable housing features for people with disabilities, these data suggest that the majority of people with disabilities are not offered housing protections under this legislation.

To address the growing concern surrounding the lack of accessibility requirements applicable to single-family homes, disability advocates have begun endorsing "visitability" requirements for newly constructed single-family homes receiving federal funds. In 2003, U.S. Representative Janice Schakowsky introduced the Inclusive Home Design Act which proposed that all new federally funded, single-family homes be built to meet three basic accessibility requirements, including (a) at least one no-step entrance, (b) 32" clearance for doors and hallways on the main level, and (c) at least one wheelchair-accessible bathroom. Although this bill has repeatedly died in Congress, disability advocates continue to emphasize the importance of a form of legislation that extends adaptable housing protections to single-family residences. As more people age into disability, the demand for accessible housing will continue to increase, making the market for accessible housing even more competitive. Additionally, in certain

geographical areas (e.g., rural locations), single-family homes may be the only type of rental properties available.

As described, because there are no federally endorsed legal requirements to make housing fully accessible to a person with a disability, many people with disabilities are not able to afford modifications to make their home usable to them (Tabbarah et al., 2000), and very few people with disabilities report receiving any type of insurance or government subsidies for these modifications (Freedman & Agree, 2008). As a result, many people with disabilities continue to live in homes that are not usable to them. Thus, despite recent advances in the deinstitutionalization and independent living movements, many people with mobility impairments remain isolated or dependent in their communities due to a lack of affordable and accessible housing (White et al., 2010).

Supply & Demand

Approximately one-third of households in the United States, or 35.1 million households, have one or more residents living with a disability (National Council on Disability, 2010). Housing estimates show that there is a 60% probability that a person with a mobility impairment will reside in a newly constructed home over the course of its lifespan (Smith et al., 2008). However, research shows that 96.09% of all housing stock is not accessible to people with mobility impairments, and 89.24% of people with mobility impairments are living in housing that is not accessible to them (Bo'sher et al., 2015). Data analyzed from the 2018 National Health Interview Survey suggest that 40.7 million adults in the United States report having a mobility impairment (National Center for Health Statistics, 2018). Thus, these combined data suggest that approximately 36.3 million people with mobility impairments in the United States are living in inaccessible housing.

National statistics related to home accessibility features in the United States largely rely on data generated from the American Housing Survey (AHS), a survey funded by HUD and conducted by the U.S. Census Bureau. Although the AHS has been conducted since 1973, the AHS first included disability indicators in 2009 and survey questions about housing accessibility features in 2011. AHS data were used in a report published by the HUD Office of Policy Development and Research titled, "Accessibility of America's Housing Stock: Analysis of the 2011 American Housing Survey" (Bo'sher et al., 2015). For the purposes of describing nationally reported housing accessibility features, Bo'sher et al. (2015) separated the accessibility level of housing units into three levels. The first level, "Potentially Modifiable," describes a home that includes (a) "stepless entry into the dwelling from the exterior," (b) "bathroom on the entry level *or* presence of elevator in the unit," and (c) "bedroom on the entry level *or* presence of elevator in the unit" (p. 22). The second level, "Livable for Individuals with Moderate Mobility Difficulties," describes a home that includes all of the elements in Level 1, in addition to features that include (a) "no steps between rooms or rails/grab bars along all steps" and (b) "accessible bathroom with grab bars" (p. 23). The third level, "Wheelchair Accessible," describes a home that includes all of the elements of Levels 1 and 2, in addition to features that include (a) "extra-wide doors or hallways," (b) "no steps between rooms," (c) "door handles instead of knobs," (d) "sink handles/levers," (e) "wheelchair-accessible electrical switches, outlets, and climate controls," and (f) "wheelchair-accessible kitchen countertops, kitchen cabinets, and other kitchen features" (p. 23).

Results from Bo'sher et al. (2015) show that 33.34% of all housing stock includes accessibility features represented by Level 1, 3.76% include accessibility features represented by Level 2, 0.15% include accessibility features represented by Level 3, and 62.75% do not include

any type of accessibility features. These statistics indicate that only 3.91% of all housing stock meet a definition of "livable" for people with moderate mobility difficulties. For households including at least one person with a mobility impairment, 39.50% report living in a home with Level 1 accessibility features, 10.17% report living in Level 2, 0.59% report living in Level 3, and 49.74% report living in a home without any accessibility features. Thus, statistics suggest that only 10.76% of people with mobility impairments are living in housing that is considered "livable" to them.

Greiman and Ravesloot (2016) also analyzed data from the 2011 AHS and computed an odds ratio of having a stepped entrance for various groups compared to owners with no impairments (i.e., reference group). Results show that renters with mobility impairments are more likely to have a stepped entrance (OR = 0.880) than are owners with mobility impairments (OR = 0.588). Greiman and Ravesloot (2016) also calculated an odds ratio for having a stepped entrance adjusted for housing unit type, geography, and year built. Results from these calculations show that (a) compared to single-family homes (i.e., reference group), modular homes are more likely to have a stepped entrance (OR_{adj} = 5.64), followed by apartments (OR_{adj} = 3.99) and duplexes (OR_{adj} = 1.05); (b) compared to homes in urban areas (i.e., reference group), rural homes are less likely to have a stepped entrance (OR_{adj} = 0.86); and (c) compared to homes built before 1920 (i.e., reference group), newer homes (i.e., homes built between 2010 and 2011) are less likely to have a stepped entrance (OR = 0.35). Although Henning-Smith and Gimm (2018) report that people with mobility impairments are more likely to own their home and to reside in single-family homes, these data highlight that people with mobility impairments face limited choices surrounding accessible housing options available to them.

With respect to the prevalence of specific accessibility features among the homes of people with mobility impairments, results from Bo'sher et al. (2105) show that 54.7% cannot enter their home without steps, 86.7% do not have widened doorways/hallways, 31.0% have steps between rooms, 59.5% do not have handrails/grab bars in their bathroom, 84.5% do not have built-in shower seats, 91.2% do not have raised toilets, 15.9% do not have an entry-level bedroom, and 9.2% do not have an entry-level bathroom. Based on these results, Bo'sher et al. (2015) conclude that the U.S. housing stock is not well-equipped to support people with disabilities living in the community. As the demand for accessible housing continues to grow, the results of Bo'sher et al. (2015) highlight that only a small proportion of all homes, including newly constructed homes, incorporate basic accessibility features. Unfortunately, however, if people with mobility impairments are unable to locate, afford, or modify housing to fit their individualized needs, they may suffer a variety of adverse outcomes related to their health, social participation, and overall quality of life.

Outcomes of Inaccessible Housing

The usability of the home environment is central to maintaining independence in the home and community. In order to participate in social and community activities, a person must be able to bathe, dress, and leave home (Imrie, 2004). As the data from Bo'sher et al. (2015) suggest, however, many people with mobility impairments are forced to endure suboptimal or inaccessible living conditions. The inaccessibility of the home environment may result in a variety of adverse outcomes for people with disabilities, including increased risk for physical exertion (Greiman et al., 2018), ADL limitations (Stineman et al., 2007), and fall-related injuries (Berg, Hines, & Allen, 2002). Unfortunately, if the person is subject to these adverse outcomes

over time, and if the accessibility of the home environment is left untreated, these factors could eventually put the person at increased risk for institutionalization (Stineman et al., 2012).

If a person's home is not usable to them, they may exert additional energy completing activities of daily living. Greiman et al. (2018) analyzed data from the Health and Home Survey (HHS) to further explore the relationship between activities in the home, including bathing, and exertion. Results from analyses of the HHS data show that people with mobility impairments are significantly more likely than people without disabilities to report high levels of exertion during activities of daily living, including cleaning (39.3% vs. 19.8%), bathing (33.7% vs. 10.7%), using storage spaces (28.5% vs. 14.6%), entering and exiting the home (27.0% vs. 10.4%), preparing food (23.7% vs. 8.2%), using the toilet (23.6% vs. 7.4%), and using the bedroom (20.3% vs. 8.7%). Additionally, results show that people with mobility impairments who report an unmet need of bathroom grab bars report significantly higher levels of exertion while bathing (39%) than people with mobility impairments who report a met need of grab bars (19%). Based on these data, Greiman et al. (2018) suggest that, if people have limited energy to expend throughout the day, completing ADLs may lead to a "high cost" of energy expenditure, especially if a person's home is unusable to them.

People living in inaccessible homes may also report greater levels of difficulty when completing daily living activities. Stineman et al. (2007) analyzed data from the National Health Interview Survey on Disability (NHIS-D) and computed odds ratios of perceived difficulty completing ADLs (i.e., dressing, toileting, eating, and getting in/out of chairs) based on the reported met or unmet need of home accessibility features. Results show that, compared to people with met need of home accessibility features (i.e., reference group), people with unmet need are more likely to experience ADL difficulty, including increased risk of ADL difficulty

due to an unmet need of widened doorways (OR = 5.9), ramps in the home (OR = 3.7), railings in the home (OR = 3.2), automatic doors (OR = 5.7), bathroom modifications (OR = 4.1), kitchen modifications (OR = 5.7), and elevators (OR = 4.3). Additionally, Stineman et al. (2007) assessed the odds of ADL difficulty based on various socioeconomic characteristics (e.g., income, education, and race/ethnicity) and found that reported unmet need of home accessibility features was a much stronger predictor of ADL difficulty than these socioeconomic variables.

If a person continues to complete ADLs despite an inaccessible home environment, they may put themselves at increased risk for fall-related injury. Berg, Hines, and Allen (2002) analyzed data from wheelchair users who completed the NHIS-D and who reported an injurious fall in the past 12 months. Results show that wheelchair users who did not report an injurious fall were more likely to report various types of home accessibility features than people who did report an injurious fall, including modifications to the bathroom (45.4% vs. 35.6%), widened doorways/hallways (43.1% vs. 28.9%), modifications to the kitchen (17.8% vs. 13.3%), stair railings (39.7% vs. 26.7%), easy-open doors (19.0% vs. 11.1%), all five accessibility features (6.9% vs. 0.0%), and no accessibility features (33.3% vs. 53.3%). These data suggest that people with more accessible homes are less likely to report an injurious fall.

Stineman et al. (2012) analyzed data collected from the Second Longitudinal Study of Aging (LSOA II) to assess the relationship of perceived home environmental barriers and nursing home admission. Home environmental barriers were defined as one or more unmet needs of home accessibility features, including an unmet need for a ramp, railing, widened doorway, kitchen modification, easy open door, accessible parking, or elevator/stair glide. Odds ratio results show that, compared to people who did not perceive home environmental barriers (i.e., reference group), people with perceived home environmental barriers were more likely to be

admitted to a nursing home (OR = 2.80; OR_{adj} = 1.43). Although the causal relations of nursing home admission cannot be determined from this analysis, results of Stineman et al. (2012) represent an important effort to examine the relationship between perceived home accessibility and institutionalization.

These studies highlight that people with mobility impairments who report a lack or unmet need of home accessibility features are more likely to report greater levels of exertion (Greiman et al., 2018), ADL limitations (Stineman et al., 2007), injurious falls (Berg, Hines, & Allen, 2002), and institutionalization (Stineman et al., 2012). In addition to the effects these adverse outcomes may have on caregivers, family, and the person's overall quality of life, outcomes due to inaccessible housing may have extensive societal and economic impacts. Fortunately, however, if people receive a home modification to improve the accessibility and usability of their home, emerging research shows that the adverse outcomes associated with inaccessible housing may be reversed or improved.

Home Modification Interventions

The social model of disability recognizes that the degree to which a person may experience a disability is significantly influenced by their environment (Shakespeare, 2006). For example, although a person with a mobility impairment may not be able to bathe using a standard bathtub, they may have no difficulty bathing when provided a walk-in shower, grab bars, hand-held shower head, and bath bench. In this way, the supports offered in the environment have the potential to eliminate, or greatly reduce, a person's disability. Home modifications provide an important contribution to reducing a person's disability within their home. Features within the home environment can be specifically tailored to a person with a disability to maximize their home usability and independence. The following sections will

summarize the experimental designs, intervention components, outcome measures, and results identified within home modification intervention research.

Systematic reviews. Several systematic reviews have summarized commonly reported outcome measures of home modification interventions for community-dwelling adults with disabilities. Results of Stark et al. (2017) show that outcome measures reported in publications on home modification interventions include (a) improved functional performance, (b) reduced fall risk, and (c) reduced demands on caregivers. Results of Carnemolla & Bridge (2018) show that outcome measures reported in home modification intervention articles include (a) falls-related evidence, (b) self-care and independence, (c) physical health and well-being, (d) caregiving, (e) economic effectiveness, (f) aging process, and (g) social participation. Results of MacLachlan et al. (2018) show that outcome measures in identified home accessibility articles include (a) activities of daily living, (b) falls/injury and mortality, (c) quality of life, (d) psychological effects, (e) occupational performance, and (f) participation.

Systematic reviews have also summarized commonly reported intervention components of home modification interventions for community-dwelling adults with disabilities. Results of Stark et al. (2017) show that components of home modification interventions include (a) assessment of the person completing ADLs, (b) assessment of the home environment, (c) action planning for the implementation of the home modification, (d) implementation of the home modification, (e) follow-up consultation/training, and (f) professional (e.g., occupational therapist) expertise throughout assessment and follow-up training components. A systematic review conducted by MacLachlan et al. (2018) summarizes commonly reported types of home modifications implemented. Results of MacLachlan et al. (2018) show that home accessibility features include modifications to (a) entrances and doors (e.g., ramps, wheelchair accessible

doors, automatic doors, widened doors), (b) bathrooms (e.g., shower seats, shower modifications, grab bars, raised toilets), (c) stairways (e.g., rails, stair-lifts), and (d) others (e.g., handrails, bedrails, ground-floor bedrooms/bathrooms/laundry facilities).

Articles summarized in these systematic reviews identify studies that include (a) adults aging into disability, (b) people with other types of disabilities (e.g., low vision, dementia, psychiatric disabilities) or people without disabilities (i.e., caregivers), (c) intervention components qualitatively different than home modifications (e.g., exercise programs, physical therapy, medication supplements), and (d) outcome measures qualitatively different than home and community participation (e.g., falls-related evidence, quality of life, caregiver fatigue). Thus, for the purposes of a more detailed review of these research studies, articles selected for in-depth review will identify studies that include (a) community-dwelling adults with mobility impairments, (b) single- or multi-component interventions directly related to home modification interventions, and (c) outcome measures related to home and community participation.

Research summaries. To evaluate the effects of home modification interventions on functional performance and independence within the home, the majority of studies use a pretest-posttest group design to assess changes in reported or observed ADL difficulty or independence (e.g., Fänge & Iwarsson, 2005; Petersson et al., 2009; Wilson et al., 2009). For example, Petersson et al. (2009) conducted a longitudinal study with 103 community-dwelling adults with at least one functional limitation who were in need of a home modification. Participants who were scheduled to receive a home modification were assigned to an intervention group and participants who were awaiting their application for a home modification to be reviewed were assigned to a control group. To assess perceived difficulty in completing ADLs, the researchers used the Client-Clinician Assessment Protocol (C-CAP) Part I (Lilja, 2002). In this study, the C-

CAP Part I was conducted as a structured interview to ask the participants their perceived difficulty related to feeding, dressing, grooming, bathing, transferring, walking indoors, walking in the community, getting in/out of the house, managing stairs, cooking, getting in/out of bed, getting in/out of the car, grocery shopping, cleaning, managing medication, and leisure/social activities on a 5-point scale (i.e., no difficulty, a little difficulty, difficult, a lot of difficulty, unable to do at all). The C-CAP Part I difficulty scale demonstrates acceptable internal scale validity, person response validity, and person separation reliability when used with people with disabilities in need of home modifications (Petersson et al., 2007). Data were collected at baseline/pre-intervention, 2-month follow-up/post-intervention, and 6-month follow-up/post-intervention. Types of home modifications included shower, toilet, elevator, ramp, automatic door-opener, and unspecified modifications. Results of Petersson et al. (2009) show that, although participants receiving home modifications reported less difficulty in completing life tasks at the 2- and 6-month follow-up measures, the effect sizes (*d*) reported were small to moderate (0.34 and 0.32, respectively).

Similarly, Wilson et al. (2009) conducted a randomized control group design study with 91 community-dwelling adults aging with mobility impairments. The researchers selected the Older Americans Resources and Services Instrument (OARS; Fillenbaum, 1985) to ask participants about their perceived level of independence during eating, dressing, grooming, showering, toileting, transferring, indoor mobility, community mobility, shopping, cooking, cleaning, medication management, telephone use, and finances on a 5-point scale (i.e., independent, independent with equipment, help from human, help from both human and equipment, unable to do). Data were collected at baseline/pre-intervention, 12-month follow-up/post-intervention, and 24-month follow-up/post-intervention. An occupational therapist and

an assistive technology equipment specialist conducted an individualized in-home evaluation during which they observed the participants' performance of tasks perceived to be problematic. Upon completing the in-home evaluation with the participant, the therapist and specialist made recommendations for assistive technology, home modifications, or behavior modifications. Types of assistive technology or home modification interventions included grab bars (16.7%), ADL adaptations such as dressing tools, positioning devices, and hygiene tools (14.2%), bath/shower benches (11.7%), ADL adaptations such as kitchen aids, cleaning aids, and gardening aids (10.8%), toilet equipment such as toilet frames, raised seats, and bidets (9.2%), ramps (6.7%), outside railings (6.7%), home modifications such as work surfaces, kitchen installations, thermostat changes, and door hinges (5.8%), hand-held shower heads (5.8%), transfer equipment such as floor to ceiling bars, raised furniture, and bed rails (5.8%), telephone equipment such as large numbered and volume enhanced phones (3.3%), and wheelchair cushions (1.7%). Results show that changes in ADL independence were nonsignificant for both pre/post and group comparisons.

Some articles use a combination of self-report and direct observation to examine the effects of home modification interventions on ADLs. For example, Fänge & Iwarsson (2005) conducted a longitudinal study using a sample of 131 community-dwelling adults with at least one functional limitation receiving housing adaptation grants. The researchers used the ADL Staircase instrument (Sonn & Asberg, 1991) conducted by an occupational therapist to assess both perceived and observed level of independence (i.e., independent, partly dependent, and dependent) with respect to dressing, eating, bathing, transferring, toileting, cleaning, cooking, shopping, and transportation. Data were collected 1 month prior to housing adaptation, 2-3 months following housing adaptation, and 6-7 months following housing adaptation. Various

types of home modifications were completed ranging from 1 day to several months to complete. The majority of home modifications included modifications to the bathroom (55.7%), entrances (29.0%), and interior stairways and doors (22.9%). Results of the ADL Staircase show that dependence in bathing decreased between the 2-3-month follow-up and the 6-7-month follow-up ($p = 0.0020$), although no other items were found to be significant.

In recent years, community participation has gained increasingly more recognition and acceptance as a key indicator to evaluate the success of home- and community-based services and supports for people with disabilities. This shift largely occurred in 2001, when the World Health Organization (WHO) revised the International Classification of Functioning, Disability, and Health (ICF) to remove emphasis on "absence of disability" as an historically evaluated outcome, and instead place emphasis on "community participation" as a desired outcome. Additionally, in 2012, the U.S. Department of Health and Human Services (HHS) created the Administration for Community Living (ACL), which houses the federal government's primary disability research agency, the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR). Research and Development programs funded by NIDILRR have specifically focused on improving outcomes related to community living and participation (ACL, 2019). Although the majority of research examining community participation among people with disabilities is non-experimental, previous research has examined the effects of transportation vouchers (Samuel et al., 2013), physical activity (Crawford et al., 2008; Dean et al., 2012), personal assistance services (PAS) training (Gray et al., 2009), and entrance ramps (White et al., 1995) on community participation.

Community and Home Participation

Despite an increasing emphasis on using community participation as an outcome measure to assess the effects of home- and community-based services, little research within the home modification literature identifies community participation as an outcome measure to assess the effects of home modification interventions. According to Stark et al. (2017), for example, no articles identified within the systematic review included community participation as an outcome measure. A study conducted by White et al. (1995) represents the only known home modification intervention that uses single-subject methodology to assess intervention effects. In this study, six wheelchair users eligible for community development block grant funds were recruited to participate. The dependent variable identified for the study was the number of reported community visits within a 1-week period. A weekly telephone interview was conducted with participants to obtain the self-reported frequency and location of community visits during a 1-week period. Participants were instructed that community visits were defined as crossing their property line, independent of the number of stops made during the trip. The independent variable identified for the study was the installation of an exterior ramp leading to the home entrance, which adhered to ANSI standards. A multiple baseline design was used to assess the effects of the home access modification across participants. The authors suggest that four participants reported an increase in community participation following ramp installation, whereas two participants reported a decrease in community participation.

To assess community participation as an outcome variable, a systematic review conducted by Chang et al. (2013) summarizes community participation measures for people with disabilities. Results show that measures of community participation most commonly include the Client's Assessment of Strengths, Interests, and Goals (CASIG; Wallace et al., 2001); Katz

Adjustment Scale (KAS; Katz & Lyerly, 1963); Social Functioning Scale (SFS; Birchwood et al., 1990); Activity Card Sort (ACS; Baum & Edwards, 2008), Independence Living Skills Survey (ILSS; Wallace et al., 2000), and Community Participation Indicators (CPI; Heinemann et al., 2011). A question to assess community participation included in the CASIG, for example, asks "In the past 90 days, did you use local public transportation such as the bus or train to go places yourself?" (Wallace et al., 2001, p. 107). However, these types of measures are limited in that they rely on self-report data and often include extended periods of recall, which presents a serious threat to the internal validity of these measures.

To address methodological concerns due to recall, researchers are beginning to use Ecological Momentary Assessment (EMA) to assess community participation among people with disabilities. EMA is a method that prompts participants to answer questions in real time based on event-contingent (e.g., behaviors recorded at every meal), interval-contingent (e.g., behaviors recorded every hour), or signal-contingent (e.g., behaviors recorded at the sound of a beeper) schedules (Shiffman & Stone, 1998; Shiffman & Stone, 2008). EMA was initially used within the field of behavioral medicine to assess in situ health (e.g., self-reported physical activity, pain, smoking), and has been established as a reliable and valid method for collecting data on a variety of different behaviors (Stone & Shiffman, 1994; Piasecki et al., 2007). Recently, researchers are employing EMA methods to study community participation as an outcome measure for people with disabilities (e.g., Seekins et al., 2007; Ravesloot et al., 2016; Gonda-Kotani & White, 2017). Given that EMA methodology reduces the likelihood of recall error, these methods provide a more reliable, valid, and comprehensive approach to self-reported community participation measures (Livingston et al., 2015).

Seekins et al. (2007) conducted a preliminary study to examine the utility of EMA as a measure of community participation for people with disabilities. Five participants were asked to complete EMA measures using a personal data assistant (PDA) programmed to signal six prompts per day across 7 weeks. Participants received six prompts per day between the hours of 9am and 9pm that were programmed as a randomly timed prompt within each 2-hr. interval. At each prompt, participants were asked to report their current location, activity engaged in, level of socialization, environmental barriers and facilitators, secondary conditions (e.g., pain, fatigue, depression), and perception of community connectedness and fulfillment. Survey completion results show that participants completed 77.0% of prompts within 30 min. of a scheduled prompt, and participants completed 92.7% of prompts later than 30 min. of a scheduled prompt during the same day the prompt was received. Of the 1,352 observations recorded, results show that participants were most likely to report spending the majority of time at home (62.2%, n = 841), engaging in social or leisure activities (38.7%, n = 517), and spending time alone (45.2%, n = 581).

Ravesloot et al. (2014) conducted a subsequent study to examine the temporal association of secondary conditions (e.g., pain, fatigue, and depression) related to the likelihood that participants would remain at or return home. 525 participants were asked to complete EMA questions six times a day for 2 weeks related to their current location and self-reported rating of secondary conditions. Of these 525 participants, 148 participants gave permission for the researchers to enable a global positioning system (GPS) receiver on the touchscreen tablet used for the EMA measures. Survey completion results show that participants completed 87.0% of all survey prompts. Of the 10,209 location observations reported, results show that participants were most likely to report spending the majority of time at home (70%, n = 7,132), outside (7%, n =

733), and at a business or store (6%, $n = 615$). Using the Spearman rank-order correlation coefficient, Ravesloot et al. (2014) were able to establish convergent validity of the EMA measure to assess community participation when compared to GPS coordinate data (0.92, $p < 0.01$).

In addition to community participation, EMA measures present the potential to study the way in which a person uses and interacts with their home. Although no known study has examined the effects of a home modification intervention on home participation (e.g., time allocation in various areas of interest), these data have the potential to reveal increases in the usability of a person's home that would not ordinarily be captured by a measure of functional independence. That is, even if the person requires assistance while bathing, if the person is bathing more frequently, then this would be a measure of intervention success. Ironically, Stineman et al. (2007) presented hypothetical data to illustrate the effects of home modification intervention on home usability, although actual data were not reported. That is, Stineman et al. (2007) presented an illustration to describe how the removal of environmental barriers may affect the usability of the home environment. Stineman et al. (2007) used shading to illustrate areas of a home that would be accessible to a wheelchair user and used white space to illustrate areas of a home that would be inaccessible. Stineman et al. (2007) used this illustration to demonstrate that a person's disability can be reduced by widening doorways throughout the home, installing grab bars in the bathroom, lowering kitchen cabinets, lowering a bedroom clothes rack, and building a ramp for front and back entrances to increase independence in the home. Although this is an important illustration to represent the effects that a home modification intervention can have on usability, no known study has conducted measures to replicate the theoretical illustration produced by Stineman et al. (2007).

A recent review conducted by Struckmeyer et al. (2020) identified assessments used to evaluate the usability of a person's home. Results from Struckmeyer et al. (2020) suggest that only three of the identified articles included measures of usability, although these measures were more specific to fear of falling and ADL performance (e.g., Ekstam et al., 2014). Thus, there is no known method to assess the impact of a home modification intervention on an objective measure of the way in which a person uses and interacts with their home. However, it is possible that a measure of this type may prove an important indicator of intervention success. For example, if a person receives a kitchen modification and an objective measure suggests that they are spending more time in their kitchen, this may be considered to be a measure of intervention success, regardless of whether they receive the same amount of assistance while cooking. That is, a person's independence should not be solely measured by the level of assistance received while completing various ADLs, as other assessments have traditionally suggested. Instead, an objective measure to describe the way in which a person interacts with their home before and after a home modification intervention may serve as a novel outcome measure to indicate increased usability or the need to continue to identify home usability solutions if observed usability is unchanged.

Purpose

Previous research examining the effects of home modification interventions have evaluated outcomes related to the ability to complete ADLs, risk of falling, and fatigue placed on caregivers (Stark et al., 2017). However, no known research has examined the effects of a home modification intervention on objective measures of community or home participation. Thus, the proposed study offers the hypothesis that the collection of these measures may offer additional insight or be used as an indicator to assess the effects of home modification interventions, which

is based on the premise that increased home usability will allow participants to better allocate time and activity in the areas of their choice. For example, this study hypothesizes that if a person's bathroom is made more usable, they may spend less time in the bathroom and allocate more time and energy to participate in other areas of the home or community, such as in the kitchen, living room, or outside. Thus, the purpose of the study is to evaluate the effects of a home modification intervention on community and home participation.

Method

Participants and Setting

The investigator is the Research Project Coordinator for a large NIDILRR-funded project, the Research and Training Center on Promoting Interventions for Community Living (RTC/PICL). The RTC/PICL represents a five-year, $4.375 million dollar grant from the National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR) to study the effectiveness of evidence-based interventions in increasing the community participation of people with mobility impairments. As part of the research conducted under the RTC/PICL, we recruited a sample of 210 participants with mobility impairments living in the greater Kansas City, Missouri, and Missoula, Montana, communities through Centers for Independent Living (CILs). CILs are consumer-controlled, nonresidential agencies that are designed and operated within a local community by people with disabilities. CILs provide five core services to people with disabilities living in the community, including (a) advocacy, (b) information and referral, (c) independent living skills, (d) peer support and mentoring, and (e) transition services, which includes assisting youth with disabilities who are transitioning to independent living for the first time and people living in institutional settings (e.g., nursing homes) transitioning to community-based settings. To support community-based research, it is

important to partner with CILs to implement research in real-world settings to enhance the sustainability of the intervention after the research project has concluded. Thus, CIL staff served as researchers on the project and were trained to recruit consumer participants, deliver the intervention, and assist throughout the research process. All study procedures took place between May 2017 and December 2019, with study interventions implemented between June 2017 and November 2019.

First, CIL staff recruited potential participants into the study and confirmed that they met eligibility criteria for participating in the study. Eligibility criteria required the participant to be at least 21 years old, have a mobility impairment, be their own legal guardian, and be living in a community-based setting. After the staff identified a participant eligible for the study, they reviewed the study consent form and gained consent from the participant to participate in the study. Participants were randomly assigned to intervention and control groups to conduct a randomized controlled trial of the Home Usability Program. Intervention participants worked with Center for Independent Living (CIL) staff at The Whole Person (thewholeperson.org) in Kansas City and Summit Independent Living (summitilc.org) in Missoula to complete a home usability intervention. Effects of the intervention were assessed using pre- and post-survey measures. Control participants did not complete an intervention and completed the pre- and post-survey measures only. Study procedures took place at the CIL, in the participants' homes, and by telecommunication methods. All study procedures were approved by the Universities of Kansas and Montana Institutional Review Boards (IRBs).

Measures

Home and Community Survey. Prior to working with CIL staff on the home usability intervention, participants were asked to complete a survey measure called the Home and

Community Survey. Participants had the option to complete the survey using either a paper and pencil method or online via an electronic survey tool (i.e., Qualtrics). The Home and Community Survey included a demographics form (see Appendix A), home safety measure (see Appendix B), and assistive technology use measure (see Appendix C). The demographics form included measures of age, gender, race, employment, and annual household income. The home safety measure is an internally developed measure and asked the participant to report their level of safety when completing various activities in their home. The assistive technology use measure is an internally developed measure and asked the participant to report types of mobility aids or assistance utilized.

Ecological Momentary Assessment. Following completion of the Home and Community Survey, participants were asked to complete daily surveys on a smartphone device, also known as Ecological Momentary Assessment (EMA). That is, a smartphone was programmed to sound an alarm at a random time within two-hour intervals between the hours of 7am and 11pm. Participants completed a total of 8 surveys per day for 7 days, which provided a total of 56 response opportunities. Participants received a total of $50 for completing the week of smartphone surveys and the Home and Community Survey described above.

Prior to beginning the EMA measure, CIL staff scheduled a meeting with participants to review the EMA device and survey. During this training, participants were instructed that the smartphone device would “alarm” to prompt them to answer a series of questions about their current activity that would take a few minutes to complete. Participants had the option of “snoozing” the device up to two times per prompt in which the device “snoozed” for 10 minutes each time they selected “snooze.” If the participant did not complete the survey in the 10 minutes following the final (third) alarm, the survey closed and was recorded as a missed survey.

Participants were encouraged to complete as many surveys as possible. Participants were also instructed to take the device wherever they went during the day and to charge the device every night to receive all the scheduled alarms. For this study, EMA completion rates were 81.57% for all participants, although completion rates were higher during pre-EMA administration (85.24%) compared to post-EMA administration (77.89%).

Upon reviewing device instructions with participants and providing them with a copy of an EMA Device and Survey Guide, CIL staff practiced completing a survey on the smartphone with the participant. First, the participant was asked to complete the Home Characteristics Survey (see Appendix D) on the CIL staff's device to help them become comfortable with using the smartphone device. The Home Characteristics Survey is an internally developed measure that asks about accessibility features present within the home. These questions were only asked once during the EMA training procedure. Following completion of the Home Characteristics Survey, CIL staff practiced completing the EMA measure with the participant on the CIL staff's device so that the participant could experience the alarms and survey prompts and have the opportunity to ask any questions. Finally, the participant's smartphone device was scheduled to begin the EMA surveys on the day following the EMA training.

To measure community participation, participants answered daily EMA surveys that asked, "Where are you?" (see Appendix E). Participants could indicate if they were at home, outside, business/store, transportation vehicle, office building, someone else's home, school/educational facility, healthcare facility, restaurant/bar, church/religious facility, gym/exercise facility, venue, or other. For coding purposes, responses were coded as "home" if the participant indicated the home response, and responses were coded as "community" if the participant indicated the response of outside, business/store, transportation vehicle, office

building, someone else's home, school/educational facility, healthcare facility, restaurant/bar, church/religious facility, gym/exercise facility, or venue. Responses indicated as "other" were coded according to the categories of "home" or "community" if an un-biased categorization was possible (e.g., the participant indicated they were at home using the response of "other"). Responses indicated as "other" that could not be coded using an un-biased categorization method were excluded from analysis. Finally, a percentage of community participation was calculated by dividing the total number of responses indicated as being present in the community by the total number of responses indicated as being present in the home or in the community.

If participants reported being at home, they were asked the question: "Since the last prompt, where in your home have you been?" (see Appendix F). This measure was used to assess home participation. Participants could then indicate if they had visited their bathroom, living room/family room, bedroom, kitchen, dining room, spare room, upstairs, basement, garage, porch/balcony, front/back yard, or other. Responses indicated as "other" were excluded from the current analyses. For coding purposes, responses for each room were coded as having been "present" or "absent" in a given room. Finally, a percentage of home participation was calculated by dividing the total number of responses indicated as having visited a specified area of interest (e.g., bathroom) by the total number of responses indicated as having visited or having not visited the specified area of interest since the last survey prompt.

The Home Usability Program

Once intervention participants completed the "Home and Community Survey" and the week of EMA smartphone surveys, CIL staff worked with them to complete the Home Usability Program (http://useablehome.ri.umt.edu). To begin the Home Usability Program, CIL staff worked with the participant to identify problems in their home that they would like to address.

Resources were provided that could be used if the participant found them helpful to identify home usability problems. These included the "How Usable is My Home" questionnaire (see Appendix G) and the 2015 American Association of Retired Persons (AARP) *HomeFit Guide* home assessment (see Appendix H). The CIL staff discussed home usability problems with the participant and asked the participant to identify a primary home usability problem that they would like to work to address. Then, the CIL staff worked with the participant to set goals for addressing the home usability problem. The CIL staff also worked with the participant to identify a home usability network, which included identifying personal resources (e.g., financial contributions and family or friends who could help) and community resources (e.g., funding from community grants or service agencies) to address the home usability goal. Participants were also provided with a spending budget of up to $350 from grant funds, which was instrumental if personal or community resources were not able to be identified. Finally, CIL staff worked with the consumer to implement the home modification identified during the home assessment. Following implementation, the CIL staff confirmed completion of the home modification and the consumer's satisfaction with the home modification. In order for the researchers to be able to assess the effects of the home modification intervention, participants completed the Home and Community Survey and the week of smartphone EMA surveys for a second time. Participants received a total of $50 for completing the second administration of these survey activities.

Research Design and Analyses

A randomized controlled trial (RCT) was used to evaluate the effects of the home modification intervention. That is, participants were randomly assigned to either the intervention group or a control group. Participants assigned to the intervention group were asked to complete pre-survey measures, completed the Home Usability Program, and completed post-survey

measures, whereas participants assigned to the control group were asked to complete pre-survey measures, wait for a period of 3 months, and complete post-survey measures.

All descriptive and comparative analyses were conducted in IBM SPSS (Version 26). First, demographics characteristics of study participants with mobility impairments were calculated. Comparisons made between participants (i.e., control and intervention group comparisons) were calculated using unpaired (i.e., independent) *t*-tests for both continuous and dichotomous variables. Although the Pearson chi-squared test is typically suggested for testing whether two proportions are equal, statisticians have cited the robustness of the *t*-test for testing the equality of two independent binomial proportions (e.g., D'Agostino et al., 1988; Hirji et al., 1991). Homogeneity of variance was tested using Levene's Test of Equality of Variances when conducting the unpaired *t*-tests to determine if equal variance was or was not assumed.

Second, comparative analyses were conducted to examine differences in community and home participation between control and intervention group participants. Within-group change scores were calculated by subtracting mean post-test scores from mean pre-test scores. To examine differences among participant pre- and post-test scores, comparative analyses were calculated using paired (i.e., dependent) *t*-tests. Between-groups differences were analyzed by calculating the differences between the absolute value of change for control and intervention group participants. Comparisons made between participants (i.e., control and intervention group comparisons) were calculated using unpaired *t*-tests using absolute value change scores.

Third, comparative analyses were conducted to examine differences in perceptions of home safety between control and intervention group participants. Within-group change scores were calculated by subtracting mean post-test scores from mean pre-test scores. To examine differences among participant pre- and post-test scores, comparative analyses were calculated

using paired *t*-tests. Comparisons made between participants (i.e., control and intervention group comparisons) were calculated using unpaired *t*-tests.

Fourth, comparative analyses were conducted to examine differences in community and home participation based on pre-test data examining home characteristics. Comparisons made between participants (e.g., stepped entrance and no-step entrance comparisons) were calculated using unpaired *t*-tests.

Fifth, comparative analyses were conducted to examine differences in community and home participation based on pre-test data examining perceptions of home safety. Comparisons made between participants (e.g., not safe entering home and safe entering home comparisons) were calculated using unpaired *t*-tests.

Finally, comparative analyses were conducted to examine differences in community and home participation based on pre-test data examining assistive technology use. Comparisons made between participants (e.g., no mobility aid and mobility aid comparisons) were calculated using unpaired *t*-tests.

Data exclusion procedures. If participants did not choose to participate in any component of the research study, this decision was honored, and participants could choose which components they would like to continue working on or if they would like to withdraw from the research study. For example, some participants chose to complete the survey measures, but did not choose to participate in the Home Usability Program. Additionally, some participants chose to complete the pre-survey measure and participate in the Home Usability Program but did not choose to complete the post-survey measure. For illustrative purposes, a diagram of the number of participants included in each analysis is included in Appendix I. For the purposes of the analyses conducted, participant data were excluded from comparative analyses among control

and intervention group participants if an intervention group participant did not participate in the home usability intervention or if the participant did not complete both pre- and post-survey measures. Thus, illustrated in Appendix I, the number of participants varies across analyses to maximize sample size for all analyses.

Results

Table 1 depicts demographic characteristics of study participants with mobility impairments. Results show that participants were a mean of 53.7 years of age. Participants were more likely to be female (62.9%) than male (37.1%). Participants were more likely to be White (74.6%) followed by Black/African American (17.8%), American Indian/Alaska Native (7.6%), Asian (0.5%), and other (4.1%). The total sample also included a small number of participants who identified as Hispanic/Latino (4.1%). Participants were more likely to be unemployed (79.6%) than employed part time (14.8%) or employed full time (5.6%). Participants were more likely to report an annual household income of ≤ $10,000 (40.8%) than an annual household income of $10,001 to $20,000 (26.7%), $20,001 to $30,000 (8.4%), $30,001 to $40,000 (7.3%), $40,001 to $50,000 (6.3%), $50,001 to $60,000 (1.0%), or >$60,000 (9.4%). Participants were more likely to report using a mobility aid (80.5%) than no mobility aid (19.5%). Of participants who reported using a mobility aid, participants were more likely to report using a cane/walking stick (37.8%) followed by using the assistance of other people (31.8%), walker (23.0%), power wheelchair (19.9%), manual wheelchair (18.9%), brace (11.7%), oxygen/breathing equipment (4.6%), scooter (4.6%), crutch/crutches (2.0%), artificial limb (1.5%), service animal (1.5%), and other (11.2%). Finally, between-groups differences were examined to ensure effective randomization among control and intervention group participants. These results show that no

statistically significant differences were found related to demographic characteristics between control and intervention group participants.

Table 2 depicts a comparative analysis of community and home participation between control group and intervention group participants using EMA data. For the 67 participants assigned to the control group, within-group change scores were calculated by subtracting mean post-test scores from mean pre-test scores. These data suggest control group participants significantly increased ($p < 0.05$) their participation in their living room (change score = 4.69), kitchen (change score = 5.53), and porch/balcony (change score = 2.80). For the 59 participants assigned to the intervention group, within-groups change scores were also calculated. These data suggest that intervention group participants significantly increased ($p < 0.05$) their participation in their bedroom (change score = 5.42). Finally, between-groups differences were analyzed by calculating the differences between the absolute value of change among control and intervention group participants. These results show that no statistically significant differences in community and home participation exist between the control and intervention groups.

Table 3 depicts a comparative analysis of community and home participation between control group and bathroom intervention group participants. The results depicted for the control group are the same as depicted from the analysis conducted from Table 4. For the 22 participants assigned to the bathroom intervention group, within-groups change scores were calculated. These data suggest that no within-groups change scores were statistically significant at the $p < 0.05$ level. Again, between-groups differences were analyzed by calculating the differences between the absolute value of change among control and bathroom intervention group participants. Our analyses show that no statistically significant differences in community and home participation exist between the control and bathroom intervention groups.

Table 4 depicts a comparative analysis of perceptions of home safety between control group and intervention group participants. For the 80 participants assigned to the control group and the 70 participants assigned to the intervention group, within-group change scores were calculated by subtracting mean post-test scores from mean pre-test scores. These data suggest that no within-groups change scores were statistically significant at the $p < 0.05$ level. Finally, between-groups differences were analyzed by calculating the change score differences between control and intervention group participants. These results show that no statistically significant differences in perceptions of home safety exist between the control and intervention groups.

Table 5 depicts a comparative analysis of perceptions of home safety between control group and bathroom intervention group participants. The results depicted for the control group are the same as depicted from the analysis conducted from Table 6. For the 25 participants assigned to the bathroom intervention group, within-groups change scores were calculated. These data suggest that no within-groups change scores were statistically significant at the $p < 0.05$ level. Again, between-groups differences were analyzed by calculating the change score differences between control and bathroom intervention group participants. Our analyses show that no statistically significant differences in perceptions of home safety exist between the control and bathroom intervention groups.

Table 6 depicts results from a pre-test comparative analysis of community and home participation based on home characteristics conducted using an unpaired *t*-test. Results show that participants who reported inadequate lighting in their kitchen were significantly less likely ($p = 0.004$) to report participating in their kitchen (37.14%) than participants with adequate lighting in their kitchen (58.15%). In addition to home characteristics, Table 6 depicts results from a pre-test comparative analysis of community and home participation and perceptions of home safety

conducted using an unpaired *t*-test. Results show that participants who did not feel safe entering their home were significantly less likely ($p = 0.049$) to report participating in their community (16.47%) than participants who felt safe entering their home (21.55%). Participants who did not feel safe using their bedroom were significantly less likely ($p = 0.011$) to report participating in their bedroom (46.34%) than participants who felt safe using their bedroom (59.08%). Finally, participants who did not feel safe using their kitchen were significantly less likely ($p = 0.001$) to report participating in their kitchen (45.66%) than people who felt safe using their kitchen (60.65%).

Table 7 depicts results from a pre-test comparative analysis of community and home participation and assistive technology use conducted using an unpaired *t*-test. Results show that participants who do not use a mobility aid were significantly less likely ($p = 0.004$) to report participating in the bathroom (56.57%) than participants who use a mobility aid (69.73%). Additionally, participants who do not use a mobility aid were significantly less likely ($p = 0.013$) to report participating in the bedroom (47.41%) than participants who use a mobility aid (59.05%). Additionally, Table 7 depicts results from a pre-test comparative analysis of community and home participation based on wheelchair use conducted using an unpaired *t*-test. Results show that participants who do not use a wheelchair were significantly more likely ($p = 0.008$) to report participating in the basement (3.94%) than wheelchair users (0.38%).

Discussion

Although the identified purpose of the present study was to examine differences in community and home participation following a home usability intervention, results from our first, principal analysis (Table 2) show that no statistically significant differences in community and home participation were found between the control and intervention groups. Although within

group change scores show significant differences among pre- and post-test scores, these results should be interpreted with caution since these significant differences were observed across both intervention and control groups. Because there is no attributable factor that may be considered to explain the significant differences within the control group, it is possible that these significant differences should be interpreted to be largely adventitious (although it is possible that results may have been observed due to participant reactivity). Thus, although there are no robust conclusions that we can interpret using these data, a hypothesis was proposed that the unsystematic approach to home modification interventions may have directly impacted the significance level of observed findings.

To elaborate, the implemented home modification intervention did not systematically control for the specific type of home modification received. Although components of the home modification intervention were controlled for (i.e., home assessment, identification of a home usability goal, goal setting to address the home usability goal, and implementation of the home modification), the type of home modification implemented was tailored based on individualized assessment outcomes and needs. Based on this assessment, some participants received a bathroom modification, some participants received a kitchen modification, and some participants received a living room modification (types of home modifications implemented are summarized in Appendix J). However, it is possible that only certain types of home modifications affect someone's community participation, such as a person who has more energy to go out into their community after receiving a bathroom modification or a person who is better able to go out into their community after receiving a home entrance modification.

To provide context to this discussion, it is important to note that nonsignificant findings are not unique to the analyses at hand. As noted previously, a systematic review conducted by

Stark et al. (2017) reports that limited evidence exists to support that home modifications improve functional performance for people with disabilities. In fact, other scholars have cited the complexity of home modification interventions. For example, Fänge & Iwarsson (2005) suggest that home modification interventions represent a "black box" that "challenges traditional approaches to evaluation" (p. 301). Through the use of group designs to evaluate the effects of home modification interventions, it becomes difficult to identify which type of modification makes the most significant impact for an individual, especially provided the complexity and variation of individual physical abilities, environmental settings, assistive technology, and personal assistance services (Gitlin, 1998). In reviewing methodological issues specific to home modification interventions, Gitlin (1998) suggests that researchers "confront difficult issues concerning the standardization of intervention protocols and their implementation, and the identification and measurement of appropriate outcomes" (p. 192). Although more than two decades have passed since Gitlin (1998) summarized these methodological concerns, researchers continue to cite a need for the development of "more sophisticated designs and analyses" to assess the effects of home modification interventions (Cho et al., 2016).

Researchers have suggested that future studies may consider home modification types by implementing only specified types of home modifications within a given study (Fänge & Iwarsson, 2005). To address this suggestion, a second analysis was conducted to include a sample of participants who received an intervention specific to a single room: the bathroom. The bathroom was selected for analysis because it represented the area of the home in which the largest number of interventions specific to a single room were implemented, which contributed to the largest sample size possible for this analysis.

Unfortunately, results from our second analysis (Table 3) also show that no statistically significant differences in community and home participation were found between the control and bathroom intervention groups. First and foremost, it is possible that our nonsignificant findings may be due to the fact that people receiving a home modification specific to their bathroom included a sample size of only 22 participants. That is, because implementation of the home usability intervention was designed to assess home modification interventions specific to a consumer's individualized needs, a large sample size of participants who received an intervention specific to an identified area of interest (e.g., bathroom) or a specified intervention type (e.g., grab bars) was not obtained. Additionally, although our second analysis attempted to control for the type of modification received (i.e., modifications specific to the bathroom), it was not possible to adequately address this hypothesis given the data that we had access to as part of the present research study. That is, even though only bathroom modifications were included in our second analysis, the specific type of bathroom modification was still not systematically controlled for. For example, some participants received a raised toilet seat, some received grab bars, some received a shower chair/transfer bench, etc.

To further explore if we may be able to examine observable differences in community and home participation between the control and intervention groups, we hypothesized that the type of measurement used to examine changes in community and home participation also may not have been sensitive enough to measure a small change in community and home participation following a home modification. That is, it is possible that asking participants to report their location more frequently throughout the day or for longer than a duration of one week may have had the potential to detect smaller changes. We proposed a hypothesis that a different type of measure (i.e., perceptions of home safety) may be used to better consider the effects of a home

modification intervention between control and intervention group participants. That is, our hypothesis was based on the consideration that people who received an intervention in their home (e.g., shower) may report feeling safer when completing an activity associated with that area (e.g., bathing). Thus, we conducted an additional analysis to examine differences between the control and intervention groups based on measures of home safety.

Again, results from our third analysis (Table 4) show that no statistically significant differences in perceptions of home safety were found between the control and intervention groups. Given these nonsignificant findings, we also sought to control (to the best of our ability) the type of modification received. Thus, we conducted a fourth analysis in which we included only intervention participants who received a modification specific to the bathroom to better control for this limitation. Results from our fourth analysis (Table 5) also show that no statistically significant differences in perceptions of home safety were found between the control and bathroom intervention groups. Of course, the limitations relevant to sample size and a lack of control for intervention function are also applicable to these analyses.

Another factor that may have contributed to the limited evidence of home modification interventions is a lack of control for the quality or robustness of the modification received. CIL staff often were not able to identify other sources of funding for home modifications and had to rely on the $350 allocated to the home modification as part of the research grant. Thus, interventions implemented for this study typically cost $350 or less to implement. However, it is possible that interventions larger in magnitude, such as a full bathroom remodel, may have a more robust effect on community and home participation than interventions lesser in magnitude, such as a nonslip bathmat.

As described above, we hypothesized that a primary limitation of the study is a lack of control for the type and quality of the home modification implemented. Thus, we decided to conduct analyses using pre-survey data only to compare participant outcomes based on accessibility characteristics being present in the home or not present in the home. We hypothesized that these data would provide a larger sample size of participants who do or do not have an accessibility feature present in their home. By considering specific types of home characteristics, we hypothesized that we may be able to show differences between groups of participants who did report these accessibility features being present in their home compared to participants who did not report to have these accessibility features. In this way, our hypothesis was that the specific type of accessibility feature (e.g., stepped vs. no-step entrance) would be more adequately controlled for.

Results from our fifth analysis (Table 6, home characteristics) show that participants who report having adequate light in their kitchen report spending more time in their kitchen. Surprisingly, no significant differences were found to exist between participants who reported other types of accessibility features. For example, participants who reported having a no-step entrance were not significantly more likely to participate in their community than participants who reported having a stepped entrance. One hypothesis for these nonsignificant findings is that participants who live in housing without various accessibility features are living in these settings because they do not identify that they need these accessibility features. Thus, a primary limitation of these analyses is that, although we asked participants to report the presence/absence of accessibility features within their home, we did not ask participants to report their need for these accessibility features. Given this limitation, we hypothesized that we may better consider

differences among groups based on their perceptions of feeling safe or unsafe when using various areas of their home.

Results from our sixth analysis (Table 6, personal factors) show that participants who report feeling safe when using their home entrance are significantly more likely to participate in their community. Additionally, participants who report feeling safe when using their bedroom are more likely to participate in their bedroom, and participants who report feeling safe when using their kitchen are more likely to participate in their kitchen. It is possible that these differences based on perceptions of home safety tell the most compelling story of the analyses conducted to this point. One additional consideration is that differences in bathroom participation may be affected by the participant's functional ability level. For example, a person with more limited mobility may take longer to complete activities of daily living in the bathroom, regardless of perceptions of safety. Thus, to better consider functional ability as a factor affecting differences in observed participation, we conducted a final analysis to consider disability severity as a factor affecting community and home participation.

Results from our final, seventh analysis (Table 7) show that participants who use a mobility aid were significantly more likely to report participating in their bathroom and bedroom to a greater degree than participants who do not use a mobility aid. One hypothesis for these significant findings is that participants with more limited mobility may spend more time in their bathroom to complete activities of daily living and may spend more time in bed throughout the day. Additionally, these results show that wheelchair users are significantly less likely to report spending time in their basement. These results highlight the decreased usability of areas in the home when inherent barriers exist (e.g., stairs) and may also indicate the validity of the

community and home participation measures when used to assess the ways in which people with disabilities use and interact with their home.

Recommendations for Future Research

Increased experimental control. As described above, future research may consider methodologies in which only certain types of home modifications are implemented in an effort to better control for the variability in outcomes that may be observed when functionally different types of interventions are implemented across participants. That is, future research may consider home modification types by implementing only specified types of home modifications related to a single function within a given study (Fänge & Iwarsson, 2005). Although controlling for the type of home modification may be preferable, however, it is worth noting that there are challenges associated with this type of methodology.

First, individual home environments do not always permit a systematic approach to modification type. For example, although a systematic home modification study may recruit participants who receive the installation of grab bars for bathing, the type of grab bar (e.g., permanent vs. adjustable), grab bar position, type of shower/tub (e.g., no-step vs. stepped entry), bathroom size, and combined types of assistive technology used (e.g., shower/tub seat, handheld shower head), may all significantly impact the usability of the shower/tub, despite an attempted systematic approach to the intervention type. Second, a prescriptive approach to home modification interventions may not adequately control for the participant's identified need for these types of home modifications. That is, consistent with the independent living philosophy, participants should identify that they need the individual home modification, rather than having it prescribed to them. In addition to ethical considerations involving the importance of promoting

consumer choice and control, the independent living approach helps to minimize threats to external validity by controlling for perceived home modification need.

To address these challenges, it is arguable that controlling for the specific function of a home modification (e.g., ability to toilet safely) may be preferable to controlling for specific modification types based on functional purpose (e.g., toilet grab bars, raised toilet seat). By defining modifications based on their function, rather than their topography, researchers may better control for the variations of home modifications implemented across participants while continuing to emphasize consumer choice and control. It is possible that a functional approach may also consider unique strategies that consumers may use to toilet comfortably, such as the use of a "bathroom walker" designated to serve as grab bars for toileting. In this way, home modification interventions could consider changes in a consumer's perceived ability, energy, or safety when using their toilet, regardless of the types of equipment used to achieve this outcome. Thus, specifying the function of the home modification intervention may allow researchers to more adequately control for intervention groups considered across comparative analyses.

Additionally, it may be worth noting that the present study did not systematically match the types of usability concerns identified by intervention group participants to those of control group participants. That is, an assessment to identify and prioritize home usability concerns was only completed by participants assigned to the intervention group. Thus, no data were collected to consider types of usability concerns that control group participants may identify in order to match control and intervention group participants based on usability concerns. Finally, no data were collected to consider the procedural fidelity of the implementation of the Home Usability Program. Although satisfaction with the home modification intervention was confirmed across participants, it is possible that the degree to which CIL staff adhered to each component of the

Home Usability Program may have varied across participants. Thus, future research may do better to collect procedural fidelity data in an effort to inform if the interventions was implemented consistently across participants.

Single-subject design. It is possible that research employing a single-subject design may provide an additional solution to enable the assessment of home modification interventions given their complex nature. By using a design in which the participant serves as their own control, rather than using designs that rely on comparisons based on group outcomes, single-subject design has the potential to assess a more accurate portrayal of intervention effects. Additionally, it is possible that more clear or robust effects may be observed if individual outcomes are not diluted within group summaries. That is, it is possible that the focus on group means within home modification research has contributed to the limited evidence of its effects. For example, if the home modification had a positive effect on half of the participants and had an equally negative effect on the other half, the positive effects would be statistically cancelled out by the negative effect on the other half. Thus, although our group-level analyses did not result in significant findings, it is possible that data analyzed at the individual level may tell a more meaningful story.

To illustrate this point, several results analyzed at the individual are reviewed. Although these results do not demonstrate experimental control, these cases may help to clarify the proposed hypothesis. Appendix K depicts the data for Darlene. The x-axis indicates the various areas of interest and the y-axis indicates the percentage of community and room participation. The black bars indicate pre-test data, and the grey bars indicate post-test data. Darlene's home usability intervention involved the installation of grab bars in her bathroom. The data presented in Appendix K suggest that Darlene's community participation increased, bathroom participation

decreased, and living room, bedroom, and kitchen participation largely stayed the same. Appendix K also depicts the data for Kendrick. Kendrick lived in an apartment that was not accessible to him, so his home usability goal was to move into an apartment that presented better accessibility features with respect to the entrance and home interior. Although these data do include confounds given the different home environment, they highlight the comprehensive changes to community and home participation that may be observed when a comprehensive intervention is implemented.

Although no known study uses a single-subject design to examine the effects of an interior home modification intervention, a shift in recent literature has employed the use of case studies to better capture the complexity of home modification interventions on individualized outcomes (e.g., Carnemolla, 2018). While these studies represent a move in the right direction, these case studies are largely qualitative in nature. Thus, there is a need to establish a line of research that provides individualized quantitative assessment, which may help to address the long-standing call for effective home modification strategies based on individualized needs and home environments (e.g., Gitlin, 1998).

Individualized outcomes. An additional limitation is that participants were not asked if they wanted to increase or decrease their community and home participation. That is, it is possible that participants prefer to be in their home instead of their community, and it is possible that increased community participation was not a socially relevant outcome for them. Thus, future research should consider consumer choice and control when using physical participation in the community as an intervention success indicator. Again, results analyzed at the individual level (see Appendix K) may help to illustrate the point at hand. For example, Juan's home usability goal was to have an outdoor deck installed. Following installation of his deck, we

observed a large decrease in his community participation and a large increase in his yard participation. Similarly, Keisha's home usability goal was to receive a variety of assistive technology to aid her in the kitchen while cooking. Although we observed a decrease in her community participation, we observed an increase in her kitchen participation. Even though community participation may decrease for some participants, these data highlight the point that this decrease may, in fact, be an indicator of intervention success.

It is possible that this disregard for individualized outcomes based on consumer-identified goals may have also contributed to nonsignificant findings. For example, it is possible that a bathroom modification may have led some participants to spend more time in their bathroom, such as a person who is able to bathe using an accessible bathtub for the first time. Alternatively, a bathroom modification may have led other participants to spend less time in their bathroom, such as a person who is able to bathe more efficiently and quickly. By using an individualized approach to intervention, we can ensure that consumers select outcomes that are socially relevant to them – or, in other words, that the consumer actually *wants* to increase the number of times that they go out into their community. By taking a clinical approach to home usability, clinicians can continue to work with a consumer until a desired outcome chosen by the consumer is achieved, such as increased community participation, increased time spent in the kitchen, or decreased time lying down after bathing. Thus, it is proposed that people with disabilities should always maintain choice and control in their decision-making, which includes assisting researchers in determining indicators of intervention success that are individualized to them.

In this way, socially relevant outcomes may be able to inform analyses at both the individual and group level. For this dissertation study, the way in which community participation

was considered may not have been the most appropriate method to detect measurable change following a home modification intervention. That is, community participation was defined as participating outside of the home so that specific types of community participation were not considered. For example, it is possible that "optional" or "recreational" types of community participation (e.g., going to a movie theater, shopping, visiting family/friends) may be impacted to a greater degree than "necessary" types of community participation (e.g., going to a doctor's appointment, work, or a pharmacy). As a result, changes in community participation may have been better observed if specific types of community participation were more adequately controlled for.

Outcome measure. Given the mixed results cited within the home modification intervention literature, it is possible that home modification interventions had effects on outcomes not captured by the outcome measures selected. To address a more systematic and objective approach to capturing the effects of individual components of home modifications, emerging technology may prove useful to provide a more comprehensive approach to examining intervention effects. A growing body of literature uses sensor technology to detect activity within the home, including time, location, and level of activity (see Daniel et al., 2009, for a review). For example, pressure monitors may be placed within various areas of the home (e.g., under a mattress) to assess what time a person went to bed, how many times a person got up, and the length of time they were up throughout the night. This technology may be combined with other sensor technologies (e.g., motion detectors or state change sensors attached to doors, cabinets, or toilet lids) to provide a more comprehensive approach to examining activity within the home (Buckland et al., 2006). These types of sensor technologies are primarily employed in telehealth monitoring and research, where they are used to alert caregivers or telehealth staff when a

change in a person's daily routine is observed (Barnes et al., 2006; Kaye & Hayes, 2006), when a potential fall is detected (Nazarko, 2007), or when an appliance has been left on (Mrazovac et al., 2011).

However, it is possible that a more detailed examination of activity within the home may be measured by radio frequency (RF) tomography, which provides a method by which researchers can remotely and objectively examine the time, location, and level of activity by a person within their home without the use of cameras or wearable technologies (Nannuru et al., 2012). Although no known study has examined the utility of RF tomography as an outcome measure to assess the effects of home modification interventions, RF tomography has been studied and validated in the literature to be sensitive in monitoring change in behavioral patterns or activity within the home (see Shukri & Kamarudin, 2017, for a review).

Kaltiokallio et al. (2012) evaluated the use of RF tomography for detecting changes in activities of daily living for long-term residential monitoring. The participant's apartment was divided into six areas-of-interest (i.e., bed, bathroom, kitchen, sofa, table, and entrance). Before the long-term study was conducted, the experimenters tested the accuracy of the RF tomography by comparing the "true location" of the participant recorded by direct observation to the "estimated" location of the participant recorded by the RF tomography for defined areas-of-interest. Results of this calibration study show that the RF tomography was 100% accurate in detecting true positives and generated no false positive recordings. The authors present findings from the long-term experiment in which data are displayed for the participant describing the time, location, and duration spent within each identified area-of-interest. Results are displayed to represent the participant's daily activities within a 20-min. and a 2-day time period, in addition to the average time spent within each identified area-of-interest over a one-week time period. As

reported by the authors, this technology allows caregivers the ability to observe changes in behavioral routine, such as changes in wakeup time, duration of time spent in the kitchen, and frequency of leaving the apartment.

Ironically, a criticism cited within the RF tomography literature is the limitation of its use as a remote healthcare alert technology. As suggested by Susnea et al. (2019), the use of RF tomography may lead to systematic false alerts due to the sensitivity of the device. As stated by Susnea et al. (2019), even moving a piece of furniture "may lead to changes of the user's habitual motion pathways through the environment, resulting in large deviations from the recorded routine" (p. 6). Although RF tomography has been used to assess changes in ADLs within the context of ambient assisted living, no known study has used RF tomography as an outcome measure to assess the effects of a home modification intervention. However, previous research cites the accuracy of RF tomography to detect ADLs within the home, in addition to the sensitivity of RF tomography to detect changes in ADLs. Thus, RF tomography may have good potential as a method to objectively measure changes in ADLs following a home modification intervention.

In addition to the applications that using RF tomography as an outcome measure may provide, there is great potential for future research and clinical application. For example, researchers collecting information using Ecological Momentary Assessment (EMA) methods could ask the participant to report their level of pain or fatigue within the home over an extended period of time. Longitudinal extraction of these data using cross-measures analyses could allow researchers to create heat maps to display locations in the home where the consumer reports the highest levels of pain or fatigue. Researchers could also examine the consumer's home participation to assess if specific behaviors or routines are more or less likely to result in high

levels of reported pain or fatigue. Additionally, engineers studying future applications of RF tomography are examining applications to detect human breathing rate within the home (e.g., Patwari et al., 2013). Thus, future opportunities for research and clinical application are bountiful, and specific applications may be revealed as cross-measures analyses yield data that are meaningful to researchers and other stakeholders.

Implications for Policy

The severe lack of accessible and affordable housing represents one of the largest crises that Americans with disabilities are facing at this time. As discussed previously, no federally endorsed legislation currently exists to make housing fully accessible to people with disabilities. Unfortunately, the disability housing crisis will continue to worsen as the lack of responsiveness to this priority continues. As an ever-growing proportion of the population ages into disability, an increasingly large percentage of housing will become unusable to the population at large. More than ever, data to demonstrate the true, robust effects of home modifications on the lives of people with mobility impairments is critical to increase federal, state or local funding for home modifications.

It is important to note that the social validity of the outcome measures used must also be considered. In theory, legislators represent the types of evidence valued by their constituents. As such, it is important to identify what types of evidence these constituents are interested in. For the majority of the population, for example, it may be deemed irrelevant if a person with a mobility impairment increased the amount of time allocated in their kitchen following a kitchen modification. To the disability community, however, these indicators may be used to represent increased independence and quality of life. In this sense, perhaps the largest limitation of this study is that we did not explicitly ask people with mobility impairments if the types of outcome

measures identified for the study were important to them. Thus, future research is needed to establish socially relevant outcome measures determined to be important across people with mobility impairments, disability advocates, and the general population to more appropriately determine socially relevant outcomes of interest to legislators. It is possible that cost savings models may be prioritized by the population at large to demonstrate the effects of home modifications on decreasing associated medical costs or increasing economic growth through community participation.

Regardless of the outcome identified, it is possible that the $350 amount allocated as funding for home modifications during the present study may not be enough to make a dramatic impact in a person's life. Depending on the outcome measure utilized, it may be possible that a greater allocation of funding for home modifications is needed to demonstrate robust effects. If this is true, additional research is needed to compare costs between new construction and modifications to existing dwellings. For example, it may cost substantially less to construct homes with widened doorways from the beginning rather than retrofitting widened doorways to an already constructed home. If this is true, this research would help to inform legislators of the urgent need to authorize basic home visitability requirements to newly constructed homes as soon as possible.

Although new construction requirements may help to begin to address the housing crisis, the growing need for accessible and affordable housing will not be solved by new construction requirements alone. There will be a continuing need to increase funding for home modifications so that a greater number of people with disabilities can live in housing that is accessible to them. Although the $350 amount does not seem like an amount that would make a substantial difference in someone's life, it is worth noting that this is a considerable amount for disability

service agencies to allocate for a consumer's home modification. Thus, future research employing cost-benefit analyses is needed to explore how to maximize desired intervention effects while maintaining low costs for home modifications in order to expand services to a greater number of consumers. Regardless of how solutions are constructed, however, it is critical that we must first build a solid foundation through research.

References

American Association of Retired Persons (2015). *HomeFit Guide*. Washington, D.C.: Author.

American National Standards Institute (1986). *American national standard for buildings and facilities: Providing accessibility and usability for physically handicapped people* (ANSI A117.1-1986). New York: Author.

Americans with Disabilities Act of 1990 (ADA), Pub. L. No. 101-336, 104 Stat. 328 (1990).

Barnes, N., Webster, S., Mizutani, T., Ng, J., Buckland, M., & Reeves, A. (2006). Liverpool Telecare pilot: case studies. *Journal of Innovation in Health Informatics*, *14*(3), 197-202.

Baum, C. M., & Edwards, D. (2008). *ACS: Activity Card Sort*. AOTA Press, American Occupational Therapy Association.

Berg, K., Hines, M., & Allen, S. (2002). Wheelchair users at home: few home modifications and many injurious falls. *American Journal of Public Health*, *92*(1), 48-48.

Birchwood, M., Smith, J. O., Cochrane, R., Wetton, S., & Copestake, S. (1990). The social functioning scale the development and validation of a new scale of social adjustment for use in family intervention programmes with schizophrenic patients. *The British Journal of Psychiatry*, *157*(6), 853-859.

Bostrom, J. A. (1987). *Adaptable Housing: A Technical Manual for Implementing Adaptable Dwelling Unit Specifications*. U.S. Department of Housing and Urban Development, Rockville, MD.

Bo'sher, L., Chan, S., Ellen, I. G., Karfunkel, B., & Liao, H. L. (2015). *Accessibility of America's Housing Stock: Analysis of the 2011 American Housing Survey (AHS).* Washington, DC: U.S. Department of Housing and Urban Development, Office of Policy Development and Research Report.

Buckland, M., Frost, B., & Reeves, A. (2006). Liverpool Telecare Pilot: Telecare as an information tool. *Journal of Innovation in Health Informatics*, *14*(3), 191-196.

Carling, P. J. (1989). Access to housing: Cornerstone of the American dream. *Journal of Rehabilitation*, *55*(3), 6.

Carnemolla, P. (2018). Ageing in place and the internet of things–how smart home technologies, the built environment and caregiving intersect. *Visualization in Engineering*, *6*(1), 7.

Carnemolla, P., & Bridge, C. (2018). A scoping review of home modification interventions–Mapping the evidence base. *Indoor and Built Environment, 29*(3), 299-310.

Chang, F. H., Coster, W. J., & Helfrich, C. A. (2013). Community participation measures for people with disabilities: A systematic review of content from an international classification of functioning, disability and health perspective. *Archives of Physical Medicine and Rehabilitation*, *94*(4), 771-781.

Cho, H. Y., MacLachlan, M., Clarke, M., & Mannan, H. (2016). Accessible home environments for people with functional limitations: A systematic review. *International Journal of Environmental Research and Public Health*, *13*(8), 826.

Crawford, A., Hollingsworth, H. H., Morgan, K., & Gray, D. B. (2008). People with mobility impairments: Physical activity and quality of participation. *Disability and Health Journal*, *1*(1), 7-13.

D'agostino, R. B., Chase, W., & Belanger, A. (1988). The appropriateness of some common procedures for testing the equality of two independent binomial populations. *The American Statistician*, *42*(3), 198-202.

Daniel, K. M., Cason, C. L., & Ferrell, S. (2009). Emerging technologies to enhance the safety of older people in their homes. *Geriatric Nursing*, *30*(6), 384-389.

Dean, C. M., Rissel, C., Sherrington, C., Sharkey, M., Cumming, R. G., Lord, S. R., Barker, R. N., Kirkham, C., & O'Rourke, S. (2012). Exercise to enhance mobility and prevent falls after stroke: The community stroke club randomized trial. *Neurorehabilitation and Neural Repair*, *26*(9), 1046-1057.

Ekstam, L., Carlsson, G., Chiatti, C., Nilsson, M. H., & Fänge, A. M. (2014). A research-based strategy for managing housing adaptations: Study protocol for a quasi-experimental trial. *BMC health services research*, *14*(1), 1-10.

Fair Housing Accessibility Guidelines, 56 Fed. Reg. 9472 (Mar. 6, 1991). Design and construction requirements, compliance with ANSI A117.1 Standards, 72 Fed. Reg. 39,540.

Fair Housing Amendments Act of 1988, Pub. L. No. 100-430, 102 Stat. 1619 (1988).

Fänge, A., & Iwarsson, S. (2005). Changes in ADL dependence and aspects of usability following housing adaptation—a longitudinal perspective. *American Journal of Occupational Therapy*, *59*(3), 296-304.

Fillenbaum, G. G. (1985). Screening the elderly: A brief instrumental activities of daily living measure. *Journal of the American Geriatrics Society*, *33*(10), 698-706.

Freedman, V. A., & Agree, E. M. (2008). *Home Modifications: Use, Cost, and Interactions with Functioning Among Near-Elderly and Older Adults.* Washington, DC: U.S. Department of Health and Human Services.

Gitlin, L. N. (1998). Testing home modification interventions: Issues of theory, measurement, design, and implementation. *Annual Review of Gerontology and Geriatrics*, *18*(1), 190-246.

Gonda-Kotani, C., & White, G. W. (2017). The effects of contingency contracts and performance feedback on completing data entries to self-monitor community participation of people with mobility impairments: An ecological momentary study. *Journal of Prevention & Intervention in the Community*, *45*(2), 86-99.

Gray, D. B., Dashner, J. L., Morgan, K. A., Lyles, M., Scheller, M. D., Morris, C. L., & Hollingsworth, H. H. (2009). Influence of a consumer-directed personal assistance services program on the lives of persons with mobility impairments. *Disability and Health Journal*, *2*(4), 188-195.

Greiman, L., & Ravesloot, C. (2016). Housing characteristics of households with wheeled mobility device users from the American Housing Survey: Do people live in homes that facilitate community participation? *Community Development*, *47*(1), 63-74.

Greiman, L., Fleming, S. P., Ward, B., Myers, A., & Ravesloot, C. (2018). Life starts at home: Bathing, exertion and participation for people with mobility impairment. *Archives of Physical Medicine and Rehabilitation*, *99*(7), 1289-1294.

Heinemann, A. W., Lai, J. S., Magasi, S., Hammel, J., Corrigan, J. D., Bogner, J. A., & Whiteneck, G. G. (2011). Measuring participation enfranchisement. *Archives of Physical Medicine and Rehabilitation*, *92*(4), 564-571.

Henning-Smith, C., & Gimm, G. (2018). The relationship between employment, gender, and living arrangements for working-age adults with disabilities. *Journal of Vocational Rehabilitation*, *48*(3), 393-401.

Hirji, K. F., Tan, S. J., & Elashoff, R. M. (1991). A quasi-exact test for comparing two binomial proportions. *Statistics in Medicine*, *10*(7), 1137-1153.

Imrie, R. (2004). Disability, embodiment and the meaning of the home. *Housing Studies*, *19*(5), 745-763.

Inclusive Home Design Act of 2003, H.R. 2353, 108th Congress (2003).

Joint Center for Housing Studies. (2017). *America's Rental Housing 2017.* Joint Center for Housing Studies of Harvard University, Cambridge, MA.

Kaltiokallio, O., Bocca, M., & Patwari, N. (2012, October). Follow@ grandma: Long-term device-free localization for residential monitoring. In *37th Annual IEEE Conference on Local Computer Networks-Workshops* (pp. 991-998). IEEE.

Katz, M. M., & Lyerly, S. B. (1963). Methods for measuring adjustment and social behavior in the community: I. Rationale, description, discriminative validity and scale development. *Psychological Reports*, *13*(2), 503-535.

Kaye, J., & Hayes, T. (2006). Home health monitoring: A system to assess motor and cognitive function. *Generations*, *30*(2), 61-63.

Lilja, M. (2002). *Guidelines for using Client-Clinician Assessment Protocol (C-CAP).* Stockholm: Karolinska Institute.

Livingston, N. A., Hargrove, T., Greiman, L., Myers, A., Ipsen, C., & Ravesloot, C. (2015). An investigation into the temporal scaling of community participation measurement. *Rehabilitation Psychology*, *60*(4), 367.

MacLachlan, M., Cho, H. Y., Clarke, M., Mannan, H., Kayabu, B., Ludolph, R., & McAuliffe, E. (2018). Report of the systematic review on potential benefits of accessible home environments for people with functional impairments. In *WHO Housing and Health Guidelines*. World Health Organization.

Mrazovac, B., Bjelica, M. Z., Teslic, N., & Papp, I. (2011, September). Towards ubiquitous smart outlets for safety and energetic efficiency of home electric appliances. In *2011 IEEE International Conference on Consumer Electronics-Berlin (ICCE-Berlin)* (pp. 322-326). IEEE.

Nannuru, S., Li, Y., Zeng, Y., Coates, M., & Yang, B. (2012). Radio-frequency tomography for passive indoor multitarget tracking. *IEEE Transactions on Mobile Computing*, *12*(12), 2322-2333.

National Center for Health Statistics (2018). Summary health statistics: National Health Interview Survey, 2018.

National Council on Disability (2010). *The State of Housing in America in the 21st Century: A Disability Perspective.* Washington, DC: Author.

National Institute on Disability, Independent Living, and Rehabilitation Research (NIDILRR): 2018-2023 Long-Range Plan (2019). Washington, DC, Department of Health and Human Services, Administration for Community Living.

Nazarko, L. (2007). Independence through telecare. *Nursing and Residential Care*, *9*(9), 414-416.

Olmstead v. L. C., 527 U.S. 581 (1999).

Patwari, N., Wilson, J., Ananthanarayanan, S., Kasera, S. K., & Westenskow, D. R. (2013). Monitoring breathing via signal strength in wireless networks. *IEEE Transactions on Mobile Computing*, *13*(8), 1774-1786.

Petersson, I., Kottorp, A., Bergström, J., & Lilja, M. (2009). Longitudinal changes in everyday life after home modifications for people aging with disabilities. *Scandinavian Journal of Occupational Therapy*, *16*(2), 78-87.

Piasecki, T. M., Hufford, M. R., Solhan, M., & Trull, T. J. (2007). Assessing clients in their natural environments with electronic diaries: Rationale, benefits, limitations, and barriers. *Psychological Assessment*, *19*(1), 25.

Ravesloot, C., Ward, B., Hargrove, T., Wong, J., Livingston, N., Torma, L., & Ipsen, C. (2016). Why stay home? Temporal association of pain, fatigue and depression with being at home. *Disability and Health Journal*, *9*(2), 218-225.

Rehabilitation Act of 1973, Pub. L. No. 93-112 (1973).

Samuel, P. S., Lacey, K. K., Giertz, C., Hobden, K. L., & LeRoy, B. W. (2013). Benefits and quality of life outcomes from transportation voucher use by adults with disabilities. *Journal of Policy and Practice in Intellectual Disabilities*, *10*(4), 277-288.

Seekins, T., Ipsen, C., & Arnold, N. L. (2007). Using ecological momentary assessment to measure participation: A preliminary study. *Rehabilitation Psychology*, *52*(3), 319.

Shakespeare, T. (2006). The social model of disability. *The Disability Studies Reader*, *2*, 197-204.

Shiffman, S., & Stone, A. A. (1998). Ecological momentary assessment: A new tool for behavioral medicine research. *Technology and Methods in Behavioral Medicine*, 117-131.

Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological momentary assessment. *Annual Review of Clinical Psychology*, *4*, 1-32.

Shukri, S., & Kamarudin, L. M. (2017). Device free localization technology for human detection and counting with RF sensor networks: A review. *Journal of Network and Computer Applications*, *97*, 157-174.

Smith, S. K., Rayer, S., & Smith, E. A. (2008). Aging and disability: Implications for the housing industry and housing policy in the United States. *Journal of the American Planning Association*, *74*(3), 289-306.

Sonn, U., & Asberg, K. H. (1991). Assessment of activities of daily living in the elderly. A study of a population of 76-year-olds in Gothenburg, Sweden. *Scandinavian Journal of Rehabilitation Medicine*, *23*(4), 193-202.

Stark, S., Keglovits, M., Arbesman, M., & Lieberman, D. (2017). Effect of home modification interventions on the participation of community-dwelling adults with health conditions: A systematic review. *American Journal of Occupational Therapy*, *71*(2), 1-11.

Stineman, M. G., Ross, R. N., Maislin, G., & Gray, D. (2007). Population-based study of home accessibility features and the activities of daily living: Clinical and policy implications. *Disability and Rehabilitation*, *29*(15), 1165-1175.

Stineman, M. G., Xie, D., Streim, J. E., Pan, Q., Kurichi, J. E., Henry-Sánchez, J. T., ... & Saliba, D. (2012). Home accessibility, living circumstances, stage of activity limitation, and nursing home use. *Archives of Physical Medicine and Rehabilitation*, *93*(9), 1609-1616.

Stone, A. A., & Shiffman, S. (1994). Ecological momentary assessment (EMA) in behavioral medicine. *Annals of Behavioral Medicine, 16*(3), 199-202.

Struckmeyer, L., Morgan-Daniel, J., Ahrentzen, S., & Ellison, C. (2020). Home Modification Assessments for Accessibility and Aesthetics: A Rapid Review. *HERD: Health Environments Research & Design Journal*, 1937586720960704.

Susnea, I., Dumitriu, L., Talmaciu, M., Pecheanu, E., & Munteanu, D. (2019). Unobtrusive monitoring the daily activity routine of elderly people living alone, with low-cost binary sensors. *Sensors*, *19*(10), 2264.

Tabbarah, M., Silverstein, M., & Seeman, T. (2000). A health and demographic profile of noninstitutionalized older Americans residing in environments with home modifications. *Journal of Aging and Health*, *12*(2), 204-228.

Vocational Rehabilitation Amendments of 1954, Pub. L. No. 83-565 (1954).

Wallace, C. J., Liberman, R. P., Tauber, R., & Wallace, J. (2000). The independent living skills survey: a comprehensive measure of the community functioning of severely and persistently mentally ill individuals. *Schizophrenia Bulletin*, *26*(3), 631-658.

Wallace, C. J., Lecomte, T., Wilde, J., & Liberman, R. P. (2001). CASIG: A consumer-centered assessment for planning individualized treatment and evaluating program outcomes. *Schizophrenia Research*, *50*(1-2), 105-119.

White, G. W., Paine-Andrews, A., Mathews, R. M., & Fawcett, S. B. (1995). Home access modifications: Effects on community visits by people with mobility impairments. *Journal of Applied Behavior Analysis*, *28*(4), 457-463.

White, G. W., Lloyd Simpson, J., Gonda, C., Ravesloot, C., & Coble, Z. (2010). Moving from independence to interdependence: A conceptual model for better understanding community participation of centers for independent living consumers. *Journal of Disability Policy Studies*, *20*(4), 233-240.

Wilson, D. J., Mitchell, J. M., Kemp, B. J., Adkins, R. H., & Mann, W. (2009). Effects of assistive technology on functional decline in people aging with a disability. *Assistive Technology*, *21*(4), 208-217.

World Health Organization (2001). International Classification of Functioning, Disability, and Health (ICF). Geneva: World Health Organization.

Table 1

Demographic characteristics of study participants with mobility impairments

Demographic variables	Study Participants ($N = 210$)[a]	Control Group ($n = 87$)	Intervention Group ($n = 75$)	p-value[b]
Age, mean (SD)[c]	53.73 (13.61)	55.46 (13.66)	52.37 (12.75)	0.147
Gender, %				
Female	62.9	60.9	67.6	0.387
Race, %[d]				
American Indian/Alaska Native	7.6	8.0	5.6	0.556
Asian	0.5	1.2	0.0	0.365
Black/African American	17.8	17.2	16.9	0.955
White	74.6	75.9	76.1	0.978
Other	4.1	2.3	4.2	0.495
Ethnicity, %				
Hispanic/Latino	4.1	1.2	4.2	0.233
Employment, %				
Employed full time	5.6	8.0	5.6	0.556
Employed part time	14.8	16.1	14.1	0.729
Unemployed	79.6	75.9	80.3	0.509
Annual household income, %				
≤ $10,000	40.8	42.4	38.2	0.609
$10,001 to $20,000	26.7	24.7	26.5	0.805
$20,001 to $30,000	8.4	5.9	10.3	0.316
$30,001 to $40,000	7.3	11.8	5.9	0.212
$40,001 to $50,000	6.3	5.9	8.8	0.487
$50,001 to $60,000	1.0	1.2	1.5	0.875
$60,001 to $70,000	2.1	3.5	1.5	0.431
$70,001 to $80,000	1.6	1.2	0.0	0.373
$80,001 to $90,000	1.0	1.2	0.0	0.373
$90,001 to $100,000	0.5	0.0	0.0	1.000
> $100,000	4.2	2.4	7.4	0.143

(*table continues*)

Demographic variables	Study Participants ($N = 210$)[a]	Control Group ($n = 87$)	Intervention Group ($n = 75$)	p-value[b]
Mobility aid, %[e]				
No mobility aid	19.5	23.0	15.9	0.276
Other people	31.8	26.4	37.7	0.135
Walker	23.0	20.7	22.9	0.745
Cane/walking stick	37.8	36.8	45.7	0.260
Crutch/crutches	2.0	1.1	1.4	0.878
Service animal	1.5	2.3	1.4	0.703
Manual wheelchair	18.9	17.2	21.4	0.510
Power wheelchair	19.9	20.7	20.0	0.916
Scooter	4.6	6.9	4.3	0.487
Brace	11.7	12.6	7.1	0.260
Artificial limb	1.5	2.3	0.0	0.207
Oxygen/breathing equipment	4.6	4.6	2.9	0.575
Other	11.2	10.3	15.7	0.319

SD = Standard deviation

[a] 48 participants were not assigned to the intervention or control groups if they became ineligible, deceased, withdrew, or declined the intervention after the administration of the pre-survey.

[b] Analyzed by unpaired *t*-test.

[c] Participant age ranged from 18 to 94 years.

[d] Participants were able to report all races that were applicable to them.

[e] Participants were able to report more than one type of mobility aid.

Table 2

Comparative analysis of community and home participation between control group and intervention group participants

	Control Group (n = 67)				Intervention Group (n = 59)				
Outcome measures	Pre	Post	Change scores (post-pre)[a]	Abs. change scores[b]	Pre	Post	Change scores (post-pre)[a]	Abs. change scores[b]	p-value[c]
Community Participation[d]	18.93	18.11	-0.82	10.46	20.75	21.23	0.48	10.12	0.873
Home Participation[e]									
Bathroom	65.59	69.26	3.67	15.53	64.59	68.46	3.87	12.58	0.285
Living Room	61.51	66.20	4.69*	12.68	61.12	60.85	-0.27	14.01	0.651
Bedroom	54.94	58.99	4.05	14.84	58.83	64.25	5.42*	13.56	0.636
Kitchen	52.79	58.31	5.53*	14.37	59.42	58.65	-0.77	13.01	0.641
Dining Room	20.34	23.44	3.09	12.59	26.64	28.05	1.41	13.28	0.827
Spare Room	7.02	7.00	-0.02	5.81	8.93	8.17	-0.77	5.11	0.719
Upstairs	4.17	5.13	0.95	3.11	6.35	5.96	-0.38	3.83	0.632
Basement	3.22	3.04	-0.17	2.13	1.27	1.51	0.24	1.14	0.207
Garage	5.94	4.84	-1.10	3.35	4.87	5.31	0.44	3.14	0.859
Porch/Balcony	6.13	8.92	2.80*	6.34	11.45	14.36	2.91	9.31	0.193
Yard	7.92	8.77	0.86	6.82	9.85	11.84	1.98	10.47	0.143

[a] Analyzed by paired t-test.

[b] Within group change scores calculated using absolute value.

[c] Analyzed by unpaired t-test using absolute value change scores.

[d] To measure community participation, participants answered daily smartphone surveys that asked, "Where are you?" Community participation was calculated as a percentage by dividing the total number of responses indicated as being present in the community by the total number of responses indicated as being present in the home or in the community.

[e] If participants reported being at home, they were asked the question: "Since the last prompt, where in your home have you been?" Home participation variables were calculated as a percentage by dividing the total number of responses indicated as having visited a specified area of interest (e.g., bathroom) by the total number of responses indicated as having visited or having not visited the specified area of interest since the last survey prompt.

* Change scores (post-pre) were statistically significant ($p < 0.05$).

Table 3

Comparative analysis of community and home participation between control group and bathroom intervention group participants

	Control Group (n = 67)				Bathroom Intervention Group (n = 22)				
Outcome measures	Pre	Post	Change scores (post-pre)[a]	Abs. change scores[b]	Pre	Post	Change scores (post-pre)[a]	Abs. change scores[b]	p-value[c]
Community Participation[d]	18.93	18.11	-0.82	10.46	16.75	15.45	1.30	11.31	0.738
Home Participation[e]									
Bathroom	65.59	69.26	3.67	15.53	74.15	73.42	0.73	13.37	0.604
Living Room	61.51	66.20	4.69*	12.68	68.61	69.26	-0.65	11.48	0.740
Bedroom	54.94	58.99	4.05	14.84	59.98	60.20	-0.21	9.78	0.175
Kitchen	52.79	58.31	5.53*	14.37	63.75	63.39	0.36	12.56	0.643
Dining Room	20.34	23.44	3.09	12.59	20.75	20.90	-0.16	17.40	0.299
Spare Room	7.02	7.00	-0.02	5.81	10.52	10.23	0.29	4.09	0.527
Upstairs	4.17	5.13	0.95	3.11	11.31	9.20	2.10	5.36	0.325
Basement	3.22	3.04	-0.17	2.13	0.53	0.24	0.28	0.58	0.195
Garage	5.94	4.84	-1.10	3.35	3.74	1.99	1.75	3.26	0.957
Porch/Balcony	6.13	8.92	2.80*	6.34	18.98	19.20	-0.22	11.50	0.107
Yard	7.92	8.77	0.86	6.82	14.70	9.27	5.42	10.73	0.267

[a] Analyzed by paired t-test.

[b] Within group change scores calculated using absolute value.

[c] Analyzed by unpaired t-test using absolute value change scores.

[d] To measure community participation, participants answered daily smartphone surveys that asked, "Where are you?" Community participation was calculated as a percentage by dividing the total number of responses indicated as being present in the community by the total number of responses indicated as being present in the home or in the community.

[e] If participants reported being at home, they were asked the question: "Since the last prompt, where in your home have you been?" Home participation variables were calculated as a percentage by dividing the total number of responses indicated as having visited a specified area of interest (e.g., bathroom) by the total number of responses indicated as having visited or having not visited the specified area of interest since the last survey prompt.

* Change scores (post-pre) were statistically significant ($p < 0.05$)

Table 4

Comparative analysis of perceptions of home safety between control group and intervention group participants

	Control Group (n = 80)			Intervention Group (n = 70)			
Home Safety Measure[a]	Pre	Post	Change scores (post-pre)[b]	Pre	Post	Change scores (post-pre)[b]	p-value[c]
Entrance	3.99	4.10	0.11	4.03	4.30	0.27	0.351
Kitchen	3.82	3.75	-0.08	3.86	3.79	-0.06	0.936
Toilet	3.97	4.12	0.14	4.22	4.23	0.02	0.409
Shower	3.46	3.64	0.18	3.48	3.75	0.27	0.624
Living Room	4.39	4.31	-0.07	4.40	4.48	0.08	0.264
Storage	3.82	3.87	0.05	3.80	3.73	-0.06	0.477
Bedroom	4.13	4.20	0.08	4.10	4.27	0.17	0.566
Cleaning	3.44	3.48	0.04	3.53	3.53	0.00	0.831

[a] Analyzed on a five-point Likert-type scale from 1 *Not at all safe* to 5 *Very much safe*.

[b] Analyzed by paired t-test; no within group change scores (post-pre) were statistically significant (p-value < 0.05).

[c] Analyzed by unpaired t-test.

Table 5

Comparative analysis of perceptions of home safety between control group and bathroom intervention group participants

	Control Group (n = 80)			Bathroom Intervention Group (n = 25)			
Home Safety Measure[a]	Pre	Post	Change scores (post-pre)[b]	Pre	Post	Change scores (post-pre)[b]	p-value[c]
Entrance	3.99	4.10	0.11	3.73	3.95	0.23	0.620
Kitchen	3.82	3.75	-0.08	3.78	3.70	-0.09	0.962
Toilet	3.97	4.12	0.14	4.17	4.39	0.22	0.730
Shower	3.46	3.64	0.18	3.17	3.65	0.48	0.237
Living Room	4.39	4.31	-0.07	4.26	4.52	0.26	0.100
Storage	3.82	3.87	0.05	3.78	3.52	-0.26	0.171
Bedroom	4.13	4.20	0.08	3.87	4.26	0.39	0.153
Cleaning	3.44	3.48	0.04	3.43	3.30	-0.13	0.499

[a] Analyzed on a five-point Likert-type scale from 1 *Not at all safe* to 5 *Very much safe*.

[b] Analyzed by paired t-test; no within group change scores (post-pre) were statistically significant (p-value < 0.05).

[c] Analyzed by unpaired t-test.

Table 6

Comparative analysis of community and home participation (pre-test) based on home characteristics and perceptions of home safety

	Community[a]		Bathroom[b]		Living Room[b]		Bedroom[b]		Kitchen[b]	
	Mean	*p*-value[c]	Mean	*p*-value[c]	Mean	*p*-value[c]	Mean	*p*-value[c]	Mean	*p*-value[c]
Home characteristics (*n*)										
Stepped entrance (73)	19.65	0.869								
No-step entrance (84)	19.20									
No toilet grab bars (91)			55.10	0.056						
Toilet grab bars (66)			68.32							
No bath bars (68)			60.78	0.135						
Bath bars (89)			69.25							
Inadequate living room light (25)					53.05	0.142				
Adequate living room light (129)					62.78					
Inappropriate bed height (14)							46.80	0.155		
Appropriate bed height (90)							58.80			
Inadequate kitchen light (24)									37.14	0.004**
Adequate kitchen light (75)									58.15	
Personal factors[d] (*n*)										
Not safe entering home (60)	16.47	0.049*								
Safe entering home (128)	21.55									
Not safe using toilet (40)			66.66	0.947						
Safe using toilet (147)			66.33							
Not safe bathing (88)			68.21	0.412						
Safe bathing (101)			64.84							
Not safe using living room (26)					57.39	0.074				
Safe using living room (162)					62.91					
Not safe using bedroom (43)							46.34	0.011**		
Safe using bedroom (145)							59.08			
Not safe using kitchen (61)									45.66	0.001***
Safe using kitchen (125)									60.65	

[a] To measure community participation, participants answered daily smartphone surveys that asked, “Where are you?” Community participation was calculated as a percentage by dividing the total number of responses indicated as being present in the community by the total number of responses indicated as being present in the home or in the community.
[b] If participants reported being at home, they were asked the question: “Since the last prompt, where in your home have you been?” Home participation variables were calculated as a percentage by dividing the total number of responses indicated as having visited a specified area of interest (e.g., bathroom) by the total number of responses indicated as having visited or having not visited the specified area of interest since the last survey prompt.
[c] Analyzed by unpaired *t*-test.
[d] Home Safety Measure analyzed on a five-point Likert-type scale from 1 *Not at all safe* to 5 *Very much safe*. Not safe represents scores 1, 2, & 3 and Safe represents scores 4 & 5.
* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

Table 7

Comparative analysis of community and home participation (pre-test) based on assistive technology use

Outcome measure	No Mobility Aid (n = 58)	Mobility Aid[a] (n = 133)	p-value[b]	No Wheelchair (n = 127)	Wheelchair[c] (n = 64)	p-value[b]
Community Participation[d]	22.00	18.99	0.263	20.40	18.72	0.510
Home Participation[e]						
Bathroom	56.57	69.73	0.004**	65.67	66.89	0.781
Living Room	58.61	62.71	0.402	60.76	62.78	0.665
Bedroom	47.41	59.05	0.013*	55.86	55.08	0.861
Kitchen	51.28	56.17	0.313	54.24	56.23	0.666
Dining Room	19.51	22.61	0.495	20.94	23.03	0.628
Spare Room	5.49	8.09	0.333	7.89	6.15	0.495
Upstairs	4.39	5.55	0.638	6.19	3.23	0.206
Basement	4.61	2.00	0.067	3.94	0.38	0.008**
Garage	4.17	4.40	0.905	3.98	4.94	0.594
Porch/Balcony	5.95	8.90	0.250	9.79	5.04	0.052
Yard	8.20	8.35	0.956	9.58	5.99	0.162

[a] Includes walker, cane/walking stick, crutch/crutches, manual wheelchair, power wheelchair, scooter, brace, and artificial limb categorizations.

[b] Analyzed by unpaired t-test.

[c] Includes manual wheelchair, power wheelchair, and scooter categorizations.

[d] To measure community participation, participants answered daily smartphone surveys that asked, "Where are you?" Community participation was calculated as a percentage by dividing the total number of responses indicated as being present in the community by the total number of responses indicated as being present in the home or in the community.

[e] If participants reported being at home, they were asked the question: "Since the last prompt, where in your home have you been?" Home participation variables were calculated as a percentage by dividing the total number of responses indicated as having visited a specified area of interest (e.g., bathroom) by the total number of responses indicated as having visited or having not visited the specified area of interest since the last survey prompt.

* $p < 0.05$; ** $p < 0.01$

Appendix A

Demographics Form

1. What is your age? _____

2. What is your sex? (check one)
□ Male
□ Female

3. What is your race? (check all that apply)
□ American Indian/Alaskan Native
□ Asian
□ Black/African American
□ Native Hawaiian/Pacific Islander
□ White
□ Other: _____

4. Are you Hispanic/Latino?
□ Yes
□ No

5. What is your current employment status? (check one)
□ Employed full time with pay (30 hours per week or more)
□ Employed part time with pay (29 hours per week or less)
□ Not employed

6. What is your annual household income, including personal income, spouse or partner's income, as well as other income sources like interest, retirement, or social security payments? (check one)

□ $10,000 or less
□ $10,001 to $20,000
□ $20,001 to $30,000
□ $30,001 to $40,000
□ $40,001 to $50,000
□ $50,001 to $60,000
□ $60,001 to $70,000
□ $70,001 to $80,000
□ $80,001 to $90,000
□ $90,001 to $100,000
□ More than $100,000

Appendix B

Home Safety Measure					
Please rate how safe you feel doing things in your home.					
	Not at all 1	**A little 2**	**Somewhat 3**	**Quite a bit 4**	**Very much 5**
How safe do you feel when entering and exiting your home?	○	○	○	○	○
How safe do you feel preparing a meal in your home/kitchen?	○	○	○	○	○
How safe do you feel using your toilet?	○	○	○	○	○
How safe do you feel using your shower/tub to bathe?	○	○	○	○	○
How safe do you feel using your living room/space?	○	○	○	○	○
How safe do you feel using storage places like closets and cupboards?	○	○	○	○	○
How safe do you feel using your bedroom for dressing or getting ready for bed?	○	○	○	○	○
How safe do you feel when cleaning and tidying up around your home?	○	○	○	○	○

Appendix C

Assistive Technology Use Measure	
When going out into the community, which types of special equipment or help from others do you use? (check all that apply)	
□ No special equipment or help used □ Other people □ Walker □ Cane or walking stick □ Crutch or crutches □ Service animal such as a guide dog □ Manual wheelchair	□ Power wheelchair □ Scooter □ Brace □ Artificial limb □ Oxygen or breathing equipment □ Other (specify): _____

Appendix D

Home Characteristics Survey
1. Is it possible to enter your home WITHOUT climbing up or down any steps or stairs? Please consider all entrances and any ramps that could be used. (*Check one*) □ Yes □ No
2. Thinking about the pathway from the street to the home entrance you use the most, are there any of the following? (*Check all that apply*) □ Curbs □ Uneven pathway (*such as cracked pavement, no sidewalk, sloped/rough/slick ground surface*) □ Blocked pathway (*such as path blocked by telephone pole, tree, dumpster, debris, etc*.) □ Manual doors or gates (*such as no automatic door/gate opener*) □ Inadequate lighting (*such as no porch or street lamps*) □ No place to rest (*such as no sitting area to pause to rest*)
3. Thinking about all entrances to your home, how many entrances are there? (*Enter a number*)
You will be asked questions 3a-3c for each entrance you indicate in this response.
3a. How many steps/stairs are there to enter your home at entrance #? (*Enter a number*)
If your response is more than 0, you will be asked: Do these steps have handrails? □ Yes □ No
3b. Is there inadequate lighting at entrance #? □ Yes □ No
3c. Is this the entrance you use the most to go out into your community (*such as for shopping, medical appointments, etc*.)? □ Yes □ No
4. Thinking about your kitchen, do you have any of the following? (Check all that apply) □ Inadequate lighting □ Uneven or slippery flooring (*such as rugs or slick tile*) □ Round knobs on the sink/faucet □ Stovetop with controls on the back panel (*any kitchen appliance that forces you to reach over a hot surface*)
5. Thinking about the bathroom you use the most for toileting, are there grab bars around the toilet? (*Check one*) □ Yes □ No
If you answer "no," you will be asked 5a.
5a. Do you need or want grab bars? □ Yes □ No

6. Again, thinking about the bathroom you use the most for toileting, are there any of the following? (*Check all that apply*)
□ Stairs (*such as along the pathway to the bathroom*)
□ Door with a round knob
□ Inadequate lighting
□ Uneven or slippery flooring (*such as bathmats or slick tile*)
□ Round knobs on the sink/faucet
□ Cluttered space (*that makes it difficult to move around*)

7. Thinking about the bathroom you use the most for bathing, are there grab bars around the shower/tub? (*Check one*)
□ Yes
□ No

If you answer "no," you will be asked 7a.

7a. If no, do you need or want grab bars?
□ Yes
□ No

8. Which do you use the most often for bathing? (*Check one*)
□ Bathtub with a shower
□ Walk-in shower
□ Sink

9. Again, thinking about the bathroom you use the most for bathing, are there any of the following? (*Check all that apply*)
□ Stairs (*such as along the pathway to the bathroom*)
□ Door with a round knob
□ Inadequate lighting
□ Uneven or slippery flooring (*such as bathmats or slick tile*)
□ Round knobs on the sink/faucet
□ Round knobs on the shower/tub faucet
□ Cluttered space (*that makes it difficult to move around*)

10. Thinking about your bedroom, do you have any of the following? (*Check all that apply*)
□ Door with a round knob
□ Inadequate lighting
□ Uneven flooring
□ Cluttered space (*that makes it difficult to move around*)
□ Inappropriate bed height (*either too low or too high to transfer*)

11. Thinking about your main living areas, how many steps/stairs are there to access these main living areas? (*Enter a number*)

If your answer is greater than 0, you will be asked question 11a.

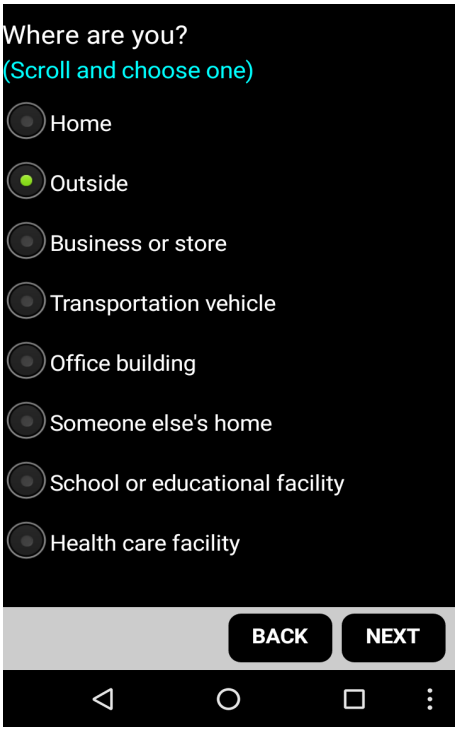
11a. Do these steps have handrails?
□ Yes
□ No

11b. Is there adequate lighting?
□ Yes
□ No

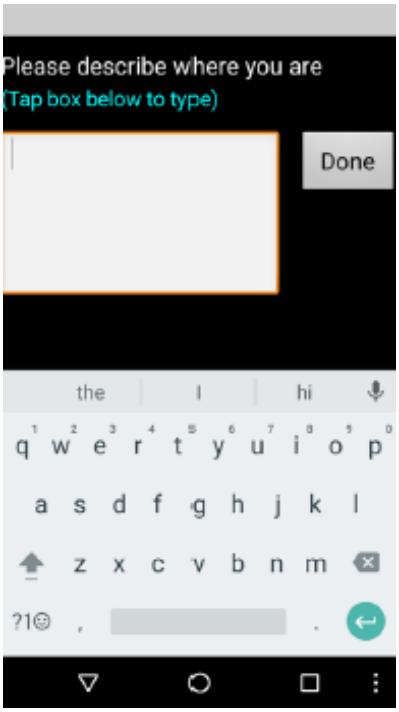
Appendix E

Question: Where are you?
(*Scroll and choose one*)

Home
Outside (*such as parking lot, sidewalk, forest, park, outdoor recreation complex*)
Business or store (*such as a grocery store, shopping mall, laundromat, hair dresser*)
Transportation vehicle (*defined as private, public*)
Office building (*defined as government, private*)
Someone else's home
School or educational facility
Healthcare facility (*such as hospital, doctor's office, rehabilitation facility*)
Restaurant or bar
Church or religious facility
Gym or exercise facility
Venue (*such as movies, theater, museum, or sports arena*)
Other



If you selected "other," this screen will appear:
Question: Please describe where you are.
(*Tap box below to type*)



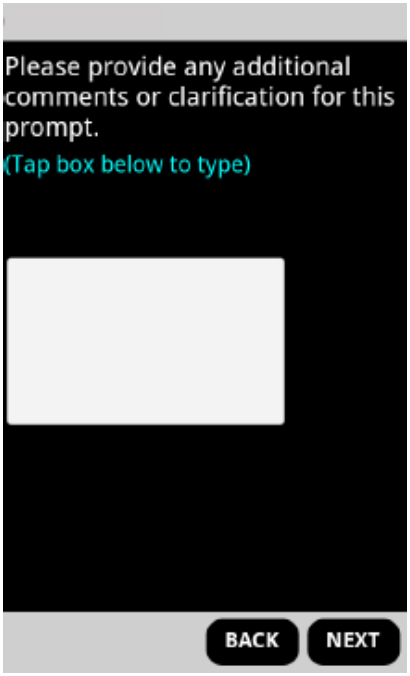
Appendix F

Question: Since the last prompt, where in your home have you been?
(*Scroll and check all that apply*)

<u>You will only be asked this question when you indicate that you are at home.</u>

Bathroom
Living room/family room
Bedroom
Kitchen
Dining room
Spare room (*such as a guest bedroom or office*)
Upstairs
Basement
Garage
Porch/balcony
Yard (front or back)
Other

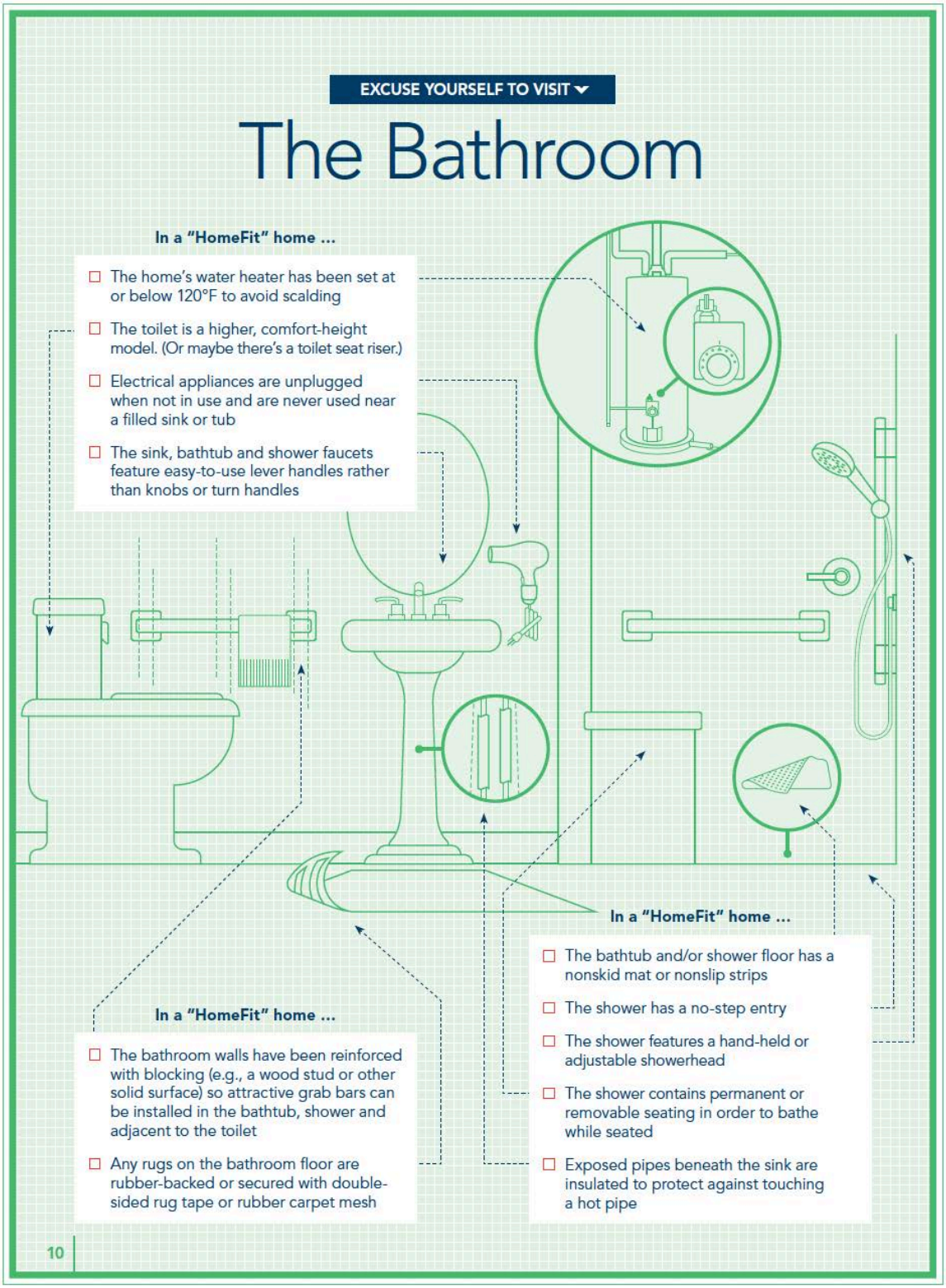
If you selected "other," this screen will appear:
Question: Please provide any additional comments or clarification for this prompt.
(*Tap box below to type*)



Appendix G

How Usable is My Home? Questionnaire					
Please rate how satisfied you are with doing things in your home.					
	Not at all	**A little bit**	**Somewhat**	**Quite a bit**	**Very much**
1. How satisfied are you with your ability to enter and exit your home?	○	○	○	○	○
2. How satisfied are you with your ability to prepare a meal in your home/kitchen?	○	○	○	○	○
3. How satisfied are you with your ability to use your toilet?	○	○	○	○	○
4. How satisfied are you with your ability to use your shower/tub to bathe?	○	○	○	○	○
5. How satisfied are you with your ability to use your living room?	○	○	○	○	○
6. How satisfied are you with your ability to use your storage places like closets and cupboards?	○	○	○	○	○
7. How satisfied are you with your ability to use your bedroom for dressing and going to bed?	○	○	○	○	○
8. How satisfied are you with your ability to clean and tidy up your home?	○	○	○	○	○
9. How satisfied are you with your ability to participate in your community?	○	○	○	○	○

Appendix H


EXCUSE YOURSELF TO VISIT
The Bathroom
In a "HomeFit" home ...
☐ The home's water heater has been set at or below 120°F to avoid scalding
☐ The toilet is a higher, comfort-height model. (Or maybe there's a toilet seat riser.)
☐ Electrical appliances are unplugged when not in use and are never used near a filled sink or tub
☐ The sink, bathtub and shower faucets feature easy-to-use lever handles rather than knobs or turn handles
In a "HomeFit" home ...
☐ The bathtub and/or shower floor has a nonskid mat or nonslip strips
☐ The shower has a no-step entry
☐ The shower features a hand-held or adjustable showerhead
☐ The shower contains permanent or removable seating in order to bathe while seated
☐ Exposed pipes beneath the sink are insulated to protect against touching a hot pipe
In a "HomeFit" home ...
☐ The bathroom walls have been reinforced with blocking (e.g., a wood stud or other solid surface) so attractive grab bars can be installed in the bathtub, shower and adjacent to the toilet
☐ Any rugs on the bathroom floor are rubber-backed or secured with double-sided rug tape or rubber carpet mesh
10

NOW GET COOKING IN

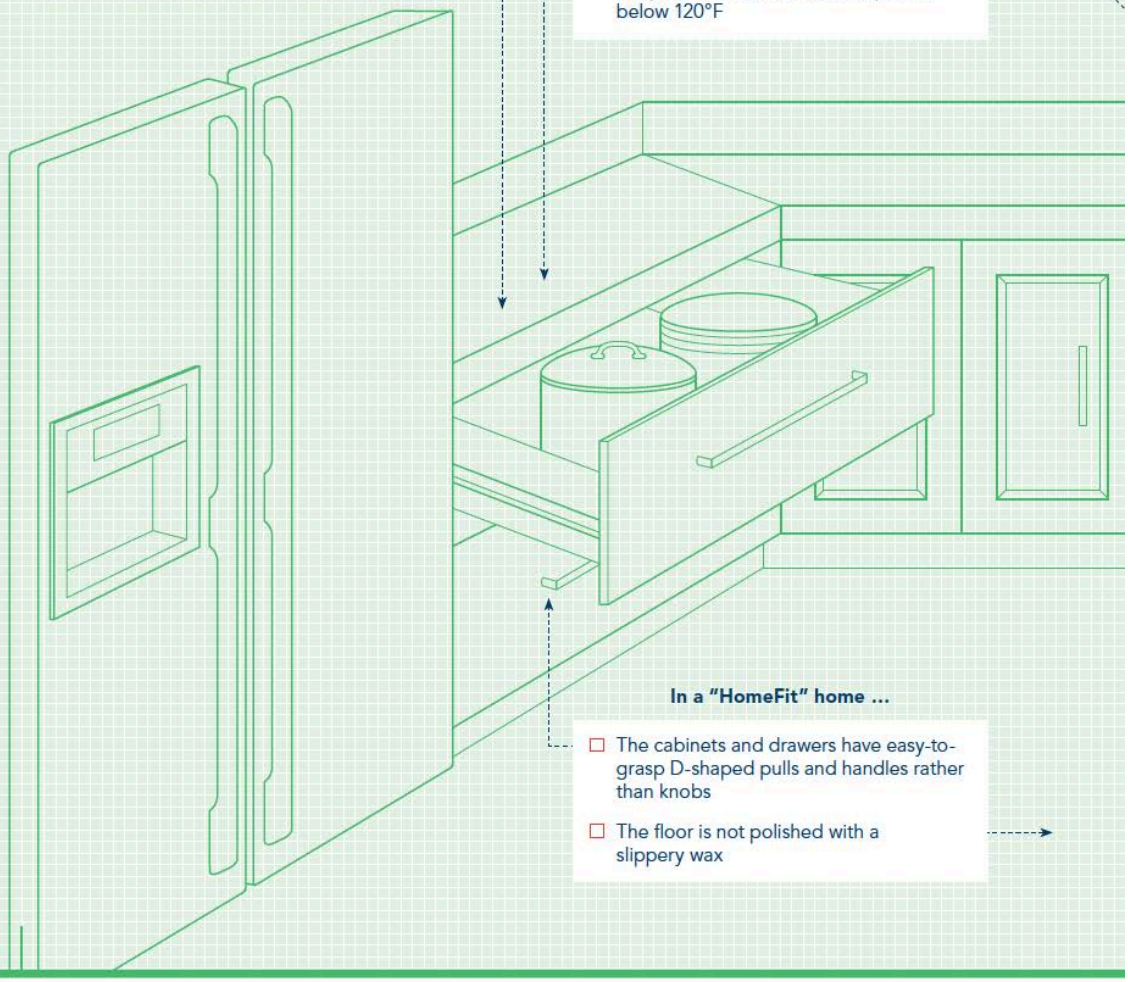
The Kitchen

In a "HomeFit" home ...

- ☐ The cabinetry is easy to access
- ☐ There's pull-out cabinetry or shelves beneath counters and Lazy Susans in corner cabinets

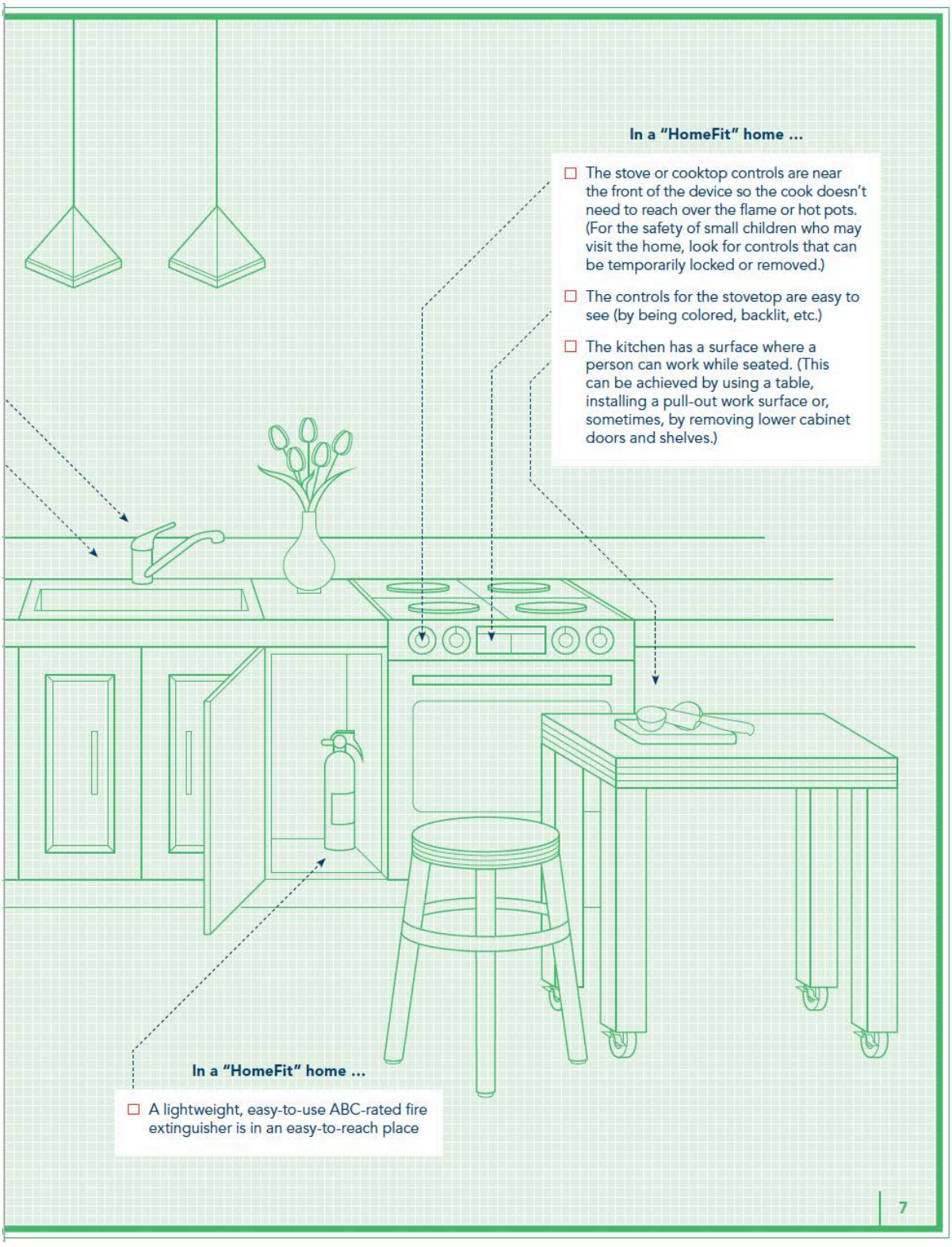
In a "HomeFit" home ...

- ☐ There's suitable task lighting for the sink, stove and other work areas
- ☐ The kitchen has a lever-, touch- or sensor-style faucet rather than one with turn-style knobs or handles
- ☐ The sink faucet is pressure-balanced, temperature-regulated and kept at or below 120°F



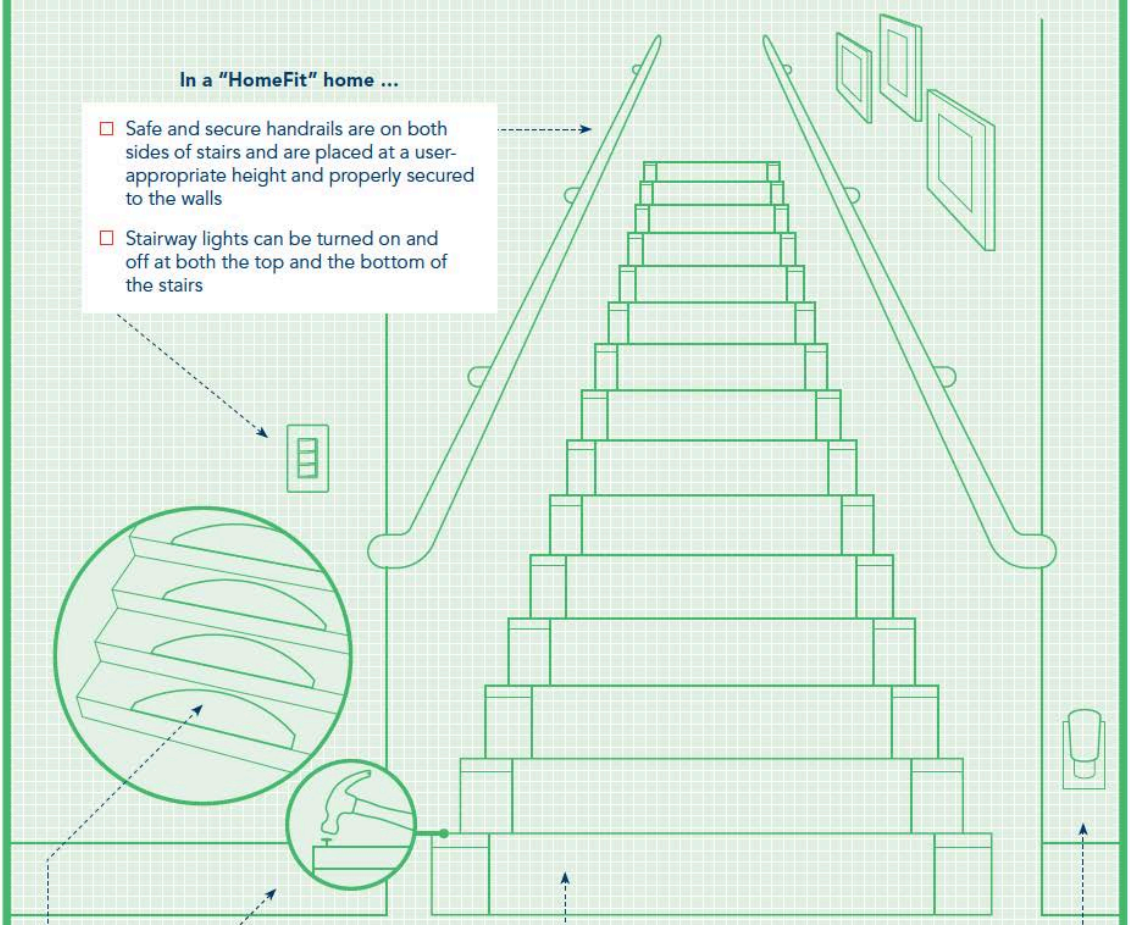
In a "HomeFit" home ...

- ☐ The cabinets and drawers have easy-to-grasp D-shaped pulls and handles rather than knobs
- ☐ The floor is not polished with a slippery wax


In a "HomeFit" home ...
☐ The stove or cooktop controls are near the front of the device so the cook doesn't need to reach over the flame or hot pots. (For the safety of small children who may visit the home, look for controls that can be temporarily locked or removed.)
☐ The controls for the stovetop are easy to see (by being colored, backlit, etc.)
☐ The kitchen has a surface where a person can work while seated. (This can be achieved by using a table, installing a pull-out work surface or, sometimes, by removing lower cabinet doors and shelves.)
In a "HomeFit" home ...
☐ A lightweight, easy-to-use ABC-rated fire extinguisher is in an easy-to-reach place
7

THEN GO TO THE

Steps and Stairways



In a "HomeFit" home ...

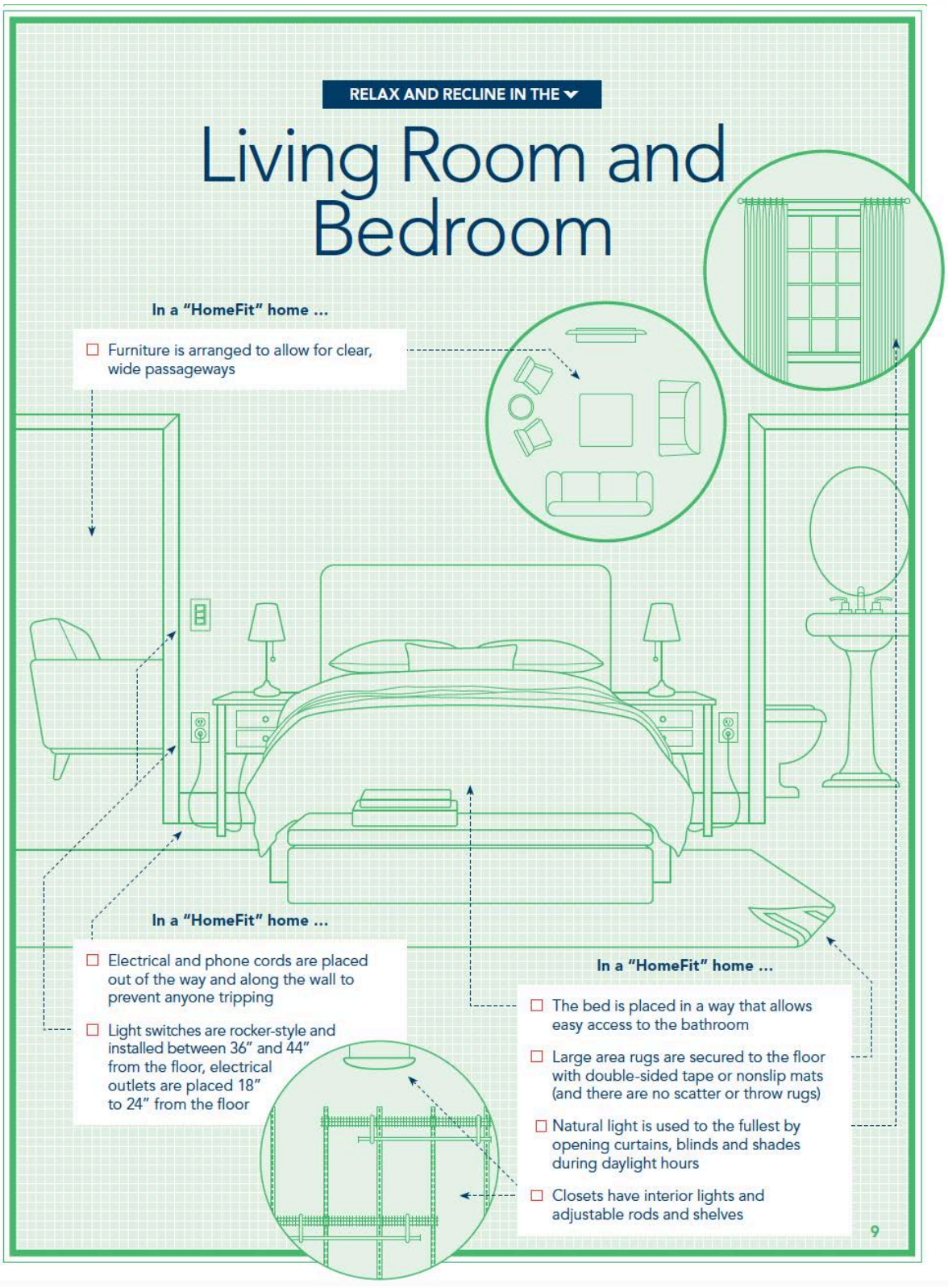
- ☐ Safe and secure handrails are on both sides of stairs and are placed at a user-appropriate height and properly secured to the walls
- ☐ Stairway lights can be turned on and off at both the top and the bottom of the stairs

In a "HomeFit" home ...

- ☐ Automatic night-lights are plugged into outlets near steps and staircases
- ☐ All stairs are clear of clutter
- ☐ Carpeted steps feature a tightly placed, woven low-pile carpet with thin padding. (If the carpet is patterned, the pattern isn't so busy that it makes the steps difficult to see.)

In a "HomeFit" home ...

- ☐ Exterior and interior stair treads are in good condition with no weak or missing steps, loose bricks, raised nail heads, open backs, etc.
- ☐ Uncarpeted steps feature a nonslip surface such as adhesive strips

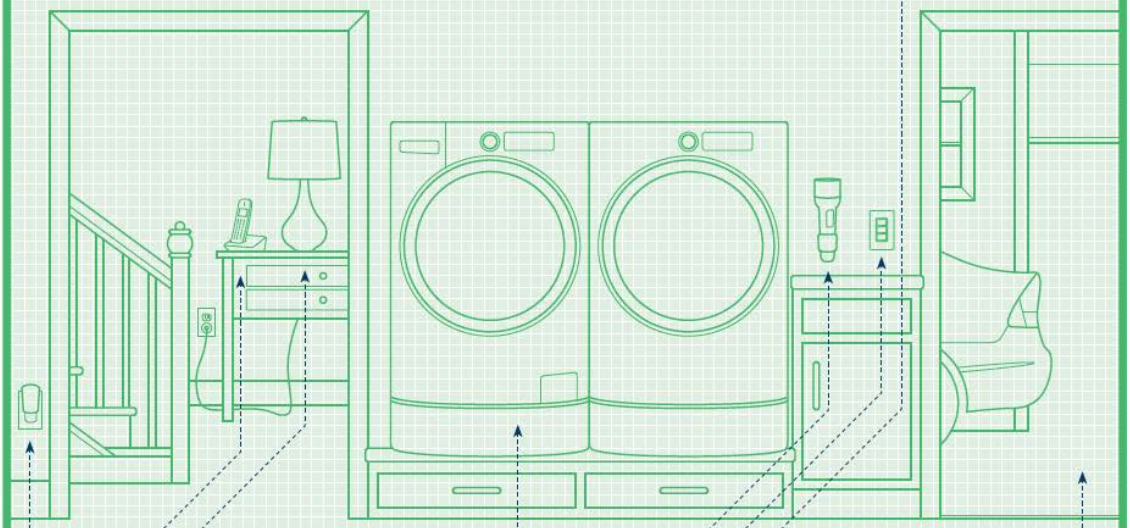

RELAX AND RECLINE IN THE
Living Room and Bedroom
In a "HomeFit" home ...
☐ Furniture is arranged to allow for clear, wide passageways
In a "HomeFit" home ...
☐ Electrical and phone cords are placed out of the way and along the wall to prevent anyone tripping
☐ Light switches are rocker-style and installed between 36" and 44" from the floor, electrical outlets are placed 18" to 24" from the floor
In a "HomeFit" home ...
☐ The bed is placed in a way that allows easy access to the bathroom
☐ Large area rugs are secured to the floor with double-sided tape or nonslip mats (and there are no scatter or throw rugs)
☐ Natural light is used to the fullest by opening curtains, blinds and shades during daylight hours
☐ Closets have interior lights and adjustable rods and shelves
9

AND STAY SAFE

Elsewhere and Throughout the Home

In a "HomeFit" home ...

- ☐ Light bulbs are properly rated for the fixtures they are in and are of the highest allowed wattage



In a "HomeFit" home ...

- ☐ The home contains some touch control lamps and devices that automatically turn lights on and off at set times
- ☐ The laundry area features an easier-to-use front-loading washer, and the washer and dryer sit on raised platforms
- ☐ A telephone is available in or near multiple rooms (including the bedroom and bathroom)
- ☐ Automatic plug-in night-lights are placed in hallways, bathrooms and near steps

In a "HomeFit" home ...

- ☐ Smoke and carbon monoxide detectors are installed on every floor and can be heard in all bedrooms
- ☐ Traditional toggle light switches have been replaced with easier-to-use rocker panel switches
- ☐ Flashlights are kept in multiple rooms (in case of a power failure)
- ☐ There is at least one step-free entrance into the home

Appendix I

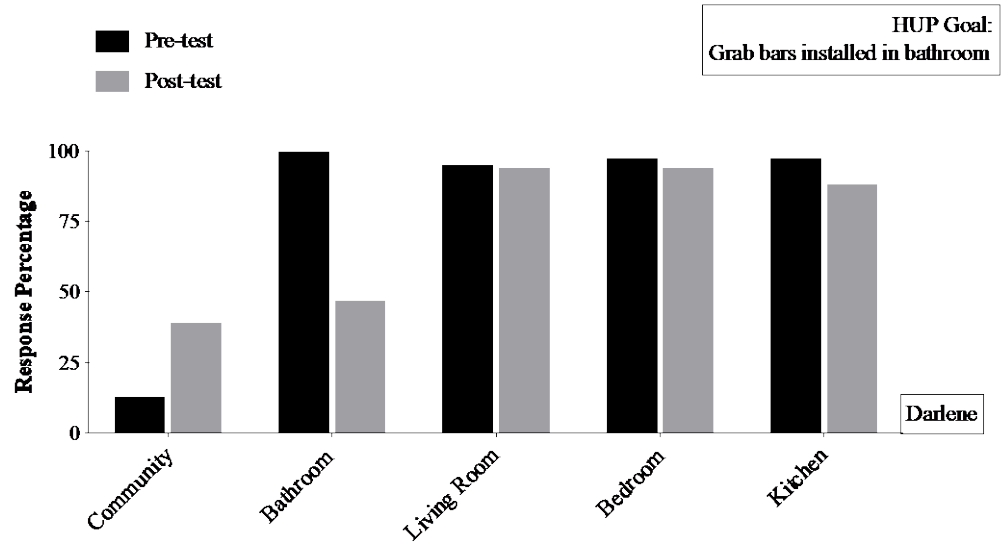
<table>
<tr><td colspan="6">$N = 210$
Table 1. Demographics of total study participants</td></tr>
<tr><td colspan="2">$n = 126$
Table 2. Participants who completed pre- and post-EMA measures</td><td colspan="2">$n = 150$
Table 4. Participants who completed the pre- and post-Home & Community Survey</td><td>$n = 157$
Table 6.
Participants who completed the Home Characteristics Survey and pre-EMA measures</td><td>$n = 191$
Tables 6 & 7.
Participants who completed the pre- Home & Community Survey and pre-EMA measures</td></tr>
<tr><td>$n = 67$
Control Group</td><td>$n = 59$
Intervention Group</td><td>$n = 80$
Control Group</td><td>$n = 70$
Intervention Group</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td></td><td>$n = 22$
Table 3.
Bathroom Intervention Group</td><td></td><td>$n = 25$
Table 5.
Bathroom Intervention Group</td></tr>
</table>

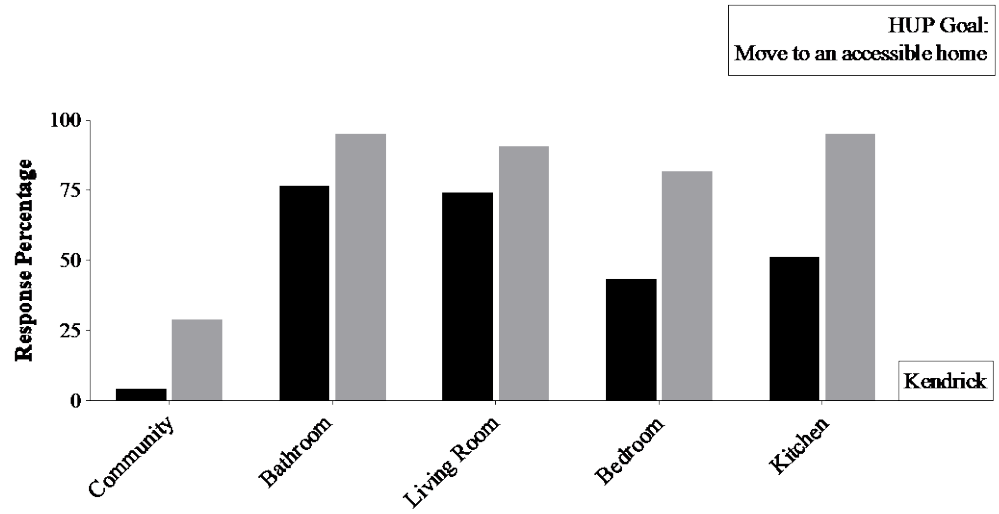
Appendix J

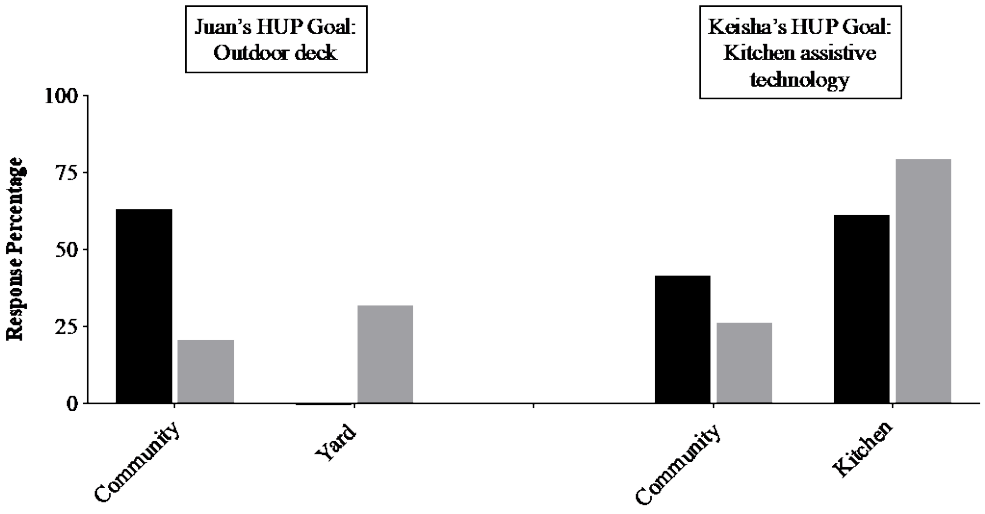
Category Type	Type of Home Modification Implemented	*n*
Assistive Technology		**10**
	Reacher tool	4
	Walker	2
	Long-handled shoehorn	1
	Seizure response watch	1
	Shoes	1
	Transfer board	1
Bathroom		**30**
	Shower chair/transfer bench	10
	Grab bars	5
	Hand-held showerhead	5
	Lever doorknobs	2
	Bathtub safety rail	1
	Lever sink faucet	1
	Non-slip bathmat	1
	Pedestal sink	1
	Raised toilet seat	1
	Showerhead holder	1
	Stackable bath steps	1
	Toilet safety frame	1
Bedroom		**10**
	Mattress topper	3
	Bedrail	2
	Mattress	2
	Bedroom chair	1
	Bedside tables	1
	Heated blanket	1
Cleaning and Storage		**13**
	Robot vacuum	6
	Organization and clutter removal	5
	Long-handled duster brush	2
Entrance		**13**
	Security camera/video doorbell	3
	Electronic lock for front door	2
	Front-entrance handrails	2
	Door threshold leveling	1
	Garage door repair	1
	Gutter repair	1
	Paved walkway	1
	Ramp	1
	Deck installation	1

Kitchen		**11**
	Cutting board	3
	Cut resistant gloves	1
	Freezer	1
	Jar opener	1
	Knife safety guard	1
	Mandoline slicer	1
	Palm peeler	1
	Rocking knife	1
	Table leg extensions/raised table	1
Living Room		**6**
	Couch	2
	Recliner with lift	2
	Lamp	1
	Seat cushions	1
Moving to New Home		**3**
	Deposit support for new apartment	3
Other		**9**
	Fire extinguisher	2
	Desk	1
	Exercise bike	1
	Refinished floors	1
	Repainted walls	1
	Shopping cart	1
	Space heater	1
	Smart thermostat	1

Appendix K


Pre-test
Post-test
HUP Goal:
Grab bars installed in bathroom
Response Percentage
100
75
50
25
0
Darlene
Community
Bathroom
Living Room
Bedroom
Kitchen


HUP Goal:
Move to an accessible home
Response Percentage
100
75
50
25
0
Kendrick
Community
Bathroom
Living Room
Bedroom
Kitchen


Juan's HUP Goal:
Outdoor deck
Keisha's HUP Goal:
Kitchen assistive technology
Response Percentage
100
75
50
25
0
Community
Yard
Community
Kitchen