

Suitability and adaptability of a real-time location system to mitigate item loss in dementia care facilities

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Abstract

Background: Older adults with dementia frequently exhibit hiding and hoarding behaviors, resulting in item loss. In long-term care facilities (LTCFs), item loss negatively impacts the quality of care and increases stress for both staff and residents.

Objective: To evaluate the suitability and adaptability of a novel real-time location system (RTLS) tag technology in mitigating item loss within LTCFs to improve care and operational efficiency.

Methods: 30 semi-structured interviews were conducted with long-term care staff members to assess the frequency and impact of item loss in LTCFs and to understand the adaptations needed to increase the RTLS technology's utility in settings that care for older adults.

Results: Findings reveal that the loss of personal belongings and facility-owned items remains a prevalent and persistent challenge in LTCFs. Respondents recognized the RTLS technology's potential to improve item tracking and alleviate the stress associated with item loss. However, significant adaptations to the technology are necessary to meet the specific needs of the LTCF environment.

Conclusions: The study corroborates the need for item loss mitigation strategies in LTCFs. The proposed RTLS technology shows promise in addressing this need, with potential benefits for improving care quality and operational efficiency.

Keywords: older adults, dementia, item loss, technology use, long-term care, caregivers, real-time location systems

INTRODUCTION

Almost one in ten Americans 65 and older are currently living with dementia, with Alzheimer's Disease (AD) being the most common form (Alzheimer's Association, 2023; Manly et al., 2022). AD is an irreversible, degenerative disease that frequently manifests as memory loss, and hiding and hoarding items are common symptoms (Baumgarten et al., 1990; Hwang et al., 1998; Jahn, 2013). Older adults with cognitive decline and dementia make up a significant proportion of the resident population in long-term care facilities (LTCF), including assisted living and skilled nursing facilities (Alzheimer's Association, 2023).

When people with dementia living in LTCFs exhibit hiding and hoarding behaviors, it can result in the loss of items necessary for the provision of care to residents by direct care workers (DCWs) and other staff. Frequent item loss in the workplace is likely to cause stress among residents and DCWs and may disrupt care as searching for items is a time-consuming task for an already overworked and overwhelmed workforce (Bro-

dy et al., 2003; Lapane & Hughes, 2007). The time and effort spent searching for missing belongings reduces the time spent providing care to residents resulting in reduced quality of care and negatively impacting residents' quality of life (Bökberg et al., 2017; Munyisia et al., 2011; Zheng et al., 2014).

In response to item loss in clinical settings, some facilities have begun to implement real-time location systems (RTLS) into the care of patients (Berg et al., 2019; Gholamhosseini et al., 2019; Overmann et al., 2021). RTLS technologies have been explored in the context of hospital care, proving beneficial for tracking patients, staff, and assets within healthcare facilities (Fisher & Monahan, 2012). Tracking a spectrum of items in this setting, including medical devices, assistive devices, equipment, drugs, and specimens, has demonstrated tangible advantages in optimizing workflows and enhancing efficiency for both staff and patients (Fisher & Monahan, 2012; Fosso Wamba et al., 2013).

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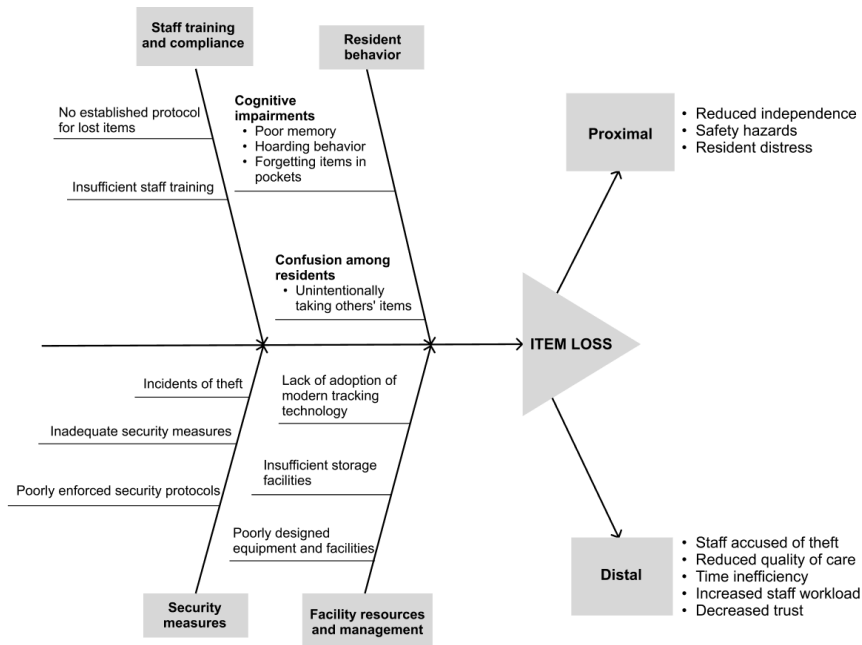


Figure 1. Fishbone diagram of the root causes and impacts of item loss based on literature review

Although item loss is recognized as a notable issue within LTCFs and a common grievance among LTCF residents, their family members, and staff, little research has been done to document specific mitigation strategies. The currently available RTLS technologies have not been designed to address the particular needs of staff and residents in LTCF environments that serve individuals with memory impairment who may misplace, take, or hide items necessary for daily care. These items include personal, medical, and facility-owned items such as clothing, denture cases, and wheelchairs, respectively. Moreover, systematic reviews have not explored what features direct care workers in LTCF settings would find most beneficial in adapting RTLS technology to meet the needs of residents and staff. In this study, we proposed a novel RTLS tag technology specifically developed for care provider use in LTCFs to help monitor and track items and evaluated the suitability and adaptability of this novel technology in LTCF settings. To do so, we conducted semi-structured, qualitative interviews with 30 individuals working in LTCFs that serve individuals with memory concerns. In understanding more about item loss in LTCFs and working to reduce its occurrence, the quality of life for older adults will improve.

Literature review

Existing literature provides insight into the types of items commonly lost in LTCFs and why those particular items are susceptible to becoming misplaced. Studies have also been conducted to understand the consequences of such item

loss in long-term care settings, with some studies beginning to explore possible technological solutions. However, a majority of lost items and RTLS research has been conducted in hospital settings and has failed to acknowledge the unique challenges faced by nursing homes and assisted living facilities serving individuals with memory concerns. In this section, we present an overview of the causes and consequences of item loss in LTCF settings serving residents with memory concerns, followed by a review of research on RTLS in other care settings, before moving on to how the technology may be adapted for use in LTCFs serving individuals with memory concerns.

The fishbone diagram helps visualize the causes and consequences of item loss in LTCFs, particularly those serving residents with memory impairments (Figure 1). The diagram groups the causes into five main categories: inventory management, staff training and compliance, resident behavior, facility and resource management, and security measures. Each of these categories is further broken down into specific contributing factors and the impact it has on different areas of resident care and work environment.

Item loss: Frequency

Numerous research studies highlight the frequency of item loss in LTCFs, two such studies that focus on the quantitative data of item loss in patients with dementia are by Hamilton et al. (2009) and McGarrigle et al. (2019). In a study involving 130 community-dwelling patients with mild to moderate Alzheimer's disease (AD), 74%

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of the participants reported recurrent incidents of misplacing items, which included the inability to recall where the item had been placed. Further, in an analysis of 2,775 users of an online dementia symptom tracking tool, 28% (787 users) selected "misplacing objects" as a symptom to monitor. This symptom was tracked across all stages of dementia but was most commonly reported in mild (32%) and severe (42%) stages of dementia (McGarrigle et al., 2019).

Two additional studies from the Netherlands closely examined item loss within nursing home settings. Van Hoof et al. (2016) led a qualitative study to investigate types of commonly lost items and the resulting consequences (van Hoof, Douven, et al., 2016). The 12 early-stage dementia patients and their family caregivers enrolled in this study participated in semi-structured interviews and card-sorting tasks. Similarly, Weernink et al. (2017) used a context mapping method with thirteen nursing home staff to understand the use of real-time location systems (RTLS) in long-term care settings (Oude Weernink et al., 2017). Together, the results from these studies found that personal care necessities that residents use and rely on daily, such as glasses, hearing aids, and dentures, are frequently lost in LTCFs (Oude Weernink et al., 2017; van Hoof, Douven, et al., 2016). Furthermore, the participants of these studies reported losing personal belongings that hold sentimental as well as monetary value including jewelry, photographs, wallets, purses, and other collectibles (Oude Weernink et al., 2017; van Hoof, Douven, et al., 2016). Articles of clothing and personal specialized assistive medical devices were also documented as being commonly misplaced (Oude Weernink et al., 2017; van Hoof, Douven, et al., 2016). These findings are consistent with another study which found that glasses, keys, and cell phones were the most commonly lost items among older adult patients and their caregivers (n = 60) (Boudet et al., 2014).

Item loss: Causes

Resident behavior - Misplacing and hiding items with the inability to retrace steps is one of several behavior changes that is recognized as a sign of AD (Alzheimer's Association, 2023). Declines in short-term memory recall can lead to confusion and to forgetting where an item was placed indicating that memory concerns were a primary driver of item loss (Hamilton et al., 2009; J.-J. Wang et al., 2012). Additionally, Confusion among residents can also occur when one resident takes another's belongings without realizing it (Hamilton et al., 2009). Hoarding behavior often seen in individuals living with AD is another common cause of item loss among older adults (Alzheimer's Association, Greater Missouri Chapter, 2017). Hoarding disorder was added to the Diagnostic and Statisti-

cal Manual of Mental Disorders, Fifth Edition in 2013 and is defined as collecting a large number of unneeded items (Nordsletten et al., 2013).

Hoarding behaviors are more prevalent in older adults, and this is especially true for older adults with cognitive impairment (Ayers et al., 2010; Diefenbach et al., 2013; Kim et al., 2001; Mitchell et al., 2019; Samuels et al., 2008). A study conducted in a Taiwanese geropsychiatric ward found almost a quarter of dementia patients (n = 133) exhibited hoarding behavior (Hwang et al., 1998). Hoarding among patients with dementia is often seen with other agitation behaviors, and it is believed that hoarding in people with dementia is related to seeking a sense of control within their lives and a desire for security (Bicer Kanat et al., 2016; Cohen-Mansfield et al., 1990; Marx & Cohen-Mansfield, 2003; Rabinowitz et al., 2005; C.-J. Wang et al., 2015; J.-J. Wang et al., 2012). Because of the excess number of belongings and the disorganization often associated with hoarding, items are frequently misplaced (Steketee & Frost, 2003).

Staff training and compliance - The level of staff training and compliance significantly impacts item loss in long-term care facilities (LTCFs). With no federal staffing requirements and state regulations varying widely, most care is provided by unlicensed workers (Han et al., 2018). Insufficient training leaves staff unprepared to handle resident needs (Drake, 2020). Staffing shortages further worsen the situation, increasing workloads and burnout (Brazier et al., 2023; Rachel & Francesco, 2018; Scales, 2021; Xu et al., 2020). A 2022 Kaiser Family Foundation study reported nearly 30% of 14,000 nursing homes experienced staffing shortages (Ochieng et al., 2022). Furthermore, inconsistent documentation protocols. Notably, many LTCFs lack standard inventorying processes to monitor items coming in and out of the facility. A study by Oude Weernink et al. (2018) found that when such protocols are in place, they often involve documenting the personal belongings residents bring in and labeling them with the resident's name (Oude Weernink et al., 2017). Documentation may also occur when contractual or rental equipment, such as wheelchairs or air mattresses, from third-party vendors, are brought into a facility for resident and staff use (Oude Weernink et al., 2017). When appropriately documented, item loss is significantly less frequent (Marzano, 2022).

Facility and resource management - Hospitals and LTCFs share similarities in terms of infrastructure, resource management, and operational needs. Therefore, insights from studies conducted in hospital settings can provide an understanding of challenges that may also be present

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in LTCFs. Facility and resource management are crucial to minimizing item loss in hospitals and LTCFs. Insufficient storage facilities can lead to poor organization and difficulty in managing supplies, making it easy for items to be misplaced (Oude Weernink et al., 2017). Poorly designed equipment and facilities can further heighten the issue by creating environments that are not conducive to effectively storing and tracking belongings (Fisher & Monahan, 2012; Kamel Boulos & Berry, 2012; Oude Weernink et al., 2017). The lack of adoption of modern tracking technology, such as inventory systems, also hinders the ability to monitor and manage items effectively. Similar challenges are faced in hospitals, emphasizing the importance of advanced tracking solutions in healthcare settings (Hall et al., 2017, 2019; Heisey-Grove et al., 2014; Masciadri et al., 2019).

Security measures - Inadequate security measures are a final cause of item loss in LTCFs. Incidents of theft can occur if proper security protocols are not in place or are poorly enforced. Ensuring robust security measures and consistently enforcing protocols can help mitigate the risk of theft and improve the overall safety of residents' belongings. Studies have shown that a significant number of theft incidents go unreported, and when reports are made, they frequently lack detail. The participants in the study also indicated that the absence of established protocols for lost items further complicates the situation, making it difficult to track and recover missing belongings. The participants in the study also indicated that the absence of established protocols for lost items further complicates the situation, making it difficult to track and recover missing belongings (Caspi et al., 2023).

Item loss: Impacts

Although the criticality of item loss can be subjective, the loss of necessary and valuable items can have adverse impacts on both staff and residents, which can have a negative impact on LTCFs. For residents, losing personal care items, such as medications, glasses, hearing aids, and dentures, can result in negative health outcomes and potentially a safety issue (Mann & Doshi, 2017). Several studies, including those by van Hoof et al. (2016), Powers (2003), and Oude Weernink et al. (2017 and 2018), have documented that the loss of these items, which are often required to complete activities of daily living increases stress, creates communication challenges, feeling of dependence and can reduce overall quality of life. (Oude et al., 2018; Oude Weernink et al., 2017; Powers, 2003; van Hoof, Douven, et al., 2016). Additionally, the loss of personal and sentimental items like jewelry and photographs can lead to emotional distress, reducing residents' sense of security and belonging within a care facility (Pow-

ers, 2003; van Hoof, Janssen, et al., 2016). For example, in an ethnographic study conducted by Powers, 2003, it was found that these personal objects often held former life connections, represented self-expression and independence, and held intrinsic value to residents. Therefore, losing such items can strain relationships between the facility, residents, and family members as replacing these items can be costly and, in some cases, impossible to do so if they hold sentimental meaning (Shenk et al., 2004; van Hoof, Janssen, et al., 2016). Additionally, privacy concerns for many residents may arise with staff entering and searching for missing items in a resident's room (Oude Weernink et al., 2017; Powers, 2003).

For DCWs and other staff in LTCFs, the repercussions of item loss extend beyond the need to replace the belongings. The increased workload associated with searching for lost belongings coupled with the pressure of widespread staffing shortages and burnout exacerbates the challenges these workers face (Brazier et al., 2023; Rachel & Francesco, 2018; Scales, 2021; Xu et al., 2020). Nearly 30% of 14,000 nursing homes surveyed in a 2022 study conducted by the Kaiser Family Foundation reported experiencing staffing shortages (Ochieng et al., 2022). This not only increases work hours but also places further pressure on employees to enhance their productivity and efficiency within tight budgetary constraints (Ochieng et al., 2022). Furthermore, individuals with psychogeriatric disorders often suspect staff of stealing and may falsely accuse staff of theft when they cannot locate their possessions, contributing to additional emotional stress DCWs regularly experience in the workplace (Brodaty et al., 2003; Costello et al., 2019; van Hoof, Douven, et al., 2016).

Item loss: Possible solutions

Intelligent assistive technologies (IATs) refer to a broad spectrum of technological devices and systems with embedded computing capabilities and network connectivity (Wangmo et al., 2019). IATs have emerged as pivotal components in the caregiving landscape for individuals with memory concerns, playing a crucial role in fostering independence and enhancing social and mental well-being (Cahill et al., 2007; Oude Weernink et al., 2017). Various forms of assistive technology have been developed to improve care and the quality of life for older adults, ranging from basic electronic reminders for medication management to advanced wearable sensors and at-home monitoring systems that can detect falls, track physical activity levels, and alert caregivers (Bharucha et al., 2009; Lopes et al., 2016; Pappadà et al., 2021). IATs can provide people with dementia guidance, prompts, and automation to help them perform activities of daily

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living (Boger & Mihailidis, 2011; Ienca et al., 2017). These technologies have the capability to enhance older adult's safety through GPS to track individuals who exhibit wandering behaviors and fall risk sensors to notify caregivers of a fall (Bantry White et al., 2010; Bowen et al., 2010; Daly Lynn et al., 2019; Oude Weernink et al., 2018). As a result, this can enhance a person with memory concerns to have social connections and independence (Cahill et al., 2007; Lee-Cheong et al., 2022). With the help of artificial intelligence, cloud computing, and the Internet of Things, IATs are becoming more adaptive and intuitive in everyday environments, providing more personalized care (Ienca et al., 2018).

RTLS systems, available in various forms like pendants, watches, tags, or bracelets with GPS-enabled technology, were first introduced in manufacturing, warehouse management, and automotive industries (Ding et al., 2008; Ferracuti et al., 2019; Thiede et al., 2021). Since then, RTLS technologies have undergone significant advancements, resulting in a diverse range of commercially available options varying in price and accuracy (Reinsch, 2020; B. Wang et al., 2013). RTLS systems involve attaching tags to assets and staff and placing fixed beacons on the premises to collect information about the location of these tags (Clarke & Park, 2006; Goyal et al., 2022; Thiede et al., 2021). To do so, RTLS technologies encompass various tracking mechanisms such as radio frequency identification (RFID), Bluetooth beacons, ultra-wideband (UWB), and Wi-Fi networks, each contributing to real-time location monitoring of both assets and individuals (Ahmed et al., 2020; Angulo et al., 2015; Chen & Chen, 2021; Dardari et al., 2015). A pilot study conducted at the smart manufacturing demonstration center (SMDC) demonstrated the effectiveness of seamless asset tracking using GPS, Wi-Fi, and Bluetooth technologies. The technology enablers evaluation matrix presented by Ahmed et al. (2020) provides a comparative analysis of tracking approaches, highlighting factors such as range, accuracy, and cost, which are crucial for selecting the appropriate technology for different areas of operations.

More recently, RTLS technologies have been adopted in healthcare settings, particularly in hospitals, with promising results (Jones & Schlegel, 2014; Kamel Boulos & Berry, 2012; Okoniewska et al., 2012; Paiva et al., 2018). RTLS have demonstrated the potential for tracking a wide range of assets, including medical devices, assistive devices, equipment, drugs, and specimens, with tangible advantages in optimizing workflows and enhancing efficiency for both staff and patients (Fisher & Monahan, 2012; Fosso Wamba et al., 2013). Among the array of IATs, RTLS also represents an innova-

tive solution, employing advanced sensors and real-time tracking to monitor the movement and location of individuals with memory concerns (Megalingam et al., 2022; Oestreicher, 2014; Raad et al., 2021; Reinsch, 2020). In the realm of dementia care, the application of RTLS has garnered attention due to its potential benefits, ranging from reducing the time spent searching for lost items to enhancing resident independence and confidence (van Hoof et al., 2018). However, RTLS has yet to be widely applied in long-term care industries due to a lack of inventory management practices, stakeholder engagement, technological and infrastructural challenges, and prevailing myths and misunderstandings about the technology (Grigorovich et al., 2021).

METHODS

In this study, we proposed an RTLS tagging technology targeted towards LTCFs, including assisted living facilities and nursing homes, to assess the impact of item loss and to gather feedback on the technology's utility and adaptability. We interviewed 30 direct care workers and staff, focusing on their professional experience, the frequency and impact of item loss, and existing protocols for handling lost items. During the interview, participants were shown a brief presentation about the novel RTLS tag technology. The participants were encouraged to ask questions about the technology and were then asked to provide feedback on its potential utility, necessity, and recommended adaptations for effective application in LTCFs. The objective of the research was to evaluate the effectiveness of RTLS in mitigating item loss issues within LTCFs and to understand staff perceptions towards adopting this technology.

Participant recruitment and eligibility

A combination of targeted recruitment and snowball sampling approaches were used to recruit participants for this study. The target recruitment strategy involved distributing flyers to assisted living facilities in Minnesota both digitally via email and paper flyers posted in employee break rooms and other spaces. Interested participants were asked to contact the research team to complete a short eligibility screening. Eligibility criteria included having dementia caregiving experience in an LTCF setting, speaking English, and being over the age of 18. As part of the snowball sampling, participants were asked to forward study information to others in their place of employment who may also be interested and eligible.

UWB technology description

The proposed RTLS technology is a small tag that can be attached to various items such as denture cases, hearing aid cases, glasses cases, jewelry boxes, wheelchairs, staff pocket talkers, and clothing items within an LTCF. The tags are compact, measuring only one cm², similar in

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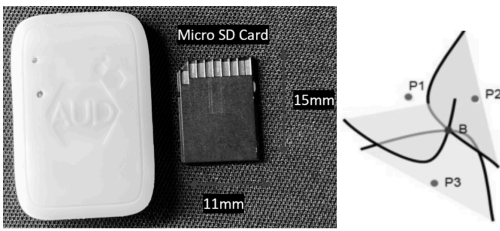


Figure 2. The RTLS tag in comparison to the size of a micro SD card. In an indoor space the location of the UWB tag (B) is determined by calculating the difference between the time of arrival of the wireless signal from the tag

size to a paper clip or micro SD card. The tags have a one-year battery life and can be easily set up using a QR code. The proposed technology is a small tag that can be attached to various items within an LTCF. Users can configure the tags using a mobile application to add the tagged item to their system and view it on a map interface. The application also enables the user to track multiple items simultaneously.

The RTLS tag uses novel UWB technology and positioning methodology. Unlike other GPS systems, UWB technology uses time-of-flight calculations. The UWB technology-enabled tags adhere to objects and wirelessly transmit signals, which are received by anchor readers with synchronized clocks in fixed locations around the facility. Because radio waves travel at known speeds, the time-of-arrival differences at the anchors indicate each tag's position.

This UWB tag system can help caregivers quickly locate misplaced objects within a one-foot radius in an LTCF. To do so, the existing RTLS technology itself is not being adapted; rather, the form in which the technology is being delivered via the small tags, is novel. The system can be used to alert caregivers if an object has been moved from a room where it is expected to remain, and the tags are tracked through geolocation within a predetermined area using the PinPoint Tracking Application, a tablet-enabled or smartphone-enabled web application. After creating a profile,

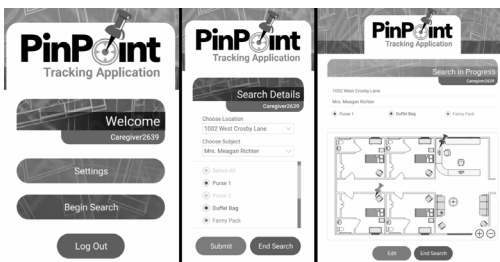


Figure 3. Images of the user interface on the PinPoint Tracking Application to track and monitor the location of tagged items

this system allows users to track single or multiple tags at one time using the app and be guided to the exact room and position of the lost item. The system provides a floor plan of the facility in which colored pins are placed to signify the presence of a specified tag.

Data collection procedures

In this study, 30 participants working in long-term care participated in a 45-minute semi-structured interview via Zoom. After obtaining verbal consent from participants, interviewers followed an interview protocol focusing on the following topics: professional experience in LTCF, experience with item loss, including the frequency of lost items, current item loss protocols, and the impact of item loss on both staff and residents. During the interview, we gave a brief presentation to participants introducing the proposed novel RTLS tag technology for use in LTCF settings. Based on their experience working in long-term care and the technology presentation, respondents provided insights into the suitability of the RTLS technology in their workplace and provided recommendations to enhance its utility in facilities that care for older adults with memory concerns. Participants received monetary compensation for their time and participation following the completion of the interview.

Data analysis

Interview questions and analysis focused on predetermined themes designed to assess the utility of the RTLS tag technology in LTCFs. Themes included the type of items lost, causes and consequences of lost items on residents and staff, advantages of the proposed technology, functional features recommendations, user app capabilities, and practical technology implementation considerations. To analyze the interview data, we used an iterative affinity mapping process to categorize and highlight information relevant to the research aims. This approach enabled us to actively identify and examine data on item loss and user needs for RTLS tag technology.

RESULTS

In total, 30 individual interviews were conducted with formal care providers working in 21 LTCFs, including assisted living facilities, skilled nursing facilities, and adult day centers across the state of Minnesota. Fourteen participants are DCWs, 8 participants are executive-level professionals, 4 participants are registered nurses (RN) or licensed practical nurses (LPN), and 4 participants are certified nursing assistants (CNAs). Individuals recruited for the study had an average of 11.7 years of experience, with the level of experience varying widely. The minimum tenure was 6 months and the maximum was 47 years. Participant characteristics and demographics are summarized in Table 1.

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Table 1. Sample characteristics and demographics

Variable	Frequency (percent)
Sex	
Male	7 (23.3 %)
Female	23 (76.7 %)
Race/Ethnicity	
White	23 (76.7 %)
Black	4 (13.3 %)
Asian	2 (6.7 %)
Hispanic	1 (3.3 %)
Years of experience	
<1	2 (6.7 %)
1 - 5.9	8 (26.7 %)
6 - 11.9	10 (33.3 %)
12 - 19.9	5 (16.7 %)
>20	5 (16.7 %)
Job title	
Direct Care Worker (DCW)	14 (46.7%)
Certified Nursing Assistant (CNA)	4 (13.3 %)
Registered Nurse (RN) or Licensed Practical Nurse (LPN)	4 (13.3 %)
Executive-level Professional	8 (26.6 %)

Descriptive statistics of demographic characteristics. Data presented are counts (%).

Participant interviews provided insight into the scope, frequency, and impact of lost items in LTCFs and how the proposed tag technology can mitigate adverse outcomes associated with item loss. We identified five priori themes to examine in this study. The themes included (1) the utility of RTLS in LTCFs, (2) the advantages of RTLS technology in LTCFs, (3) user recommendations to enhance suitability, (4) and implementation considerations. The following results section and Table 2 describe the identified problem and the role of the tag technology within each theme and are supported by participant quotes.

Utility of RTLS in LTCFs

To address the problem of item loss within LTCFs, it is first important to understand the issue of item loss and the unique challenge of item loss in these settings. During the interviews, participants commented on which items are most commonly lost in LTCFs, how those items were lost, and the impacts of item loss on both staff and residents. These findings both align with and extend existing research on item loss in long-term care among older adults.

Commonly lost items

Participants echoed results from previous studies regarding the types of items commonly lost within LTCFs, including residents' personal belongings and care necessities, as well as facility-owned items. Personal care items and devices including glasses cases, denture cases, and hearing aids cases often go missing as they tend to be used regularly. Losing these items can be a safety

concern for older adult residents who depend on them for daily functioning, and items such as wallets, purses, keys, jewelry, phones, and clothes can be expensive to replace and may hold sentimental value. It is not only residents' items that go missing, but also facility-owned items that both residents use in personal and communal areas. In particular, respondents noted that pocket talkers, wheelchairs, MP3 players, walkers, and remote controls are commonly misplaced.

Causes of item loss

Participants shared similar sentiments to existing research about the causes of item loss in regard to monitoring items coming into the facility and resident behaviors. Notably, despite research demonstrating the positive impact of standardized inventorying processes in reducing the frequency of item loss, only a small proportion of respondents reported working in a facility with such processes in place. For example, one participant noted, *"The intake is not accurate. And when families bring in more stuff like extra clothes and pictures...even if we had an accurate inventory when the resident first got here...stuff comes in and there is no easy way to keep track of who has what from a facility side. We just let families know if you are gonna bring something in...take a picture of it and make sure it gets labeled"* (P16, Female, Executive-level Professional with 9 years of experience).

Among the LTCFs that do have inventory processes, interviewees described inconsistencies within their inventorying processes. Yet even with standardized intake and inventorying procedures, item loss may still occur, as inventorying processes do not prevent items from becoming lost when individuals experiencing cognitive decline hide items, forget where items are located, and mistakenly take other residents' items that do not belong to them. A participant noted this issue as they said, *"We are dealing with dementia patients. It might be another resident's thing but someone else might try and take it. We have a lot of them that like to pick things up that are not theirs, and it's not their fault, they can't control it"* (P9, Female, Certified Nursing Assistant with 8 years of experience).

Therefore, in order for the tagging technology to be successfully deployed within long-term care settings, facilities must have a standardized procedure for documenting and inventorying valuable possessions brought to the building.

Consequences of item loss

Furthermore, as highlighted by interviewees and supported by previous research findings, the frequent incidents of item loss within long-

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Table 2. Description of major themes with exemplary quotes

Theme	Definition	Subthemes
Utility of RTLS in LTCFs	This theme highlights the causes and consequences of the most frequently lost items in LTCFs	Commonly lost items Causes of item loss Consequences of item loss
Advantages of RTLS technology in LTCFs	This theme identifies the benefits of the tag technology and app use within LTCFs	Providing a sense of security Multiple item tracking
User recommendations to enhance suitability	This theme details the identified improvements for the physical characteristics and capabilities of the tag and app user interface	Tag adherence Tag auditory and visual cues Ensuring security and increasing accessibility Expanding range and geofencing Last location history
Implementation considerations	This theme explores the practical implications of implementing the tag technology into LTCFs	Tag technology target industries Cost considerations

RTLS: Real-time location system
LTCF: Long-term care facility

term care facilities can, unfortunately, lead to feelings of mistrust, as residents may sometimes accuse staff members of theft. This suspicion can strain the relationship between caregivers and residents, may bring about feelings of resentment among staff and erode the foundation of trust that is required for providing compassionate and effective care. Addressing this issue is vital for maintaining a positive and supportive environment where residents feel secure and staff are respected.

Together, these findings demonstrate the continued burden of item loss and the need for mitigation strategies. The proposed RTLS tag technology can serve as one of these methods but must be adapted to fit the unique needs of this specific population in this environment.

Advantages of RTLS technology in LTCFs

Overall, participants were interested in and excited about the proposed technology's potential value to mitigate item loss within the LTCF industry. Notably, participants articulated the benefits of the RTLS tag technology, such as providing an emotional sense of security, serving as an organizational tool, being a time saver, deterring theft, and effectively tracking residents and items.

Providing a sense of security

The tagging technology was assessed by respondents as helping provide a sense of security for residents and staff living in LTCFs. Theft among

residents and staff is a serious concern in dementia care. Residents with dementia, due to confusion rather than malice, may enter and take items from others' rooms. Unfortunately, other residents and staff with ill intent may take advantage of individuals with dementia vulnerability and the built trust to purposefully take items (Hildreth et al., 2011). In response to this concern, one participant stated, *"I think the residents would feel more secure, and this would discourage theft"* (P18, Female, Executive-level Professional with 11 years of experience). Additionally, when items go missing, residents may mistakenly and falsely accuse employees of stealing them which can create tensions and mistrust in the relationship between residents and employees (Alzheimer's Association, 2015; Seeman, 2018). One participant recollected an instance in which this occurred, explaining, *"A resident had lost a lotion. It was \$50 lotion. She was upset. She cried and went to management and said, 'Someone stole my lotion'. Eventually, we found it in her cabinet in the bathroom. She didn't know, but she accused us, called us thieves and liars"* (P8, Female, DCW with 18 years of experience). Therefore, residents and staff alike may experience greater peace of mind and reduced anxiety, knowing that important items can be tagged and appropriately tracked within the facility.

Multiple item tracking

Participants noted that another advantage of the proposed technology to reduce item loss is its ability to track multiple items at one time. Giv-

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en that LTCFs may have residents living across several buildings on campus, it can be difficult to manage and track all personal and facility-owned belongings. Taking advantage of the various colors the tagging technology offers can aid in this task and help keep residents and staff organized. Specifically, one DCW commented on the benefits of this feature, stating, *“I like that we can track multiple things, and it shows in different colors”* (P21, Female, DCW with 10 years of experience). The feature allowing users to monitor several items simultaneously proves beneficial to prevent item loss for those working and in long-term care settings.

User recommendations to enhance suitability

Participants offered recommendations about the tag's current design and functionality to improve its utility and ease of use by staff in LTCFs. Specifically, participants addressed concerns about the tag's ability to maintain strong adherence under various environmental exposures and the lack of auditory and visual cues.

Tag adherence

To increase the utility of the tags for those who work with older adults, it has been suggested that they are adapted to be durable enough to withstand various environmental conditions. Clothing is frequently lost and misplaced as many facilities do laundry for residents. To minimize the spread of bacteria from soiled linen and clothing, LTCFs have strict sanitary laundry protocols to follow. This often involves using strong laundry detergents and high heat to wash and dry clothing, which the tags may be exposed to (Centers for Disease Control and Prevention, 2019). One participant remarked on waterproof concerns, stating, *“Lots of items get lost in the laundry. Keeping things in their pockets and forgetting about it...So, if the tag is waterproof, the tag wouldn't be damaged”* (P8, Female, DCW with 18 years of experience). Therefore, it is recommended that the tag be water and heat-resistant. Furthermore, residents with dementia may not understand or remember the tags' purpose and consequently attempt to remove them. Thus, for respondents, suitability would be increased by ensuring that the tags can strongly adhere to the item without causing damage. In doing so, this will ensure that the RTLS tags remain securely fastened to items allowing them to be tracked for their intended use of reducing item loss.

Tag auditory and visual cues

To help find tagged items quickly if misplaced, participants recommended incorporating both auditory and visual features into the tags' design.

Although the app can notify where a tagged item is located, it may be challenging to exactly pinpoint its location if buried under other items or in a drawer, for example. One participant recommended an additional audio feature to notify users when in proximity to the lost item, suggesting, *“I think it would be great if it made a little sound or beep when I'm close to it, so it's easier to find an item”* (P23, Female, DCW with 6 years of experience). This may also increase accessibility to this product for those who are visually impaired. Furthermore, a facility may have several residents using the tag technology. Therefore, a specific color-coding system in which each individual is assigned a different color may prove beneficial to organizing tagged belongings. Overall, auditory and color features may improve the ease with which to manage tagged items and enhance the overall user experience in LTCFs.

Ensuring security and increasing accessibility

To be compliant with HIPAA regulations LTCFs follow, the user software must be secure to maintain resident confidentiality and privacy across platforms. Before using the RTLS tag technology in long-term care to help mitigate item loss, discussions regarding who and when users will have access to the technology's software and app are needed. For example, would all employees in caregiver roles have login credentials, or would this be restricted to facility administration and leadership? Additionally, would employees who have credentials be able to log into the app and obtain information outside of working hours? In response to these concerns about the technology's security, one participant asked, *“Can we revoke access of staff who are no longer working? It would be a security concern for residents if workers have the app on their phones and they never logged out”* (P13, Female, Executive-level Professional with 5 years of experience).

Furthermore, participants noted the importance of addressing the physical ways in which employees interact with the software. Depending on the available resources, LTCFs may not have access to mobile devices or tablets to download an app. Therefore, one participant recommended, *“It's fine to have an app, but a website can be better so we don't have to download an app onto our phones”* (P11, Female, Executive-level Professional with 25 years of experience). Developing a desktop version of the software may allow for increased accessibility and convenience for users working in LTCFs. Whether the software could be downloaded on any type of facility-owned or a personal device, it must have safeguards to ensure resident privacy.

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Expanding range and geofencing

Item loss is a common challenge for LTCF settings of any size, whether they have ten beds or over a hundred across several buildings within one campus location. According to participants, for the tags to be most effective in reducing item loss, the RTLS technology should have an expanded range and geofencing system. Specifically, one DCW suggested, “I think it would be beneficial if it covered the whole property” (P24, Female, DCW with 12 years of experience). Developing a more comprehensive map monitoring system within each building and across buildings would increase the location accuracy of the missing item and decrease the time needed to find it. Participants also expressed interest in incorporating geofencing technology into the software, allowing the system to notify users when a tagged item exits the specified premises. This software feature would contribute to deterring theft and providing a sense of security for both residents and staff.

Last location history

In addition to knowing the current location of a tagged item, participants expressed that it would be useful to know where the item was last located within the facility. In response to the tag technology proposal, one DCW suggested, “I think one thing that would help us find stuff easier is if the tag had a location history... that way we can understand our residents’ habits and help them in a better way”. (P29, Male, DCW with 6 months of experience).

Having a feature in which the software could track and maintain a history file of previous item locations could prove beneficial to monitoring residents’ patterns and behaviors, which addresses the needs of facilities serving persons with memory concerns. As a result, knowing the most common places where a lost item is likely to be may help staff time looking for said item.

Implementation considerations

The final theme identified from the participant interviews involved the logistical implications of purchasing and implementing the technology in the long-term care industry. Despite the overall advantages the RTLS tag technology offers to reduce item loss, respondents emphasized the importance of implementing the product in specific settings and considering the costs to both the facilities and residents.

Tag technology target industries

For the tagging technology to be most effective, it must target the appropriate audience and LTCF setting. As previously stated, larger personal belongings such as keys, purses, and wallets are frequently lost. However, such items

are typically not found in skilled nursing facilities as these populations tend to require higher levels of care. Therefore, residents living in and staff working in assisted living facilities may find the tags more useful, in which private studios or apartments are more common. As one participant recommended in response to the proposed RTLS technology, “Nursing homes may not be the market, but assisted living facilities with more room for independent living would be better to target” (P15, Female, Executive-level Professional with 26 years of experience). Identifying potential suitable buyers, in particular, residents for personal use or assisted living facilities for larger-scale implementation, is crucial to more widely increasing the likelihood of successful integration of this technology into the industry.

Cost considerations

When considering implementing this technology, a major factor for several LTCFs is the cost of the product. Given the tight budgets LTCFs have to balance, the cost may serve as a potential barrier to implementing the technology even if there is interest in purchasing the product (Burns et al., 2016; Casson & McMillen, 2003). One executive-level professional expressed concerns stating, “One thing that the management would question is that is it really worth it?” (P20, Female, Executive-level Professional with 26 years of experience). Furthermore, discussions within LTCFs are needed to determine whether the residents, the facility, or a combination of the two would pay for the technology. Thus, the overall costs of manufacturing, distributing, and implementing the RTLS tag technology must be balanced with the needs of the facility, management, and residents.

DISCUSSION

RTLS technologies have shown promising results in addressing the problem of item loss in healthcare settings, but have scarcely been deployed in facilities serving residents with memory concerns. The objective of this study was to understand long-term care staff attitudes and perspectives on the perceived utility of an RTLS device in LTCFs. Our results provide insight into the potential impacts this technology could have on improving the quality of care, operational efficiency, and the types of adaptations necessary for deploying existing RTLS systems within LTCFs, particularly those serving residents with dementia and other cognitive impairments. Results from the 30 qualitative interviews with DCWs confirm that item loss is an ongoing and unresolved problem in LTCFs. Although completely preventing item loss may prove challenging due to common hoarding and hiding behaviors, the ability to reduce the time spent searching for lost items remains advantageous. Item loss disrupts

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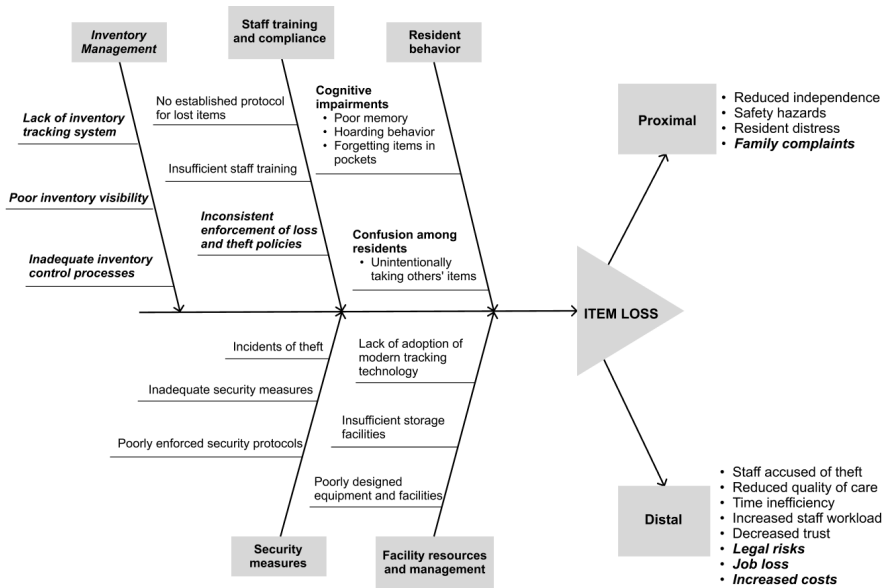


Figure 4. Fishbone diagram of the root causes and impacts of item loss based on results from participant interviews

both staff and residents; for example, the loss of critical items like glasses and dentures can make it difficult and even unsafe for residents to complete activities of daily living, such as eating and ambulating. Furthermore, inadequate staff training, lack of protocol for lost items, and intake processes are all major causes of item loss. Consequently, staff may need to provide additional assistance, which disrupts the care for other residents and strains already limited resources. Our findings reaffirm that item loss contributes to a greater sense of mistrust and tension between staff, residents, and family members, particularly due to theft accusations and other strong verbal or physical responses.

The fishbone diagram illustrates the causes and consequences of item loss, with Figure 4 presenting an adapted version that includes new categories. It includes new categories for causes like inventory management and impacts such as family complaints, decreased trust, increased costs, job loss, legal risks, and inconsistent enforcement of loss and theft policies. To reduce the causes and consequences identified in Figure 4, the LTCFs may benefit from the introduction of IATs. The RTLS tags can strengthen residents' sense of independence by helping them easily locate their belongings. This technology can reduce the incidence and accusations of theft, fostering a positive relationship between residents and care staff. Moreover, RTLS can diminish resident distress, feelings of mistrust and minimize family complaints, enhancing overall satisfaction. By pre-

venting item loss, LTCFs can mitigate legal risks, reduce associated costs, and improve time efficiency. Additionally, participants in the study identified that auditory and visual cues could aid in locating items not in plain sight. Features like color-coded tags could simplify identification and reduce confusion when used in a large care facility. Our results also indicate that improving the software is essential for privacy, user-friendliness, and accessibility. Although the RTLS technology serves as an accurate indoor tracking tool, the tags should be able to provide location tracking outside of the UWB configuration. Enhancing the technology's range and adding geofencing capabilities are important for broader monitoring across LTCF campuses, making it easier to track items that may have left the facility's premises.

For the successful implementation of RTLS technology in long-term care settings, respondents emphasized the need for the technology to be adapted to fit the unique needs of older adults with dementia and the staff. Our study confirmed the necessity for the tags to withstand conditions such as exposure to water and heat during laundry processes. Ensuring that the tags are both water- and heat-resistant is critical for their effective use in these environments. Additionally, adapting the technology to include features like location history could help staff better understand residents' habits, thereby improving the management of frequently lost items. Inadequate inventory management practices are a significant cause of item loss in both hospi-

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tals and LTCFs. Poor inventory visibility leads to situations where staff may not have a clear understanding of available supplies and their locations, resulting in misplaced items. Participants in this study expressed that the lack of protocol for inventorying aggravates item loss in LTCFs. This theme can also be extrapolated from hospital settings, emphasizing the importance of robust tracking systems in preventing such losses. Hospitals, which face similar challenges, demonstrate the need for standardized inventory management practices that could be equally beneficial in LTCFs (Elia & Gnoni, 2013; Fosso Wamba et al., 2013; Malik, 2009; Roper et al., 2015). The participants expressed interest in adopting RTLS technology into work routines to improve safety and quality of care for residents. The ability of RTLS to reduce item loss can significantly enhance operational efficiency and alleviate the disruptions caused by lost items in LTCFs. However, effective deployment requires thoughtful adaptation to the specific needs of LTCFs, particularly in terms of durability, range, and user interface. Additionally there are barriers to the effective use of RTLS in LTCFs. Standardization across facilities is essential, particularly for tracking resident belongings, as family members frequently bring additional items into the facility. Updating the software to allow family members to log valuables could aid staff in tracking and tagging items more effectively. Without a standardized intake and inventory process, the efficacy of the tag technology could be compromised. Streamlining item management in LTCFs is essential for enhancing the technology's deployment and utility.

Consideration of the financial constraints in the long-term care sector should be addressed when implementing RTLS technology. This includes improving staff training and the development of technology infrastructure to optimize the quality of care (Ko et al., 2018). Being aware of financial constraints in this sector is crucial to encourage stakeholders to invest in RTLS and product developers should also focus on creating user-friendly technologies that address issues at a lower total cost of ownership (Masciadri et al., 2019; Oude et al., 2018). Although not highlighted by participants, it is important to consider the ethical concerns related to the use of tracking technologies in care settings with vulnerable populations. The RTLS tag technology is not intended to track individuals or cell phones themselves but rather items such as clothing or facility-owned wheelchairs and other assistive technology. However, this could indirectly lead to tracking the location of individuals using these items. Therefore, residents and family members must be fully informed and

consent to the use of this technology. Future research should explore these ethical considerations and gather quantitative data to substantiate the efficacy of RTLS in alleviating the identified issues, further supporting its adoption in long-term care facilities.

CONCLUSION AND DIRECTIONS FOR FUTURE RESEARCH

The study emphasizes the impact of item loss on both staff and residents in long-term care facilities (LTCFs), highlighting the challenges of locating items promptly as a persistent issue. It is evident that the lack of standardized protocols for inventorying personal items brought into the facility exacerbates this problem. Some LTCFs have protocols, but these vary across different facilities and are influenced by factors such as the size of the facility and the resident population. This variability suggests a need for standardized procedures to record and manage items brought into LTCFs. The potential of RTLS to mitigate these challenges is notable, but the technology needs to be customized to meet the specific needs of each facility. The software component of RTLS must be user-friendly and capable of securing privacy-sensitive data, which is crucial in larger facilities. The proposed tag technology, with its user-friendly interface and login features, could be effective in large scale facilities and reduce the time and resources spent on locating lost items. Furthermore, it is important to assess the cost considerations and responsibility of bringing location systems into the industry of long-term care and to ensure that the implementation process is equitable. This will require careful consideration and cooperation among all stakeholders, including governance bodies.

After making significant changes to the RTLS tags based on the recommendations from participants in this study, future research should conduct pilot studies testing the technology with LTCF staff and residents in both assisted living and skilled nursing facilities. In doing so, privacy and ethical considerations associated with the use of location-tracking technologies with vulnerable populations should be addressed. The pilot studies should also focus on metrics like the reduction in time spent searching for lost items and include a comparative analysis of RTLS with other technologies available in the market. Researchers should further quantify the time loss and financial costs related to searching for or replacing lost items to provide a greater understanding of the potential positive impact of the RTLS tag technology in LTCFs.

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Author contributions

Conception: PG, GH
Performance of Work: AS
Interpretation or Analysis of Data: AS
Preparation of the Manuscript: AS, EM
Revision for Important Intellectual Content: JM, PG, GH
Supervision: JM

Ethical considerations

This study received ethics approval from the University of Minnesota Internal Review Board (STUDY00008368).

Conflict of interest

The authors have no conflicts of interest to report.

REFERENCES

- Ahmed, F., Phillips, M., Phillips, S., & Kim, K.-Y. (2020). Comparative Study of Seamless Asset Location and Tracking Technologies. *Procedia Manufacturing*, 51, 1138–1145. <https://doi.org/10.1016/j.promfg.2020.10.160>
- Alzheimer's Association. (2015). 2015 Alzheimer's disease facts and figures. *Alzheimer's & Dementia: The Journal of the Alzheimer's Association*, 11(3), 332–384. <https://doi.org/10.1016/j.jalz.2015.02.003>
- Alzheimer's Association. (2023). 2023 Alzheimer's disease facts and figures. *Alzheimer's & Dementia*, 19(4), 1598–1695. <https://doi.org/10.1002/alz.13016>
- Alzheimer's Association, Greater Missouri Chapter. (2017). Rummaging, Hiding, and Hoarding Behaviors (p. 3). https://www.alz.org/media/greatermissouri/rummaging_hiding_and_hoarding_behaviors.pdf
- Angulo, I., Onieva, E., Perallos, A., Salaberria, I., Bahillo, A., Azpilicueta, L., Falcone, F., Astráin, J. J., & Villadangos, J. (2015). Low Cost Real Time Location System Based in Radio Frequency Identification for the Provision of Social and Safety Services. *Wireless Personal Communications*, 84(4), 2797–2814. <https://doi.org/10.1007/s11277-015-2767-6>
- Ayers, C. R., Saxena, S., Golshan, S., & Wetherell, J. L. (2010). Age at onset and clinical features of late life compulsive hoarding. *International Journal of Geriatric Psychiatry*, 25(2), 142–149. <https://doi.org/10.1002/gps.2310>
- Bantry White, E., Montgomery, P., & McShane, R. (2010). Electronic Tracking for People with Dementia Who Get Lost outside the Home: A Study of the Experience of Familial Carers. *The British Journal of Occupational Therapy*, 73, 152–159. <https://doi.org/10.4276/030802210X12706313443901>
- Baumgarten, M., Becker, R., & Gauthier, S. (1990). Validity and Reliability of the Dementia Behavior Disturbance Scale. *Journal of the American Geriatrics Society*, 38(3), 221–226. <https://doi.org/10.1111/j.1532-5415.1990.tb03495.x>
- Berg, B., Longley, G., & Dunitz, J. (2019). Improving Clinic Operational Efficiency and Utilization with RTLS. *Journal of Medical Systems*, 43(3), 56. <https://doi.org/10.1007/s10916-019-1174-z>
- Bharucha, A. J., Anand, V., Forlizzi, J., Dew, M. A., Reynolds, C. F., Stevens, S., & Wactlar, H. (2009). Intelligent Assistive Technology Applications to Dementia Care: Current Capabilities, Limitations, and Future Challenges. *The American Journal of Geriatric Psychiatry*, 17(2), 88–104. <https://doi.org/10.1097/JGP.0b013e318187dde5>
- Bicer Kanat, B., Altunoz, U., Kirici, S., Bastug, G., & Ozel Kizil, E. T. (2016). Hoarding Behavior in Three Different Types of Dementia Cases. *Turkish Journal of Psychiatry*. <https://doi.org/10.5080/u7992>
- Boger, J., & Mihailidis, A. (2011). The future of intelligent assistive technologies for cognition: Devices under development to support independent living and aging-with-choice. *NeuroRehabilitation*, 28(3), 271–280. <https://doi.org/10.3233/NRE-2011-0655>
- Bökberg, C., Ahlström, G., & Karlsson, S. (2017). Significance of quality of care for quality of life in persons with dementia at risk of nursing home admission: A cross-sectional study. *BMC Nursing*, 16(1), 39. <https://doi.org/10.1186/s12912-017-0230-6>
- Boudet, B., Giacobini, T., Ferrané, I., Fortin, C., Mollaret, C., Lerasle, F., & Rumeau, P. (2014). Quels sont les objets égarés à domicile par les personnes âgées fragiles ? Une étude pilote sur 60 personnes. *NPG Neurologie - Psychiatrie - Gériatrie*, 14(79), 38–42. <https://doi.org/10.1016/j.npg.2013.10.004>
- Bowen, M. E., Craighead, J., Wingrave, C. A., & Kearns, W. D. (2010). Real-Time Locating Systems (RTLS) to improve fall detection. *Gerontechnology*, 9(4), 464–471. <https://doi.org/10.4017/gt.2010.09.04.005.00>
- Brazier, J. F., Geng, F., Meehan, A., White, E. M., McGarry, B. E., Shield, R. R., Grabowski, D. C., Rahman, M., Santostefano, C., & Gadbois, E. A. (2023). Examination of Staffing Shortages at US Nursing Homes During the COVID-19 Pandemic. *JAMA Network Open*, 6(7), e2325993. <https://doi.org/10.1001/jamanetworkopen.2023.25993>
- Brodady, H., Draper, B., & Low, L.-F. (2003). Nursing home staff attitudes towards residents with dementia: Strain and satisfaction with work. *Journal of Advanced Nursing*, 44(6), 583–590. <https://doi.org/10.1046/j.0309-2402.2003.02848.x>
- Burns, D., Cowie, L., Earle, J., Folkman, P., Froud, J., Hyde, P., Johal, S., Jones, I. R., Killett, A., & Williams, K. (2016). Where does the money go? Financialised chains and the crisis in residential care.
- Cahill, S., Begley, E., Faulkner, J. P., & Hagen, I. (2007). "It gives me a sense of independence" – Findings from Ireland on the use and usefulness of assistive technology for people with dementia. *Technology and Disability*, 19(2–3), 133–142. <https://doi.org/10.3233/TAD-2007-192-310>
- Caspi, E., Xue, W.-L., & Liu, P.-J. (2023). Theft of Controlled Substances in Long-Term Care Homes: An Exploratory Study. *Journal of Applied Gerontology: The Official Journal of the Southern Gerontological Society*, 42(7), 1588–1599. <https://doi.org/10.1177/07334648231153731>

Suitability and adaptability of a real-time location system

- Casson, J. E., & McMillen, J. (2003). Protecting nursing home companies: Limiting liability through corporate restructuring. *Journal of Health Law*, 36(4), 577–613.
- Centers for Disease Control and Prevention. (2019, April 2). Laundry | Background | Environmental Guidelines | Guidelines Library | Infection Control | CDC. <https://www.cdc.gov/infectioncontrol/guidelines/environmental/background/laundry.html>
- Chen, R., & Chen, L. (2021). Smartphone-Based Indoor Positioning Technologies. In W. Shi, M. F. Goodchild, M. Batty, M.-P. Kwan, & A. Zhang (Eds.), *Urban Informatics* (pp. 467–490). Springer. https://doi.org/10.1007/978-981-15-8983-6_26
- Clarke, D., & Park, M. D. (2006). Active-RFID System Accuracy and Its Implications for Clinical Applications. 21–26. <https://doi.org/10.1109/CBMS.2006.33>
- Cohen-Mansfield, J., Marx, M. S., & Rosenthal, A. S. (1990). Dementia and Agitation in Nursing Home Residents: How Are They Related? *Psychology and Aging*, 5(1), 3–8. <https://doi.org/10.1037/0882-7974.5.1.3>
- Costello, H., Walsh, S., Cooper, C., & Livingston, G. (2019). A systematic review and meta-analysis of the prevalence and associations of stress and burnout among staff in long-term care facilities for people with dementia. *International Psychogeriatrics*, 31(8), 1203–1216. <https://doi.org/10.1017/S1041610218001606>
- Daly Lynn, J., Rondón-Sulbarán, J., Quinn, E., Ryan, A., McCormack, B., & Martin, S. (2019). A systematic review of electronic assistive technology within supporting living environments for people with dementia. *Dementia* (London, England), 18(7–8), 2371–2435. <https://doi.org/10.1177/1471301217733649>
- Dardari, D., Closas, P., & Djurić, P. M. (2015). Indoor Tracking: Theory, Methods, and Technologies. *IEEE Transactions on Vehicular Technology*, 64(4), 1263–1278. <https://doi.org/10.1109/TVT.2015.2403868>
- Diefenbach, G. J., DiMauro, J., Frost, R., Steketee, G., & Tolin, D. F. (2013). Characteristics of Hoarding in Older Adults. *The American Journal of Geriatric Psychiatry*, 21(10), 1043–1047. <https://doi.org/10.1016/j.jagp.2013.01.028>
- Ding, B., Chen, L., Chen, D., & Yuan, H. (2008). Application of RTLS in Warehouse Management Based on RFID and Wi-Fi. 2008 4th International Conference on Wireless Communications, Networking and Mobile Computing, 1–5. <https://doi.org/10.1109/WiCom.2008.1249>
- Drake, A. (2020). Direct care work is real work: Elevating the role of the direct care worker (p. 43). PHI. <https://www.phinational.org/wp-content/uploads/2020/07/Direct-Care-Work-Is-Real-Work-2020-PHI.pdf>
- Ferracuti, N., Norscini, C., Frontoni, E., Gabellini, P., Paolanti, M., & Placidi, V. (2019). A business application of RTLS technology in Intelligent Retail Environment: Defining the shopper's preferred path and its segmentation. *Journal of Retailing* and Consumer Services, 47, 184–194. <https://doi.org/10.1016/j.jretconser.2018.11.005>
- Fisher, J. A., & Monahan, T. (2012). Evaluation of real-time location systems in their hospital contexts. *International Journal of Medical Informatics*, 81(10), 705–712. <https://doi.org/10.1016/j.ijmedinf.2012.07.001>
- Fosso Wamba, S., Anand, A., & Carter, L. (2013). A literature review of RFID-enabled healthcare applications and issues. *International Journal of Information Management*, 33(5), 875–891. <https://doi.org/10.1016/j.ijinfomgt.2013.07.005>
- Gholamhosseini, L., Sadoughi, F., & Safaei, A. (2019). Hospital Real-Time Location System (A Practical Approach in Healthcare): A Narrative Review Article. *Iranian Journal of Public Health*, 48(4), 593–602.
- Goyal, D., Balamurugan, S., Senthilnathan, K., Annapoorani, I., & Israr, M. (Eds.). (2022). Chapter 7: RTLS: An Introduction. In *Cyber-Physical Systems and Industry 4.0: Practical Applications and Security Management*. Apple Academic Press. <https://doi.org/10.1201/97811003129790>
- Grigorovich, A., Kulandaivelu, Y., Newman, K., Bianchi, A., Khan, S. S., Iaboni, A., & McMurray, J. (2021). Factors Affecting the Implementation, Use, and Adoption of Real-Time Location System Technology for Persons Living With Cognitive Disabilities in Long-term Care Homes: Systematic Review. *Journal of Medical Internet Research*, 23(1), e22831. <https://doi.org/10.2196/22831>
- Hall, A., Brown Wilson, C., Stanmore, E., & Todd, C. (2019). Moving beyond 'safety' versus 'autonomy': A qualitative exploration of the ethics of using monitoring technologies in long-term dementia care. *BMC Geriatrics*, 19(1), 145. <https://doi.org/10.1186/s12877-019-1155-6>
- Hall, A., Wilson, C. B., Stanmore, E., & Todd, C. (2017). Implementing monitoring technologies in care homes for people with dementia: A qualitative exploration using Normalization Process Theory. *International Journal of Nursing Studies*, 72, 60–70. <https://doi.org/10.1016/j.ijnurstu.2017.04.008>
- Hamilton, L., Fay, S., & Rockwood, K. (2009). Misplacing objects in mild to moderate Alzheimer's disease: A descriptive analysis from the VISTA clinical trial. *Journal of Neurology, Neurosurgery & Psychiatry*, 80(9), 960–965. <https://doi.org/10.1136/jnnp.2008.166801>
- Han, X., Yaraghi, N., & Gopal, R. (2018). Winning at All Costs: Analysis of Inflation in Nursing Homes' Rating System. *Production and Operations Management*, 27(2), 215–233. <https://doi.org/10.1111/poms.12804>
- Heisey-Grove, D., Danehy, L.-N., Consolazio, M., Lynch, K., & Mostashari, F. (2014). A national study of challenges to electronic health record adoption and meaningful use. *Medical Care*, 52(2), 144–148. <https://doi.org/10.1097/MLR.0000000000000038>
- Hildreth, C. J., Burke, A. E., & Golub, R. M. (2011). Elder Abuse. *JAMA*, 306(5), 568. <https://doi.org/10.1001/jama.306.5.568>
- Hwang, J.-P., Tsai, S.-J., Yang, C.-H., Liu, K.-M., & Lirng, J.-F. (1998). Hoarding Behavior in Dementia

Suitability and adaptability of a real-time location system

- tia: A Preliminary Report. *The American Journal of Geriatric Psychiatry*, 6(4), 285–289. <https://doi.org/10.1097/00019442-199800640-00003>
- Ienca, M., Jotterand, F., Elger, B., Caon, M., Pappagallo, A., Kressig, R., & Wangmo, T. (2017). Intelligent Assistive Technology for Alzheimer's Disease and Other Dementias: A Systematic Review. *Journal of Alzheimer's Disease*, 56, 1–40. <https://doi.org/10.3233/JAD-161037>
- Ienca, M., Wangmo, T., Jotterand, F., Kressig, R. W., & Elger, B. (2018). Ethical Design of Intelligent Assistive Technologies for Dementia: A Descriptive Review. *Science and Engineering Ethics*, 24(4), 1035–1055. <https://doi.org/10.1007/s11948-017-9976-1>
- Jahn, H. (2013). Memory loss in Alzheimer's disease. *Dialogues in Clinical Neuroscience*, 15(4), 445–454.
- Jones, T. L., & Schlegel, C. (2014). Can Real Time Location System Technology (RTLs) Provide Useful Estimates of Time Use by Nursing Personnel? *Research in Nursing & Health*, 37(1), 75–84. <https://doi.org/10.1002/nur.21578>
- Kamel Boulos, M. N., & Berry, G. (2012). Real-time locating systems (RTLs) in healthcare: A condensed primer. *International Journal of Health Geographics*, 11(1), 25. <https://doi.org/10.1186/1476-072X-11-25>
- Kim, H. J., Steketee, G., & Frost, R. O. (2001). Hoarding by elderly people. *Health & Social Work*, 26(3), 176–184. <https://doi.org/10.1093/hsw/26.3.176>
- Ko, M., Wagner, L., & Spetz, J. (2018). Nursing Home Implementation of Health Information Technology: Review of the Literature Finds Inadequate Investment in Preparation, Infrastructure, and Training. *Inquiry: A Journal of Medical Care Organization, Provision and Financing*, 55, 46958018778902. <https://doi.org/10.1177/0046958018778902>
- Lapane, K., & Hughes, C. (2007). Considering the Employee Point of View: Perceptions of Job Satisfaction and Stress Among Nursing Staff in Nursing Homes. *Journal of the American Medical Directors Association*, 8(1), 8–13. <https://doi.org/10.1016/j.jamda.2006.05.010>
- Lee-Cheong, S., Amanullah, S., & Jardine, M. (2022). New assistive technologies in dementia and mild cognitive impairment care: A PubMed review. *Asian Journal of Psychiatry*, 73, 103135. <https://doi.org/10.1016/j.ajp.2022.103135>
- Lopes, P., Pino, M., Carletti, G., Hamidi, S., Legué, S., Kerhervé, H., Benveniste, S., Andéol, G., Bonsom, P., Reingewirtz, S., & Rigaud, A.-S. (2016). Co-Conception Process of an Innovative Assistive Device to Track and Find Misplaced Everyday Objects for Older Adults with Cognitive Impairment: The TROUVE Project. *IRBM*, 37(2), 52–57. <https://doi.org/10.1016/j.irbm.2016.02.004>
- Manly, J. J., Jones, R. N., Langa, K. M., Ryan, L. H., Levine, D. A., McCammon, R., Heeringa, S. G., & Weir, D. (2022). Estimating the Prevalence of Dementia and Mild Cognitive Impairment in the US: The 2016 Health and Retirement Study Harmonized Cognitive Assessment Protocol Project. *JAMA Neurology*, 79(12), 1242–1249. <https://doi.org/10.1001/jamaneuro.2022.3543>
- Mann, J., & Doshi, M. (2017). An investigation into denture loss in hospitals in Kent, Surrey and Sussex. *British Dental Journal*. <https://doi.org/10.1038/sj.bdj.2017.728>
- Marx, M. S., & Cohen-Mansfield, J. (2003). Hoarding Behavior in the Elderly: A Comparison Between Community-Dwelling Persons and Nursing Home Residents. *International Psychogeriatrics*, 15(3), 289–306. <https://doi.org/10.1017/S1041610203009542>
- Marzano, S. (2022). Improving Inpatient Belonging Process to Eliminate Reimbursement Costs and Improve Patient Satisfaction [Masteressay, University of Pittsburgh]. <https://d-scholarship.pitt.edu/42613/>
- Masciadri, A., Comai, S., & Salice, F. (2019). Well-ness Assessment of Alzheimer's Patients in an Instrumented Health-Care Facility. *Sensors (Basel, Switzerland)*, 19(17), 3658. <https://doi.org/10.3390/s19173658>
- Megalingam, R. K., P, V. K. Tejaswi., Kota, A. H., & Reddy, C. P. K. (2022). Indoor Tracking of Dementia Patients without GPS. 2022 2nd International Conference on Innovative Practices in Technology and Management (ICIPTM), 2, 471–476. <https://doi.org/10.1109/ICIPTM54933.2022.9753888>
- Mitchell, E., Tavares, T. P., Palaniyappan, L., & Finger, E. C. (2019). Hoarding and obsessive-compulsive behaviours in frontotemporal dementia: Clinical and neuroanatomic associations. *Cortex*, 121, 443–453. <https://doi.org/10.1016/j.cortex.2019.09.012>
- Munyisia, E. N., Yu, P., & Hailey, D. (2011). How nursing staff spend their time on activities in a nursing home: An observational study. *Journal of Advanced Nursing*, 67(9), 1908–1917. <https://doi.org/10.1111/j.1365-2648.2011.05633.x>
- Nordsletten, A. E., Reichenberg, A., Hatch, S. L., Cruz, L. F. de la, Pertusa, A., Hotopf, M., & Mataix-Cols, D. (2013). Epidemiology of hoarding disorder. *The British Journal of Psychiatry*, 203(6), 445–452. <https://doi.org/10.1192/bjp.bp.113.130195>
- Ochieng, N., Chidambaram, P., & Published, M. M. (2022, April 4). Nursing Facility Staffing Shortages During the COVID-19 Pandemic. KFF. <https://www.kff.org/coronavirus-covid-19/issue-brief/nursing-facility-staffing-shortages-during-the-covid-19-pandemic/>
- Oestreicher, L. (2014). Finding Keys for People with Mild Dementia – Not Just a Matter of Beeping and Flashing. In D. D. Schmorrow & C. M. Fidopias-tis (Eds.), *Foundations of Augmented Cognition. Advancing Human Performance and Decision-Making through Adaptive Systems* (pp. 315–324). Springer International Publishing. https://doi.org/10.1007/978-3-319-07527-3_30
- Okoniewska, B., Graham, A., Gavrilova, M., Wah, D., Gilgen, J., Coke, J., Burden, J., Nayyar, S., Kaunda, J., Yergens, D., Baylis, B., Ghali, W. A., & Ward of the 21st Century team. (2012). Multidimensional evaluation of a radio frequency identification wi-fi location tracking system in an acute-care hospital

Suitability and adaptability of a real-time location system

- setting. *Journal of the American Medical Informatics Association*: JAMIA, 19(4), 674–679. <https://doi.org/10.1136/amiajnl-2011-000560>
- Oude, W. C. E., Felix, E., Verkuijlen, P. J. E. M., Dierick-van, D. A. T. M., Kazak, J. K., & van, H. J. (2018). Real-time location systems in nursing homes: State of the art and future applications. *Journal of Enabling Technologies*, 12(2), 45–56. <https://doi.org/10.1108/JET-11-2017-0046>
- Oude Weernink, C. E., Sweegers, L., Relou, L., van der Zijpp, T. J., & van Hoof, J. (2017). Lost and misplaced items and assistive devices in nursing homes: Identifying problems and technological opportunities through participatory design research. *Technology and Disability*, 29(3), 129–140. <https://doi.org/10.3233/TAD-170179>
- Overmann, K. M., Wu, D. T. Y., Xu, C. T., Bindhu, S. S., & Barrick, L. (2021). Real-time locating systems to improve healthcare delivery: A systematic review. *Journal of the American Medical Informatics Association*: JAMIA, 28(6), 1308–1317. <https://doi.org/10.1093/jamia/ocab026>
- Paiva, S., Brito, D., & Leiva-Marcon, L. (2018). Real Time Location Systems Adoption in Hospitals—A Review and A Case Study for Locating Assets.
- Pappadà, A., Chattat, R., Chirico, I., Valente, M., & Ottoboni, G. (2021). Assistive Technologies in Dementia Care: An Updated Analysis of the Literature. *Frontiers in Psychology*, 12. <https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2021.644587>
- Powers, B. A. (2003). The significance of losing things for nursing home residents with dementia and their families. *Journal of Gerontological Nursing*, 29(11), 43–52. <https://doi.org/10.3928/0098-9134-20031101-10>
- Raad, M. Wasim., Deriche, M., & Kanoun, O. (2021). An RFID-Based Monitoring and Localization System for Dementia Patients. 2021 18th International Multi-Conference on Systems, Signals & Devices (SSD), 1–7. <https://doi.org/10.1109/SSD52085.2021.9429375>
- Rabinowitz, J., Davidson, M., De Deyn, P. P., Katz, I., Brodaty, H., & Cohen-Mansfield, J. (2005). Factor analysis of the Cohen-Mansfield Agitation Inventory in three large samples of nursing home patients with dementia and behavioral disturbance. *The American Journal of Geriatric Psychiatry: Official Journal of the American Association for Geriatric Psychiatry*, 13(11), 991–998. <https://doi.org/10.1176/appi.ajgp.13.11.991>
- Rachel, H., & Francesco, S. (2018). Factors associated with and impact of burnout in nursing and residential home care workers for the elderly. *Acta Bio Medica : Atenei Parmensis*, 89(Suppl 7), 60–69. <https://doi.org/10.23750/abm.v89i7-5.7830>
- Reinsch, M. (2020). The Adoption of RTLS in Healthcare. In *Crossing Borders—Digital Transformation and the U.S. Health Care System* (pp. 183–201). https://doi.org/10.15495/EPub_UBT_00004920
- Samuels, J. F., Bienvenu, O. J., Grados, M. A., Cullen, B., Riddle, M. A., Liang, K., Eaton, W. W., & Nestadt, G. (2008). Prevalence and correlates of hoarding behavior in a community-based sample. *Behaviour Research and Therapy*, 46(7), 836–844. <https://doi.org/10.1016/j.brat.2008.04.004>
- Scales, K. (2021). It Is Time to Resolve the Direct Care Workforce Crisis in Long-Term Care. *The Gerontologist*, 61(4), 497–504. <https://doi.org/10.1093/geront/gnaa116>
- Seeman, M. V. (2018). Understanding the Delusion of Theft. *Psychiatric Quarterly*, 89(4), 881–889. <https://doi.org/10.1007/s11126-018-9588-1>
- Shenk, D., Kuwahara, K., & Zablotsky, D. (2004). Older women's attachments to their home and possessions. *Journal of Aging Studies*, 18(2), 157–169. <https://doi.org/10.1016/j.jaging.2004.01.006>
- Steketee, G., & Frost, R. (2003). Compulsive hoarding: Current status of the research. *Clinical Psychology Review*, 23(7), 905–927. <https://doi.org/10.1016/j.cpr.2003.08.002>
- Thiede, S., Sullivan, B., Damgrave, R., & Lutters, E. (2021). Real-time locating systems (RTLS) in future factories: Technology review, morphology and application potentials. *Procedia CIRP*, 104, 671–676. <https://doi.org/10.1016/j.procir.2021.11.113>
- van Hoof, J., Douven, B., Janssen, B. M., Bosems, W. P. H., Oude Weernink, C. E., & Vossen, M. B. (2016). Losing Items in the Psychogeriatric Nursing Home: The Perspective of Residents and Their Informal Caregivers. *Gerontology & Geriatric Medicine*, 2, 23337214166669895. <https://doi.org/10.1177/23337214166669895>
- van Hoof, J., Janssen, M. L., Heesackers, C. M. C., Van Kersbergen, W., Severijns, L. E. J., Willems, L. A. G., Marston, H. R., Janssen, B. M., & Nieboer, M. E. (2016). The Importance of Personal Possessions for the Development of a Sense of Home of Nursing Home Residents. *Journal of Housing For the Elderly*, 30(1), 35–51. <https://doi.org/10.1080/02763893.2015.1129381>
- van Hoof, J., Verboor, J., Oude Weernink, C. E., Sponelee, A. a. G., Sturm, J. A., Kazak, J. K., Govers, G. M. J., & Van Zaalen, Y. (2018). Real-Time Location Systems for Asset Management in Nursing Homes: An Explorative Study of Ethical Aspects. *Information*, 9(4), Article 4. <https://doi.org/10.3390/info9040080>
- Wang, B., Toobaie, M., Danskin, R., Ngarmnil, T., Pham, L., & Pham, H. (2013). Evaluation of RFID and Wi-Fi technologies for RTLS applications in healthcare centers. 2013 Proceedings of PICMET '13: Technology Management in the IT-Driven Services (PICMET), 2690–2703. <https://ieeexplore.ieee.org/document/6641708>
- Wang, C.-J., Pai, M.-C., Hsiao, H.-S., & Wang, J.-J. (2015). The investigation and comparison of the underlying needs of common disruptive behaviours in patients with Alzheimer's disease. *Scandinavian Journal of Caring Sciences*, 29(4), 769–775. <https://doi.org/10.1111/scs.12208>
- Wang, J.-J., Feldt, K., & Cheng, W.-Y. (2012). Characteristics and Underlying Meaning of Hoarding Behavior in Elders With Alzheimer's Dementia: Caregivers' Perspective. *Journal of Nursing Research*, 20(3), 189. <https://doi.org/10.1097/jnr.0b013e3182656132>

Suitability and adaptability of a real-time location system

- Wangmo, T., Lipps, M., Kressig, R. W., & Ienca, M. (2019). Ethical concerns with the use of intelligent assistive technology: Findings from a qualitative study with professional stakeholders. *BMC Medical Ethics*, 20(1), 98. <https://doi.org/10.1186/s12910-019-0437-z>
- Xu, H., Intrator, O., & Bowblis, J. R. (2020). Shortages of Staff in Nursing Homes During the COVID-19 Pandemic: What are the Driving Factors? *Journal of the American Medical Directors Association*, 21(10), 1371–1377. <https://doi.org/10.1016/j.jamda.2020.08.002>
- Zheng, Q.-L., Tian, Q., Hao, C., Gu, J., Lucas-Carrasco, R., Tao, J.-T., Liang, Z.-Y., Chen, X.-L., Fang, J.-Q., Ruan, J.-H., Ai, Q.-X., & Hao, Y.-T. (2014). The role of quality of care and attitude towards disability in the relationship between severity of disability and quality of life: Findings from a cross-sectional survey among people with physical disability in China. *Health and Quality of Life Outcomes*, 12, 25. <https://doi.org/10.1186/1477-7525-12-25>
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