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Effect of Technology-Supported Independent Living on Occupational Performance, Satisfaction, and Cost of Care for Adults with Developmental Disabilities

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Abstract

Adults with developmental disabilities (DD) often experience barriers to independent living. This three-year longitudinal study examined the effectiveness of a smart home in increasing performance of IL skills, while reducing caregiver costs, for adults with DD. Participants were four adults with DD living in a smart home, and their caregivers. This study utilized the Canadian Occupational Performance Measure (COPM), caregiver logs, and cost data analysis to obtain results over three years. Results were analyzed using descriptive statistics. The results showed clinically significant increases in average COPM performance and satisfaction scores over the three years for all residents' self-identified tasks. Furthermore, the hours of direct caregiving decreased by 75%, which resulted in a decrease in cost of caregiving. Smart homes have the potential to decrease cost and improve independent living for individuals with DD and their caregivers. The specific technology utilized by the individuals should be further researched.

Keywords: smart home technology, independent living, developmental disabilities, caregiver costs

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The Problem

There are over 6 million people in the United States living with a developmental disability (DD) (Disability Justice, 2021). Adults with DD experience barriers with housing, which is an important aspect of independent living. Approximately 75 percent of adults with disabilities live with their parents or family members, while about 16 percent live by themselves (Diament, 2020; Golub & Berns, 2018). One option to increase independent living is hiring a full-time caregiver; however, caregiving costs are expensive. A caregiver can cost up to $11 to $31.36 per hour, accruing a large annual expense (B. Hart, personal communication, November 24, 2021; K. Lopez, personal communication, February 22, 2021). Beyond monetary costs, family caregivers of adults with DD report lower marital stability, reduced leisure time, lower quality of life (QoL), and self-doubt (Byram, 2018; Benson et al., 2021) A shortage of caregivers and high direct service provider (DSP) turnover rates (Golub & Berns, 2018) are additional barriers to independent living for this population. Alternative independent living options are becoming available to address these barriers. One promising option is designing smart homes with supportive technology that have the potential to facilitate independent living and decrease dependence on direct caregivers. A smart home sponsored by a non-for-profit organization made for four individuals with DD was researched.

Statement of the Problem/Purpose

The cost-effectiveness and the ability to increase independence for young adults with DD resulting from smart home living is unknown. Therefore, the purpose of this study was to determine the effectiveness of a specific smart home in increasing performance of and satisfaction with daily living tasks, while reducing caregiver costs, for adults with DD.

Research Questions

The research questions examined were:

- What is the cost of providing technology-assisted care to adults with developmental disabilities in a technology supported living residence?
- For adults with developmental disabilities in a technology supported living residence, does the provision of technology-assisted care:
    - Increase performance of selected daily living tasks as measured by the Canadian Occupational Performance Measure (COPM) and Caregiver Assistance Log?
    - Increase satisfaction with performance of selected daily living tasks as measured by the COPM?
    - Reduce the hours of direct caregiver assistance provided to each residence per week as measured by the Caregiver Assistance Log?

Rationale

The research study may be beneficial for a variety of entities, including state funding agencies, individuals with disabilities, family members of those with disabilities, and the not-for-profit organization that sponsored this pilot smart home. If the smart home is shown to be cost-effective over time, state funded programs could potentially decrease their spending on caregivers and instead invest in these homes. Also, families had a peace of mind knowing their child has a home that meets their needs. Finally, the sponsoring organization benefited from the research results, because it gave them data about the successes and areas for future improvement in smart homes.

Scope of Study

Five graduate-level occupational therapy students completed a study to explore how smart home technology impacts satisfaction and independence in daily living for four adult males with DD. The researchers collected data for the third and final prong of a longitudinal study that explored the effectiveness of a specific smart home created by a not-for-profit organization located in a Midwestern suburban neighborhood. The data includes the finalization of the COPM, logs completed by the in-home caregivers, and an investigation on the cost of the technologies. This data was collected in the fall of 2021.

Assumptions

The researchers assumed that residents answered the COPM honestly and to the best of their ability. Another assumption was that the COPM would be administered by one of the researchers either at the smart home or via Zoom. Also, it was assumed the COPM was an appropriate tool that would provide valid and reliable outcomes to the researchers. Additionally, the researchers assumed that the caregiver logs would be properly completed, up-to-date, and accurate. It was assumed the data regarding the cost of technology was current and accurate.

Definition of Terms

For this study the following terms are defined here. The term *smart home* was defined as a specific house designed and built prospectively with integrated technology to allow four males with DD to live more independently with minimal caregiver assistance. *Functional independence* was the ability of the four men to perform daily activities using the smart home technology to successfully participate throughout the day. *Residents* were the four individuals with developmental disabilities living in the smart home. *Caregivers* were the individuals who assisted the residents in living tasks as needed. The *caregiver log* was where time, related to resident-specific goals, was tracked by each caregiver. *Assistive technology* is technology that aids the residents in their daily living activities. *Low technology* referred to simple-to-use, inexpensive devices, such as electric razors and smart toothbrushes. *High technology* referred to more expensive and complex equipment, such as a smart fridge and smart lighting. *Canadian Occupational Performance Model (COPM)* was a standardized assessment administered to the residents to document their satisfaction with the house and their functional independence level using technology with decreased caregiver assistance.

Review of Literature

As defined by the Developmental Disabilities Assistance and Bill of Rights Act (2000), DDs are severe, chronic disabilities apparent before the age of 22, resulting in functional limitations in three or more of these areas: self-care, receptive and expressive language, learning, mobility, self-direction, capacity for independent living, or economic self-sufficiency. These limitations often impact the transition into adulthood (Lin et al., 2015). Thus, family caregivers (Grossman & Magana, 2016) and Medicaid's long-term home and community-based services (HCBS) are often utilized (Amin et al., 2021). Implementing assistive or unobtrusive smart home technology has the potential to increase independence for individuals with DDs and lower caregiver costs and burden.

Independent Living for Individuals with DD

Almost 72% of adults with DDs are living at home with a family caregiver (Braddock et al. 2013). For individuals with DD, independent living involves moving from the family home and being able to live safely alone or in a community group home (Dimitriadou, 2020; King et al., 2016). Necessary skills to live independently include safety knowledge, self-care skills, and medication management (Dimitriadou, 2020; Kim, & Dymond, 2020). Some skills challenging independent living for these individuals are cooking (Deguara et al., 2012), financial management (Barczak, 2019; Grossi et al., 2020; Matthews et al., 2017), practical and social skills (Beaudoin & Moore, 2018; Isaacson et al., 2014; Van Gameren-Oosterom et al., 2013), adaptive behavior skills (Taylor & Seltzer, 2011), and self-care skills (Fortuna et al., 2015). Parent-reported questionnaires indicate that individuals with Down Syndrome perform well using dining utensils, grooming, dressing, bathing, and toilet hygiene (Van Gameren-Oosterom et al., 2013).

Supports and Barriers to Independent Living

There are many factors that facilitate or inhibit independent living for adults with DD. Some of the biggest variables affecting QoL of independent living for adults with DD living in a community setting are the adult's characteristics, presence of staff, culture of residence, size of the residence, and caregiver turnover rate (Francis et al., 2014; Powers & Powers, 2011). Supporting factors to independent living include proper infrastructure, stable economic condition of the individuals, and family and professional supports (Dimitriadou & Kartasidou, 2017; Puyaltó & Pallisera, 2020; Shipton & Lashewicz, 2016), increased education about safety (Tassé et al., 2020), and adequate public transportation (Deguara et al., 2012). However, barriers include lack of education, lack of alternative housing options, lack of family and community support (Björnsdóttir et al., 2015; Burke et al., 2018; Dimitriadou & Kartasidou, 2017), and lack of government funding (Dimitriadou, 2020; Dimitriadou & Kartasidou, 2017).

Costs

Previous research has investigated costs of caregiving and technology. Individuals with DD often have a long-term caregiver through Medicaid's HCBS services or a family caregiver (Byram, 2018; Friedman, 2017). In 2015, the estimated average annual cost of HCBS services was $39,989 per individual (Friedman, 2017). Specifically, the economic burden for autism spectrum disorder (ASD), one of the most common DDs, is estimated to be $460.8 billion by 2025, with 79% of costs from support services and 9% caregiver costs (Buescher et al., 2014). These costs include lost productivity for parents (Leigh & Du, 2015), as incomes for families with children with ASD are 28% lower than those with typically developing children (Cidav et al., 2012). Additionally, a study in Ontario found that adults with DD tended to have higher healthcare costs than anticipated for at least one year (Lunsky et al., 2019).

Technology may be a cost-effective alternative to in-person caregiving. Electronic monitoring services cost an average of $8.76 per hour (Friedman & Rizzolo, 2017), while direct service providers cost around $11.00 to $31.36 per hour (B. Hart, personal communication, November 24, 2021; K. Lopez, personal communication, February 22, 2021). Additionally, telecare services for adults with DD were shown to reduce staff by 23%, which decreased overall costs (Perry et al., 2012). While technologies have shown to be more cost-effective over time, these are often expensive upfront. With purchasing technology, consumers are more likely to adopt smart home technology if it is perceived to be beneficial and low cost (Hwang et al., 2018; Park et al., 2017). In addition, case managers for people with DD have reported limited financial resources as being a barrier to obtaining AT (Haynes, 2013).

Assistive Technology

A wide variety of AT, such as apps and video-based instruction (VBI), is available to adults with DD to improve skills for independent living. Educational mobile applications have led to behavioral and functional changes in individuals with DD, being most effective when implemented alongside caregiver support (Janson et al., 2020). These changes include decreased error in home maintenance (Yeni et al., 2020), increased independence in a classroom (Bouck et al., 2014), and increased health literacy (O'Hara et al., 2016). These apps have also aided in teaching independent living skills, such as medication and health management, scheduling self-care activities (O'Hara et al., 2016), following a shopping list (Panerai et al., 2018), and handling money (Rus et al., 2017). Additionally, Augmentative Reality (AR) apps have shown to improve independence on targeted daily living skills for adults with DD (Bridges et al., 2020).

Similarly, VBI was effective in teaching work-related tasks (Collins et al., 2014; Cullen et al., 2017), implementing physical wellness routines (Torres et al., 2018), and teaching independent living skills, such as meal preparation (Thomas et al., 2020), tying shoes, and making a bed (Cruz-Torres et al. 2020). Additionally, individuals with ASD completed 78% of steps in hand washing without a caregiver when using VBI (Bimbrahw et al., 2012). This supports caregivers' beliefs that AT can be beneficial in increasing independence (Haynes, 2013; Rasouli et al., 2021) and saving resources, such as time and money, for people with DD (Rasouli et al., 2021). Overall, effective use of AT helped individuals with DD in areas such as independence, social participation, self-determination, and QoL (Jamwal et al., 2020; Owuor & Larkan, 2017).

Smart Technology and Appliances

Smart technology intervention improved meaningful engagement, QoL, self-expression, and self-determination for those with DD during everyday tasks and activities (Kerssens et al., 2015; Soderstrom et al., 2019). Those with cognitive and linguistic deficits using voice command devices showed 58.8% accuracy in giving verbal instructions to the device (Masina et al., 2020). Additionally, individuals with DD viewed voice command devices positively, and researchers believed that it could replace human caregivers (Masina et al., 2020; Ramadan et al., 2020). A socially assistive robot is another technology that can both support individuals with DD and relieve caregiver burden by assisting with daily routines through reminders and maintaining home safety (Arthanat et al., 2020).

Individuals with Down syndrome can use specific assistive devices to decrease difficulty and increase performance success in activities of daily living (ADLs) (Dalpra et al., 2018). Preferable features of smart appliances include controlling technology remotely, the appliance making its own decisions, and perceived value (Coskun et al., 2017). A brain computer interface (BCI) allowed people with more severe disabilities to control different smart home technologies with their brains. Using a low-cost wireless router and electroencephalogram (EEG) device, the BCI was almost 90% accurate in controlling various household technologies (Gao et al., 2018). Video doorbells and locks support independence by increasing a sense of security and allowing home entry remotely (Carnemolla, 2018).

Remote Monitoring Technology

Remote technology allows staff to connect with and monitor individuals with DDs virtually (Tassé et al., 2020). This can be in the form of health management and location tracking (Storey, 2010). Remote monitoring services, such as telehealth, may be an option to ensure health and wellness needs are met. These remote monitoring technologies may be especially beneficial in the wake of the COVID-19 pandemic. According to 51% of caregiver survey responses, individuals with DD were unable to see at least one of their healthcare providers in person throughout the COVID-19 pandemic (Jeste et al., 2020). Telehealth was shown to be effective in teaching new skills, such as cooking and crafting, to adults with DD (Pellegrino & Reed, 2020). Individuals with DD who used remote technology reported feeling safer and more independent when completing household tasks. (Taber-Doughty et al., 2010). Concerning aspects of remote support technology include privacy (Birchley et al., 2017; Chalghoumi et al., 2019), choice in camera utility and placement (Brand et al., 2019), secure data storage (Brand et al., 2019), and malfunctioning technology (Tassé et al. 2020). In 2013, only seven out of ninety-nine HCBS waivers paid for remote monitoring services, and pricing was inconsistent (Friedman & Rizzolo, 2017).

Unobtrusive Sensing Technology

Unobtrusive monitoring systems gather information about the home environment, behaviors of residents, and alert to safety concerns without sacrificing privacy or independence (Tewell et al., 2019; Tomita et al., 2007; Yu et al., 2019). Low-cost sensors were reliable and not disruptive to older individuals with disabilities when tracking consistency with participating in exercise, gardening, and housework (Tewell et al., 2019). Verbal task reminders via sensing technology created a sense of security, independence, and established routine for participants with memory impairments (Olsson et al., 2018). Sensors detecting negative behaviors, such as wandering, sent text messages to family members (Fange et al., 2020). Sensing technology led to improvements in cognitive function, ADLs, and behaviors in individuals with cognitive impairments by generating task reminders (Lazarou et al., 2016). Using this technology gives individuals with DD an opportunity to live safely in their own home while maintaining independence and privacy.

Summary

Individuals with a DD live with challenges that can impede independent living. To support participation, caregivers are often needed. However, caregivers are expensive and limit independence. Smart home technologies, such as remote monitoring technology, unobtrusive sensing technology, and a wide variety of smart appliances, have the potential to relieve family caregiver burden, reduce cost of care, and increase independence and autonomy for adults with DD. Current research is limited regarding the impact of smart home technology on independent living for individuals with DD. Therefore, the aims of this study were to analyze the effectiveness of technology-supported independent living on occupational performance, satisfaction, and caregiver costs for adults with DD.

Methods

Research Design

This descriptive case study utilized longitudinal repeated measures (Jackson, 2015) to examine technology used by individuals with DD living in a residential smart home setting over three years. Data were collected in the Fall of 2019, 2020, and 2021. This design was chosen to analyze changes in residents' satisfaction with performance of established goals over time in the smart home.

Sample

The sample included four adult males, selected from a population of adults with DD, who were involved with the sponsoring not-for-profit organization, and their caregivers. Their involvement with the not-for-profit organization made them eligible to become residents of the smart home. Residents were invited to participate in the study if they moved into the house in September 2020, were at least 18 years of age, and were diagnosed with a DD. The residents were recruited and consented in Year 1 and reconsented in Years 2 and 3. Caregivers were invited to participate in this study if they were previously a caregiver for one of the residents or employed by the sponsoring organization and working in this specific smart home. Four caregivers were consented in Year 1, three new caregivers were invited and consented in Year 2, and two of the same caregivers from Year 2 were reconsented in Year 3. Purposive sampling was used to recruit all participants (DePoy & Gitlin, 2016).

Instrumentation

Five distinct instruments were used to collect data: resident demographic questionnaire, caregiver demographic questionnaire, COPM, Caregiver Level of Assistance Logs, and Cost of Technology form. The resident demographic questionnaire included six questions about age, gender, race, diagnosis, work status, and technologies used throughout the day. The caregiver demographic questionnaire included age, gender, relation to the resident, if they were paid, number of hours worked, and how many other caregivers the residents have.

The COPM is a semi-structured interview asking individuals to self-identify three tasks of importance related to self-care, productivity, and leisure (see Appendix A). Individuals rate task importance on a ten-point scale (1 being not at all important and 10 being extremely important). Individuals then rate performance of and satisfaction with these tasks on a ten-point scale. In previous research, the COPM has shown to be a valid and feasible assessment tool (Verkerk et al., 2006) for the DD population (Law & Canadian Association of Occupational Therapists, 1991).

Caregiver Level of Assistance Logs (see Appendix B) were designed by the research team in Year 1 to document residents' required assistance. Caregiver Logs tracked the duration of time and level of assistance caregivers provided to residents with their self-identified tasks over a two-week period. Caregiver Logs rated assistance level using a Likert scale with levels ranging from 1 (dependent) to 6 (independent).

The Cost of Technology form included four questions about the cost of technology, installation and maintenance, training residents, support services, and caregivers (see Appendix C). This was collected in Year 3 from the sponsoring organization after the technology was purchased and installed.

Methods and Procedures

IRB approval was initially obtained in Year 1 of the study and was reobtained each year thereafter. In Years 1, 2, and 3, the COPM and Caregiver Logs were administered to each participant. In each year, the COPM was administered using standardized procedures to ask participants to rate their performance and satisfaction with their three self-identified tasks (see Appendix D). COPM scores were recorded on the data collection form (see Appendix A).

Each year, authors instructed the caregivers on how to complete the Caregiver Level of Assistance Log (see Appendix B). In Year 3, the research team described the form, reviewed the levels of assistance with the caregivers, and ensured there were no questions. Authors collected the Caregiver Logs at the end of each week for a total of two weeks. Authors blacked out participants' names and put participant's previously assigned code number to ensure confidentiality and privacy.

Lastly, a cost data form was given to the organization sponsoring the smart home in Year 3. The organization supplied data on the Cost of Technology form (see Appendix C).

Data Analysis

All data was analyzed using descriptive statistics to investigate trends and changes across this three-year study. Trends across each year of the study (i.e., Year 1 to Year 2, Year 2 to Year 3, and Year 1 to Year 3) were analyzed. The researchers calculated the average COPM performance to determine satisfaction scores. A change of 2 or more points was considered clinically significant (Carswell et al., 2004). Caregiver Assistance Log (see Appendix B) levels and minutes of assistance for each task were each averaged respectively per year and compared across the three years. Cost data (see Appendix C) were obtained from the sponsoring organization in Year 3 and analyzed using descriptive statistics.

Results

There were four male participants living in this smart home. The average age of the residents in Year 1 of the study was 26.5 years old. Residents were diagnosed with at least one developmental disability, including Down Syndrome, hydrocephalus, and autism (Table 1).

Seven caregivers were utilized over the course of the study. The majority were paid, non-family members of the residents (Table 2).

Table 1

Resident Demographics (N=4)

Characteristics	n (%)
Mean age (years)	26.5
Sex (male)	4 (100%)
Work status ("yes")	3 (75%)
Race ("white")	4 (100%)
Disability	
Autism	1 (25%)
Down syndrome	2 (50%)
Hydrocephalus	1 (50%)
Epilepsy	1 (25%)
Hearing or vision impairment	2 (50%)

Note. All statistics are documented using n (%) apart from age

Table 2

Years 1-3 Caregiver Demographics (N=7)

Characteristics	n (%)
Mean age (years)	38.7
Sex ("male")	4 (57%)
Family member of resident ("no")	5 (71%)
Paid ("yes")	5 (71%)

Note. All statistics are documented using n (%) apart from age

Cost of Technology-Assisted Care

The midwestern not-for-profit smart home included nearly 130 different technology devices. These devices were divided into eight categories: home automation, platform technology, remote home monitoring, adaptive equipment, external tracking, smart health/wellness, and apps (see Table 3). A full list of technology within the home can be found in Appendix E. According to the cost data provided by the organization, the total cost of technology was $97,238. The total cost includes the cost of all devices ($85,278) and the cost of technology installation ($11,960). There are also ongoing costs, such as internet, iPhones subscriptions, and IP tracking services, which totaled $3,326. These ongoing costs were not added in the total cost.

Table 3

Technology Within the Home

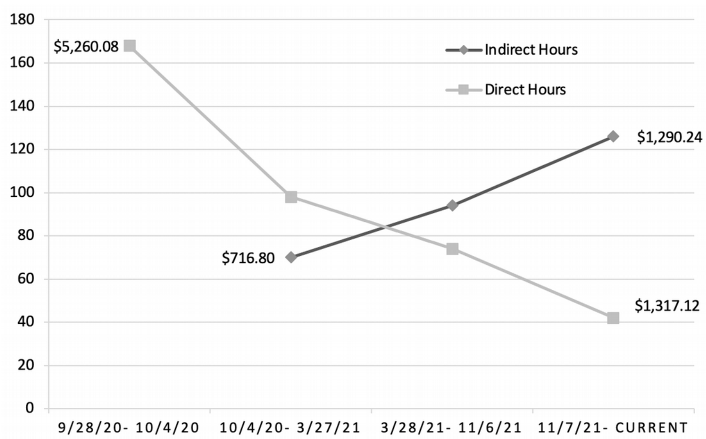
Category	Technology
Home automation	Amazon Alexa, smart appliances, light controls, security camera, smart doorbell
Platform technology	Display monitor, touchpad, mounting bracket, sensor hub, back-up generator
Remote home monitoring	Door/window sensor, smoke/fire alarm and CO detector, bed lamp
Adaptive equipment	Grab bars, electric razor, clothing hamper with wheels, rounded corners, bed alarm, smart toothbrush
External tracking	Apple watch, iPhone, smart ring
Smart health/wellness	Smart scale, smart blood pressure cuff, smart thermometer, CPAP cleaner
Apps	GrandCare, Google Calendar, Kroger, Life360
Technology residents reported using	Amazon Alexa, the GrandCare system, smart appliances, touch pads, smart phones and watches, CPAP cleaner, knife guard, hearing aids, medication reminders, bed alarms

Weekly Caregiving Costs from September 2020 to Present

Caregiving costs should also be included in the cost of technology-assisted care. The sponsoring organization noted general caregiving costs on the Cost Data form (see Appendix C). At the sponsoring organization, indirect caregivers are paid $10.24 per hour, while direct caregivers are paid $30.36 per hour. Direct caregivers were exclusively used upon move-in in September 2020. At this time, direct caregivers provided 168 hours of care, totaling $5,260.08 each week. Indirect caregiving began October 2020 at 70 hours per week, totaling $716.80 per week for indirect caregiving. Currently, direct caregivers provide 42 hours of care, totaling $1,317.12 per week. Indirect caregivers are working 126 hours per week, totaling $1,290.24 per week (see Figure 1).

Figure 1.

Number of Indirect Caregiver Hours Compared to Direct Caregiver Hours and Cost per Week



Hours of Direct Caregiver Assistance with Self-Identified Tasks

The Caregiver Assistance Log (see Appendix B) was used to measure the amount of assistance each resident required to complete their self-identified tasks over a 2-week period. In Year 1, the average minutes of direct caregiver assistance for each resident's task was approximately 33.8 minutes, while the average minutes of direct caregiver assistance in Year 3 was approximately 5.33 minutes. The caregivers' level of assistance was not included as the data were missing and inconsistent.

Performance in Self-Identified Tasks

Average COPM performance scores increased significantly from Year 1 to Year 3 for each resident across their three self-identified tasks (by 2.67 for Resident 1, by 7.33 for Resident 2, by 4.67 for Resident 3, and by 2.67 for Resident 4) (see Table 4). Overall average performance scores increased by 4.34 from Year 1 to Year 3 across all four Residents and all 12 tasks (see Figure 2), with an average performance score of 4 in Year 1 and 8.34 in Year 3. Appendix F shows all raw performance scores of the COPM in greater detail.

Table 4

Average COPM Performance and Satisfaction Scores

Resident	Performance	Satisfaction
	M	M
Resident 1		
Year 1	4.33	2.67
Year 2	6.67	6
Year 3	7	6.67
Resident 2		
Year 1	2.33	1.67
Year 2	4.67	5
Year 3	9.67	9.67
Resident 3		
Year 1	4	4
Year 2	7.67	7.33
Year 3	8.67	8.67
Resident 4		
Year 1	5.33	5.33
Year 2	6	8.67
Year 3	8	9

Satisfaction with Self-Identified Tasks

Average satisfaction scores increased significantly from Year 1 to Year 3 for each resident across their three self-identified tasks (by 4 points for Resident 1, by 8 for Resident 2, by 4.67 for Resident 3, and by 3.67 for Resident 4) (see Table 4). Overall average satisfaction scores increased by 5.08 from Year 1 to Year 3 across all four Residents and all 12 tasks, with an average satisfaction score of 3.42 in Year 1 and 8.50 in Year 3 (see Figure 3). Appendix F shows all raw satisfaction scores of the COPM in greater detail.

Figure 2

Average performance scores of all four residents

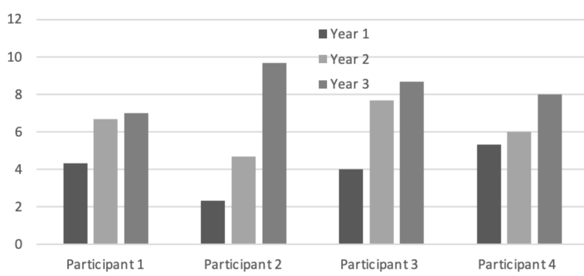
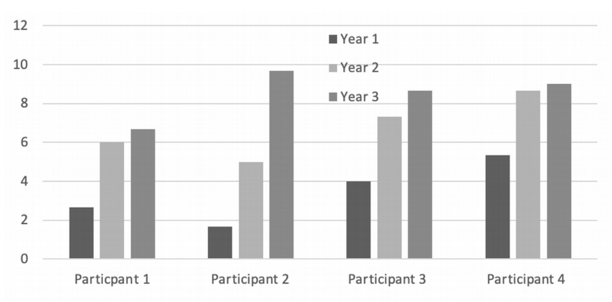


Figure 3

Average satisfaction scores of all four residents



Discussion

Cost of Technology-Assisted Care

This study suggests that the cost of providing technology-assisted care to adults with DD in a technology-supported living residence is less expensive long term than direct caregiver support. Prior to implementing technology-assisted care, the midwestern not-for-profit was paying $5,260.08 per week for direct caregiving at move-in. Now, they are paying a total of $2,607.36 for both direct and remote caregiving per week. This is saving the organization $2,652.72 per week. This is a total of $137,941.44 per year. Therefore, it only took 36.7 weeks to see the payoff from the technology cost and installation. This is consistent with previous literature suggesting indirect monitoring is more cost effective than direct monitoring (Friedman & Rizzolo, 2017). Ongoing costs were not included in this calculation, because it was not stated how frequently the costs were/are collected (weekly, annually, monthly, etc.). Additionally, the indirect caregivers at this organization are able to monitor more than one home at a time. This connects to previous literature that stated that using in-direct caregiving reduces staff, and this decrease is associated with a decrease in overall cost of caregiving (Perry et al., 2012).

Hours of Direct Caregiver Assistance with Self-Identified Tasks

Caregiver log analysis shows a reduction of direct care by an average of 28.47 minutes per resident for their self-identified tasks with the provision of technology-assisted care. The direct cause of this reduction was not assessed but may be attributed to technology use or skill improvement for self-identified tasks. Of equal importance, this reduction of direct caregiver support hours allows all four of the residents to live in their smart home with greater independence. These findings build upon recent literature suggesting indirect care can increase independence due to the absence of direct caregivers (Tassé et al., 2020). Along with reducing hours of direct care per week, this study suggests technology-assisted care coincides with increases in participants' self-ratings of performance and satisfaction.

Performance and Satisfaction in Self-Identified Tasks

When analyzing the results, the COPM data results are considered clinically significant when a change of two or more points is present over time (Carswell et al., 2004). The results of the average performance and satisfaction for all residents for all tasks over the three years are considered clinically significant, as they each had an average increase greater than two points over the three years. This means participants' perceived performance in their self-identified tasks, and satisfaction with that performance, were at least 2 points more on average in Year 3 when compared to Year 1. This suggests that through the use of the smart home and technology, the individuals with DD were more satisfied with their performance in their self-identified tasks. These results support previous literature that technology can improve individuals' performance (Dalpra et al., 2018) and satisfaction in varying tasks and daily life (Panerai et al., 2018; Yeni et al., 2020).

Technology Used

In this study, it is known that the individuals used the technology in this home. However, this study did not measure the direct effect of technology on task performance. Previous studies using focus groups and interviews have shown that technology use supports independent living for individuals with DD (Jamwal et al., 2020; Owuour & Larkan, 2017; Tassé et al., 2020). To our knowledge, there are no other studies that included smart technology for individuals with DD to the extent that this smart home possessed. Due to the amount of technology this specific smart home possesses and findings regarding reduction in direct caregiver assistance, it is assumed that the residents are utilizing the technology in the smart home, thus improving their independence. More information needs to be explored about what specific technology was used that assisted in improving function.

Clinical and Practical Implications

This smart home model can be beneficial to individuals with DD to facilitate independent living. Clinicians should consider using technology to improve performance and satisfaction with specific tasks their clients and caregivers identify as important. However, clinicians should account for the amount of time and training it may take to implement technology, as well as remain up to date on current changes in technology. Complex technology may require excessive time and support to facilitate learning for clients and all members of the interprofessional care team involved. However, occupational therapists should be knowledgeable in these technologies when working with adults who want to live independently. Occupational therapists are experienced professionals that can provide training to individuals with DD on these technologies. Additionally, technology should be specific to the user. Also, feelings about remote monitoring regarding its safety and privacy should be addressed prior to implementing use of technology to facilitate independent living (Birchley et al., 2017; Brand et al., 2019; Chalghoumi et al., 2019).

Study Limitations

The descriptive, longitudinal design of this study limits the ability to infer causal relationships between residents' performance and the technology they used. Additionally, the small sample size and lack of a comparison group limits the ability to compare these residents to other individuals with DD not living in a smart home. The cognitive, linguistic, and memory deficits of individuals with DD could also make the results of self-reported assessments, such as the COPM, unreliable (Emerson et al., 2013). This study is not easily replicated, as the home is very specific to the individual residents; therefore, the results cannot be generalized. Another limitation is that the Caregiver Log data forms had missing, inconsistent, and/or inaccurate data.

Specifically, levels of assistance were incomplete and inaccurate. Therefore, this data was omitted from the Caregiver Log analysis to prevent skewing the Caregiver Log results.

Conclusion

The results of this study suggest technology-assisted care provided in the context of a smart home may decrease caregiver costs, and as well as increase independence for individuals with DD. Over three years, the decrease in direct caregiving supplemented by technology in the smart home led to a decrease in overall cost of caregiving. Furthermore, this study found that individuals with DD who moved into a smart home improved their performance of and satisfaction with selected daily tasks over three years. Based on these findings, smart homes have the potential to be a viable and cost-effective independent living option for adults with DD. Further research regarding specific technology used is needed to develop a wider body of knowledge and to confirm these findings.

Recommendations

If this study were to be replicated, several improvements are suggested. A more in-depth look at what specific technologies are used by the residents would enhance the understanding of the role that smart home technology has in facilitating independent living. Also, calculating the frequency of use would highlight which technologies are most important in promoting independence. There is a chance the improvement in performance is not directly related to the implementation of technology, so identifying the cause could improve the rigor of this study. This could be accomplished with an experimental study with a comparison group, or a well-designed single subject study.

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Appendix A
Data Collection Form

Participant Code: _______
Date Administered: _______
Researcher Initials: _______

A member of the research team will facilitate a face-to-face semi-structured interview to complete Parts A, B, and C of the data collection form with the resident and their caregiver present. The data collection form has been written in simple language for residents with cognitive impairments to fully understand. However, researchers will adapt their language to match the cognitive level of the resident.

Part A: Resident Information (Administer Questions 1-4 at Pretest; Administer Question 5& 6 at Pretest, Year 1 & Year 2)

Researcher will begin Part A by stating the following to the resident: "We would like to ask you questions about you and the things you use to help you do things everyday. We will not tell other people what you say, and we will not use your name."

1. How old are you? _________ years
2. Do you see yourself as a boy or a girl? ❑ M ❑ F ❑ Other answer
3. Do you know what your diagnosis is?

   ____

   ____

4. Which of the following best describes your race or ethnic group:

   ❑ Caucasian ❑ African American
   ❑ Hispanic/Latino ❑ Native American
   ❑ Asian ❑ Other:_________________ Specify

5. Do you work or attend school? ❑ Y ❑ N If yes, describe

6. Can you tell us what things you use to help you during the day, like a wheelchair, an iPad, anything special to help you eat or bathe, or something to help you talk? (record all technology, assistive devices and/or any technology-related support or monitoring currently used)

   ____

   ____

   ____

   ____

Part B: Caregiver Information

Researcher will begin Part B by stating the following to the resident: "We will now ask your caregiver about how much they help you everyday. We will not tell other people what they say and we will not use your names".

7. How old are you? ___________years
8. Caregiver Gender: _____________________________
9. Are you a family member? ❑ Y ❑ N ❑ If yes describe

   ____

10. Are you paid for your caregiving activities? ❑ Y ❑ N
11. Approximate hours caregiver is present every day: _______ hours
12. Number of caregivers client currently has: _______ caregivers

Part C: COPM Scoring & Identified Occupational Goals and Tasks

The COPM will now be administered to the residents according to standardized instructions, and researchers will copy the three identified goals or tasks from the COPM scoring sheet. The following will be said to the resident: "We will now ask you about the things that you do everyday that you may have trouble with, and how that makes you feel. We will not tell other people what you say or use your name"

Identified Goal or Task	Occupational Performance Score	Satisfaction Score
Task 1		
Task 2		
Task 3		

Appendix B
Caregiver Level of Assistance Log

For Caregiver Use Only:
Date & Time: ________________
Resident Name: ________________

NOTE: residents name will be blacked out prior to transportation to Xavier University

For Researcher Use Only:
Participant Code: __________
Date: __________

Total number of hours of direct assistance and/or supervision provided for all activities and tasks in this 24 hour period: ________ hours

At the end of each shift, or 24-hour period, select whether or not (resident name) completed the following tasks. If the task was not completed during your shift, select "no" in the first box. If (name) did complete the task during your shift, select "yes" and rate level of assistance provided for each task using the 6-point scale (i.e: if (resident name) required Moderate assistance for Task 1, record assist level 3 in the Task 1 row). Then record the total time you spent assisting the resident with each task in minutes.

This form will be completed daily for 2 weeks.

Please record the amount of assistance you provided (resident's name) with each task:

6. Independent - no assistance needed from helper.
5. Setup or Cleanup Assistance - helper only assists before or after task.
4. Supervision or Touching Assistance - helper provides verbal cues or steadying assistance.
3. Moderate Assistance - helper does less than half of the effort.
2. Maximal Assistance - helper does more than half of the effort.
1. Dependent - helper does all the effort.

Task/Description	Completed?	Assist level (1-6)	Time (# of minutes you spent assisting client with this task)
Task 1:	❑ Yes ❑ No		
Task 2:	❑ Yes ❑ No		
Task 3:	❑ Yes ❑ No		

*Scale modified from the Inpatient Rehabilitation Facility - Patient Assessment Instrument (IRF-PAI) (CMS, 2019)

Appendix C

Cost of Technology Provided

- Pretest phase: no data will be collected regarding costs
- Year 1 & Year 2: The following cost-related data will be obtained from LADD data records.
    - Description & cost of the technological devices used in the home:
      ____
      ____
      ____
      ____
    - Description & cost of installation and maintenance of the devices:
      ____
      ____
      ____
      ____
    - Description & cost of training to teach resident and caregiver to use the technology:
      ____
      ____
      ____
      ____
    - Description & cost of support services (such as remote monitoring):
      ____
      ____
      ____
      ____
    - Description & cost of direct caregiving/supervision provided per week in the home:
      ____
      ____
      ____
      ____
    - Other:
      ____
      ____
      ____
      ____

Appendix D
Resident Self-Identified Tasks

Table 5

Residents Self-Identified Tasks

Resident 1		
	Task 1	To cook more food and read recipes.
	Task 2	Be more responsible with my schedule (turning off electronics at night).
	Task 3	Be more responsible with food control and maintain a healthy diet.
Resident 2		
	Task 1	To cook more and cook on the stovetop.
	Task 2	To use more SMART technology (iPhone, Siri, & Alexa-bus schedules, recipes)
	Task 3	To be able to cut food without assistance.
Resident 3		
	Task 1	Use my-cycle to do my own laundry.
	Task 2	Use iPad to watch videos to then make recipes with the stovetop and oven.
	Task 3	Use Uber/Lyft app to use transportation for activities to and from home.
Resident 4		
	Task 1	Budgeting (groceries and leisure).
	Task 2	Scheduling– planning day, getting tasks done, time management.
	Task 3	Cooking and planning healthy meals.

Appendix E

List of Technologies

Home Automation: Alexa Echo Show (2nd Gen) - 10.1" HD, Alexa Echo Dot, Alexa Echo Smart Speaker, Alexa Studio, Smart TV, Fire Alarm for Deaf (visual alerts/lighting/siren/tactical alerts); GE Crestron Express Wireless Lighting Dimmer; GE Crestron Express Wireless Exhaust Fan Switch; GE Surface Mount Leak Detector – Sink; GE Surface Mount Leak Detector – Toilet; GE Crestron Express Wireless Lighting Dimmer; Crestron Express System Control Keypad; Crestron Surface Mount Magnetic Door Contact; Crestron 10" Wall Mount Touch Panel; Crestron Express Wireless Lighting Dimmer; Crestron remote Temperature and Relative Humidity Sensor; Crestron Surface Mount Leak detector – Refrigerator; Crestron Surface Mount Leak detector – Sink; Crestron 2 Megapixel Low-Profile Dome Camera w/ Mic & Night Vision; Crestron Occupancy Sensor for Camera Notifications; Crestron infiNet EX Wireless Gateway – PANTRY; Crestron Express Wireless Switch – Disposal; Security System Service; Annual Dynamic DNS IP Tracking Service; Annual Fee for Cellular Phone Connection Service through Home; Smart Dishwasher - LADD GE GDT635HSMSS; Changed to Samsung and bought by LADD; Exterior Security Cameras; Digital Intercom Interface w/integrated camera (Door Bell); Veso Fingerprint Reader; Verso I/O Integration Module; Crestron Wireless Deadbolt w/; Touchscreen; Crestron Flush Mount Door contact; Crestron Express Wireless Lighting Dimmer; Crestron Security Keypad w/ LCD Display and RF Receiver; Crestron Surface Mount Leak detector – Sink; Crestron Passive Occupancy Sensor; smart oven range; induction cooktop; GrandcareRing Lighting; Fall Prevention; Crestron Express Wireless Lighting Dimmer; Crestron; High Power AC1900 Dual-Band Wireless Access Point; Grandcare Smart Mirrors - Wiring Only; Crestron Smart Thermostat; Tile Scrubbing Rhoomba; Nyboer locks; ADA compliant washer/dryer; Fall prevention bedroom lighting; noise machine; Crestron Sensory

Auto Blinds; Crestron Flush Mount Door contact; Sensory sitting swing; Samsung Smart Refrigerator; Crestron Security Keypad; Fiber Optic Curtain Light; LED Tube Light; Bubble Wall; Lighted Seat/Cube; Lava Lamp; LED Smart Lamp; automated faucets; Simply Human Automatic Soap Dispensers; Simply Human Shampoo Dispensers; Toilet Seat Bidet; Smart Music; Overhead garage door control; Crestron mechanical room equipment; home automation; Smoke Detector; Crestron Home Automation Placeholder - IR Blaster; Sens Room Pad; lamp switch, etc.; Sonos Smart Speaker for Home Automation; Crestron Compatible; Creston Mesh network for Wi-Fi

Platform Technology: display monitor, touchpad, mounting bracket, sensor hub; in-home battery backup/generator for internet; CAD 6 Wiring; wireless speaker for touchpad audio; platform accessories

Home Monitoring: Door/ Window Sensors (open/close): Platform; Emergency/ Panic: placed throughout home to alert DSP; "250MB+ Internet Connection; Fiber Optic Cabling (FiOptics)"; Grandcare Smoke Alarms and CO Detectors; smart fire alarm; bed/pad monitors; Additional outlets; Bed Lamp

Adaptive Equipment: Handrails in shower/toilet areas; Electric razors; clothing hamper with wheels; rounded edges in place of corners throughout home; Vibrating bed alarm; pull down seat in shower; slip resistant tile; adaptive measuring equipment; Smart toothbrush; ramp

External Tracking: iPhone; AppleWatch, Aira Smart Goggles; Smart Ring

Smart Health and Wellness Devices: Smart Scale; Smart Blood Pressure Monitor; Smart Thermometer; Pulse Proximeter; CPAP Cleaner/Sanitizer; Temi; Pria

Apps: Whisk; Google Calendar; Temi; Oral B; SmartThings; Family Hub; SmartHQ; Mi Home; Life360; Arlo; Pria; Follow; Vibrosaver; Roost; Transit; Streaks; Apple Fitness; Grandcare; Kroger

Appendix F

Raw COPM Data

Table 6

Raw COPM Data

Resident	P1	P2	P3	S1	S2	S3
Resident 1						
Year 1	3	6	4	2	5	1
Year 2	9*	6	5	9*	4	5*
Year 3	8	6	7*	9	4	7*
Resident 2						
Year 1	5	1	1	3	1	1
Year 2	5	5*	4*	5*	5*	5*
Year 3	10*	9*	10*	10*	9*	10*
Resident 3						
Year 1	4	3	5	5	4	3
Year 2	10*	7*	6	8*	6*	8*
Year 3	10	6	10*	10*	6	10*
Resident 4						
Year 1	5	5	6	6	4	6
Year 2	4	8*	6	6	10*	10*
Year 3	6*	8	10*	8	9	10

Note. P1 = performance task 1 (continuous); S1 = satisfaction task 1 (continuous).

*Clinically significant