Literature Review

THE CENTER FOR HEALTH DESIGN®

Health Environments Research
& Design Journal
1-20

DOI: 10.1177/19375867221100210
journals.sagepub.com/home/her
SAGE

Toward an Integrated Context-Based Design Approach for Dementia Residential Care Homes: A Review of Key Operational Design Problems

Ghasson Shabha, FCIBSE, MBIFM, PG Cert Ed., FHEA, IOSH[1], David J. Edwards, PhD[1], Kristi Gaines, PhD, IIDA, ASID[2], and Paul Laycok, MSc, PGCer Ed., MCIOB, MCIAT[1]

Abstract

Objectives, Purpose, or Aim: This article seeks to develop a context-based management system focusing on assessing key operational and design problems and affecting wayfinding in dementia residential care homes. **Background:** Dementia is multifaceted neurocognitive impairments largely attributed to cognitive deterioration manifested in memory loss and visuospatial deficit which have wider practical implications to both environmental safety and wayfinding and navigation of dementia user. Two key questions were addressed in this context: (1) How can cognitively facilitating assistive technology (AT) be made more user-focused to mitigate the impacts of cognitive impairments on environmental safety and wayfinding? (2) How can design intervention and changes in design topology, colors and texture, and internal finishing aid wayfinding, navigation, and orientation in dementia residential care homes? **Method:** A systematic literature review and analysis was undertaken to assess the efficacy of key cognitively-related AT to support activities of daily living and environmental safety of dementia sufferers in a care home and aid wayfinding, navigation, and orientation. **Results:** Several key design variables to facilitate wayfinding and spatial orientation were identified which include design topology, floor finishing, signposting, and use of color and texture strengthened by meaning, emotional connection to places and cognitively focused intervention via memory cueing and objects-centered recognition. **Conclusions:** Key operational and design guidelines were proposed to assist built environment, care home developers, clinicians and healthcare professionals, and care services providers. There is a need to move toward a dementia-centered design to address the challenges facing people living with dementia in care homes. This should be based on the interrelated behavioral, cognitive, and communication factors.

[1] School of Engineering and the Built Environment, Birmingham City University, Birmingham, United Kingdom
[2] Department of Design, Texas Tech University (TTU), Lubbock, TX, USA

Corresponding Author:
Ghasson Shabha, FCIBSE, MBIFM, PG Cert Ed., FHEA, IOSH, School of Engineering and the Built Environment, Birmingham City University, MP470, Birmingham B4 7XG, United Kingdom.
Email: ghasson.shabha@bcu.ac.uk

Keywords
assistive technology, cognitive impairment, dementia, navigation, spatial design

Dementia is a multifaceted neurocognitive impairment which is exasperated by a wide range of age-related medical conditions including, *inter alia*, mobility and movement, diabetes, heart and cardiovascular condition, and visual and hearing impairments. It is estimated that this condition affects more than two third of the population of the residential care home in Britain and 50% in the United States and has a far-reaching and devastating impact on affected individuals and family members caring for them (Cooper, 2014; Public Health England, 2016). As documented by the Alzheimer's Society UK (2020), actual figures about the extent of the problem vary considerably depending on selection criteria and the quality of care adapted and received to meet the needs of individuals with dementia. It is estimated that there are 850,000 people with dementia in the United Kingdom, which is predicted to rise to 1.6 million by 2040 with 70% of people in residential care homes having dementia or severe memory problems. There are over 42,000 people under the age of 65 with dementia and more than 25,000 people from Black, Asian, and minority ethnic groups are also affected (Alzheimer's Society UK, 2020). It is estimated that the total cost of care for people with dementia in the United Kingdom in 2020 is £34.7 billion which is set to rise sharply over the next two decades to a staggering £94.1 billion by 2040. The cost of social care for people with dementia is set to nearly treble by 2040, increasing from £15.7 billion in 2020 to £45.4 billion (Alzheimer's Society UK, 2020). In the United States, approximately 5 million people are living with age-related dementia (World Health Organization [WHO], 2019). Worldwide, an estimated 50 million people have dementia. According to the WHO of those worldwide, roughly 60% live in low to middle-income countries (WHO, 2019). Key features of dementia are shown in Table 1. This includes several acquired neurocognitive impairments such as (1) memory loss; (2) aphasia (inability to speak); (3) apraxia (a disorder of motor planning and clumsiness); (4) agnosia (inability to recognize shapes, objects, and individuals); and (5) executive dysfunction including planning, sequencing, monitoring, and decision making. These symptoms were observed to be crippling for many people with dementia given the processing complexities involved (Hughes, 2011).

Other cognitive impairments include spatial disorientation attributed primarily to memory loss (Monacelli et al., 2003) dyspraxia which is a form of development co-ordination disorder (DCD) affecting both fine and gross motor skills characterized by poor eye contact and visuospatial dysfunction (Buettner et al., 2010; Daykin et al., 2008; Liu et al., 1991; Passini et al., 1998). Individuals who suffer from DCD exhibit a wide range of difficulties in memory, perception, and processing albeit to a varying degree.

While DCD is often regarded as an umbrella term to cover motor coordination difficulties, it is well-documented that dyspraxia implies additional problems for dementia manifested in planning, organizing, and carrying out movements in the right order in everyday situations. It can also affect articulation and speech as well as perception and thought (Liu et al., 1991; Monacelli et al., 2003). These problems will have a wider implication to the design of dementia environment as well as the safety and well-being of people living with dementia (Lorusso et al., 2017).

Dementia-specific changes in orientation strategies are attributed to the loss of planning abilities and getting lost in unfamiliar locations due to a lack of spatial understanding. Lack of orientation strategies can lead to loss of direction in the wider built environment (Passini et al., 1995, 1998). Such deterioration is already mentioned as Stage 3 of the Global Deterioration Scale (Reisberg et al., 1982). Practical implications of cognitive impairments associated with dementia affect both activities of daily living (ADL) and occupational performance of people living with

Table 1. Key Criteria for Dementia.

	Type of Impairment	Key Characteristics
1	Memory loss (short-term)	Cognitive memory impairment Information encoding and retrieval Visuospatial deficit
2	Aphasia (inability to speak)	Intermittent or lack of verbal communication, loss of language
3	Apraxia (disorder of motor planning and clumsiness)	Fine and motor skills impairment
4	Agnosia (inability to recognize shapes, objects and individuals)	Information encoding and retrieval. Visual memory
5	Executive dysfunction (planning, sequencing, monitoring, and decision making	Decision making and planning

Source. Alzheimer's Society UK (2020).

dementia both indoor and in the wider built environment. ADL is referring to all the essential, basic self-care tasks that people need to do every day to keep themselves safe, healthy, clean, and feeling good. This could prove to be challenging for people with dementia and can impact on their functional and independent living skills.

The visuospatial deficit was identified to have wider practical implications to both safety and well-being, and wayfinding and navigation of people with dementia (Possin, 2010).

Method

A systematic literature review was conducted to identify existing articles and papers related to wayfinding for dementia. This was guided two key research questions: (1) How can cognitively facilitating assistive technology (AT) be made more user-focused to mitigate the impacts of cognitive impairments on environmental safety and wayfinding? and (2) How can design intervention and changes in design typology, colors, and textures, and internal finishing aid wayfinding, navigation, and orientation in dementia residential care homes? The purpose of this article is to gain an in-depth understanding of the current thinking regarding wayfinding research and development in cognitive AT.

Critical analysis and academic rigor were adopted throughout to arrive at wide and clear definitions of the key issues and to ensure searches are not overlooked. This was then refined by assessing the quality of the research papers by a further detailed examination.

Data Selection and Search Strategy

Prior to identifying relevant research work, it becomes important to have clearly defined criteria to narrow down the search process based on relevant key words (Higgins & Green, 2011). The search includes titles, abstract, and body text using various web search engines including PubMed, Science Direct, Elsevier, Cochrane Database, Web of Science, Ovid MEDLINE, and Scopus online repository using key words including "cognitive assistive technology for dementia," "wayfinding for dementia," "design layout and wayfinding," "design typology and wayfinding." Greater attention was given to technical terminology related to dementia as used in other countries to include, for example, "long-term residential care home," "care home," "homes for older adults with dementia," "homes for senior adults," and "nursing homes." Relevant design and wayfinding indicators were filtered and refined further to ensure greater focus. When searching key words, a query logic is modified to reflect the language used by each system and search engine.

Study Selection

A two-phase preliminary assessment was undertaken before full papers review to ensure a focused approach is fully adhered to. This was performed independently by two members of the

research team and only those papers rejected by both reviewers were excluded and removed. Based on the initial assessment of titles and abstracts 206 English written papers from 1989 to 2019 were identified from the databases above. A total of 164 papers were subsequently screened, and a total of 134 papers were sought for retrieval. Only 117 papers were assessed for eligibility where abstracts were thoroughly analyzed and scrutinized based on clarity and relevance, methodical approach adopted, number of citations, and whether they were considered as landmark papers in other relevant literature.

Several eligibility criteria were considered for inclusion in this article as follows:

- Type of study: qualitative based on participant/ peer group observation, conversational observation, focused interviews or quantitative based on a survey/questionnaire or research;
- The influence of the design typology on wayfinding of people with dementia;
- The use of ATs to improve wayfinding and environmental safety of people with dementia;
- Study participants were people with dementia; and
- The participants were living in long-term residential care homes.

Results Extraction

A flow diagram for study selection was adopted from Page et al. (2021). This was developed and refined further for the review process. As shown in Figure 1, only 75 papers were considered relevant and their full texts were reviewed independently by all four research team members to identify the key focus and points of emphasis and to determine whether the papers are design-focused or AT-focused. Any disagreement was resolved through further reflective team discussion to achieve consensus.

Reference lists of reviewed papers were searched manually for further literature information and detailed empirical data. The majority of selected papers were conducted in the United Kingdom ($n = 33$). Twenty-one papers were conducted in the United States, six in Canada, four in the Netherlands, six in Germany, two in Australia, and three in Asia.

Assessment of the Methodical Quality

The purpose of the review was to identify (1) the current assistive technologies to facilitate wayfinding and minimize environmental and safety risks involved with dementia and (2) the key influential design characteristics related to wayfinding. The papers were analyzed based on their aims and objectives, research methods, findings, benefits and outcomes, using a standardized data sheet. Data and results were extracted based on the level of evidence provided given the wide range of methods involved.

Research related to dementia is largely qualitative and interpretive, encompassing focus groups interview, semistructured interviews with caregivers and dementia care home managers, participant observation, conversational observations, and behavioral monitoring and mapping (Bryman, 2016). There are many ethical research issues involved intertwined with operational difficulties to obtain data due to a wide range of cognitive impairments associated with dementia. These militate against any robust and rigorous analysis incorporated in quantitative research such as single and double-blind controlled placebo, randomized controlled trials, cross-sectional, or large-scale questionnaire or survey using a large sample of participants.

An attempt was made to assess the selected studies in terms of the validity and robustness of the methodology adopted in relation to the results obtained. A system of classification was developed to compare and contrast the studies and assign a score based on the type of research methods involved and evidence levels presented by each study (Dawes et al., 2005; Sackett et al., 1996). This was based on a five-point ordinal scale ranging from 1 (*high*) to 5 (*low*). Scoping and systematic reviews papers were excluded from the review despite the quality of design and wayfinding guidelines provided. Papers at Levels 4 and 5 funded by ATs manufacturers and suppliers were also excluded from this review despite the guidelines and recommendations due to not meeting the

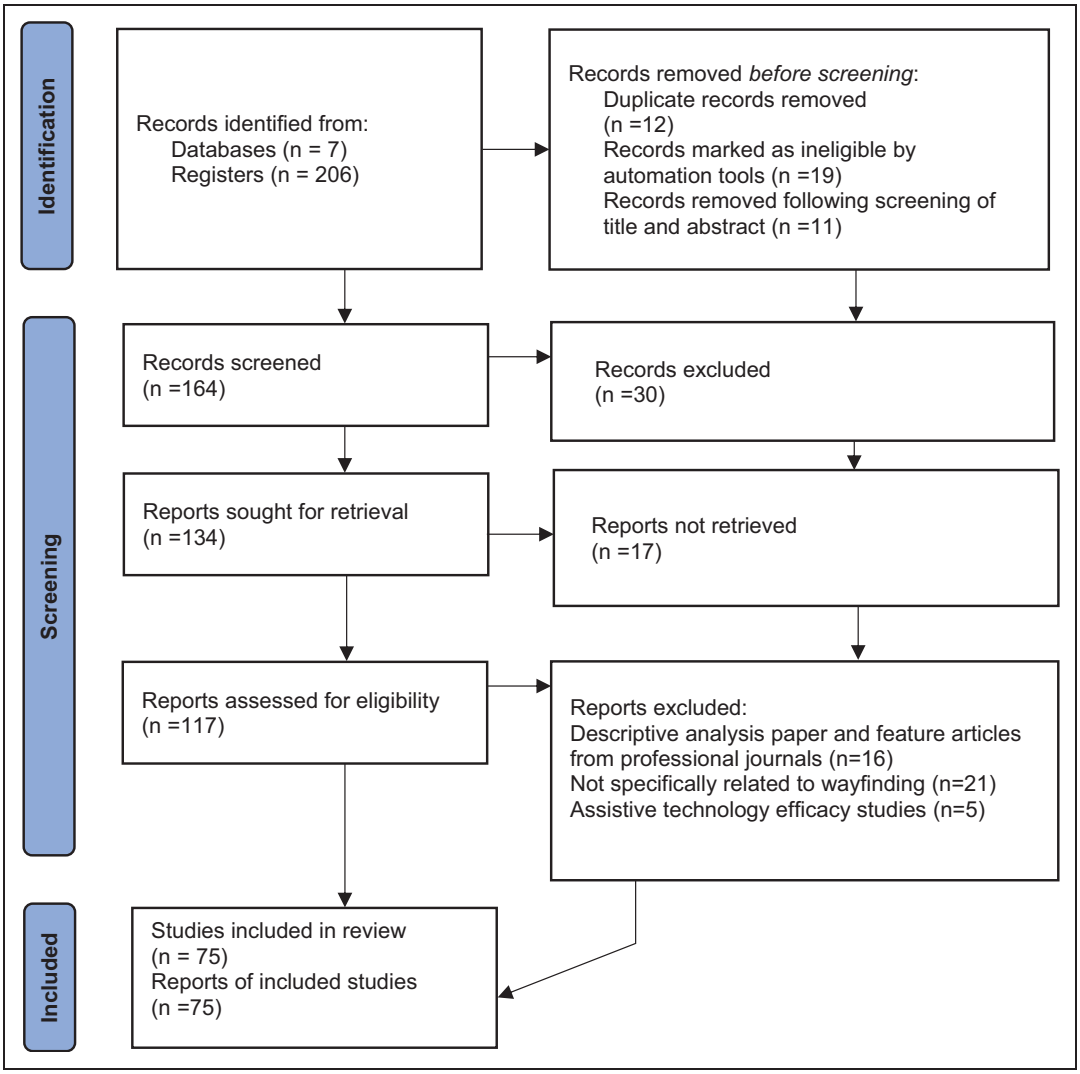

Figure 1. Study selection (Page et al., 2021).

inclusion criteria. Professional papers were equally excluded due to lacking analytical rigor as with online "Trade Literature," articles, and features.

The studies were narrowed down into four key categories:

Cognitive impairments and ATs
Environmental and safety risks and ATs.
Design typology and wayfinding.
Furnishing, colors and lighting and wayfinding.

These will be the key themes for the review which will be discussed in the following.

Cognitive Impairments and ATs

AT. A wide range of technological interventions under the banner of ATs was developed over the last 10 years. These include any item, piece of equipment, or system that is used to increase, maintain, and improve the functional capabilities and independence of people with dementia in performing ADL. These can broadly categorized into apps and mobile phones, wearables, and smart home technology and systems. The key justifications for the use of ATs are to promote independence, reduce the costs of care, and mitigate risk (Carswell et al.,

Table 2. Indicators of Deterioration in Behavioral, Cognitive, and Communication Versus Assistive Technologies and Interventions Matrix.

Key Signs and Indicators of Deterioration in Behavioral/Cognitive/ Communication	Dementia Key Impairments (Criteria 1–5) USA	Contributory Age-Related Impairments and Comorbidity	Assistive Technologies and Interventions
Interaction fluctuations in care homes integrated and AT devices and appliances	Short-term memory deficit (encoding and information retrieval difficulties)	Mobility (arthritis osteoporosis, and joints problems) Motor–neuron dysfunction Ataxia, muscle control and involuntary movement Cardiovascular problems Peripheral and central vision problems	Monitoring changes in key behavioral changes (Döpp et al., 2015; Gitlin et al., 2003) Physiological symptoms monitoring (Algase et al., 2007; Bentayeb et al. 2015)
Poor gait and posture	Dyspraxia (disorder of fine and gross motor planning and clumsiness)	Mobility problems (arthritis, osteoporosis, and joints problems) Ataxia (muscle control and involuntary movement) Poor balance Muscle weakness	Gait sensors and accelerometers (Amaefule et al., 2020; Mc Ardle et al., 2020) Visual cuing (Arditi, 2005; Begum et al., 2013; Boger et al., 2018) Physiotherapy
Confusion, disorientation, and getting lost in wayfinding	Dyspraxia Short-term memory loss Visuospatial deficit	Peripheral and central vision problems Glaucoma Cataracts Color contrast adaptation Anxiety Agitation	Wayfinding and tracking devices (Begum et al., 2013; Hartin et al., 2016) Digital and smart phones (Curry et al., 2018; Gibson et al., 2019) Global positioning system devices (Bulat et al., 2016; McKinstry & Sheikh, 2013)
Wandering and walking aimlessly	Memory loss leading to dysfunctional spatial orientation	Anxiety Agitation Depression	Wayfinding and navigation sensors (Bulat et al., 2016) Spatial memory prompt and cognitive mapping formation of places (Curry et al., 2018; Gibson et al., 2019)
Trip, slip, and fall	Dyspraxia (disorder of motor planning and clumsiness)	Motor–neuron dysfunction. Mobility problems (arthritis and osteoporosis and joints problems) Ataxia (muscle control and involuntary movement)	Gait sensors and accelerometers (Amaefule et al., 2020) Fall prevention sensors (Habib et al., 2014)

(continued)

Table 2. (continued)

Key Signs and Indicators of Deterioration in Behavioral/Cognitive/ Communication	Dementia Key Impairments (Criteria 1–5) USA	Contributory Age-Related Impairments and Comorbidity	Assistive Technologies and Interventions
Clumsiness, knocking objects around	Executive dysfunction including planning, sequencing, monitoring, and decision making Dyspraxia (disorder of motor planning and clumsiness)	Stroke Ataxia (muscle control and involuntary movement)	Wayfinding and clutter management devices (Begum et al., 2013)
Incoherent and/or intermittent verbal expression, slurred speech, or lack of communication.	Apraxia (motor speech production) Aphasia (inability to speak)	Stroke	Picture exchange, Talking mats. (Murphy et al., 2010; Lancioni et al., 2008, 2011; 2013; Perakis et al., 2009)

2009; Evans et al., 2015; Mapundu et al., 2012; Shabha, 2018). Issues of usability, ease of operation, and reliability were highlighted as the key impediments due to the neurocognitive decline associated with dementia as shown in Table 2.

Memory prompt technology. Most memory aid technologies revolve around creating a system of memory prompts for people with dementia that have the potential of exercising memory (Lancioni et al., 2008, 2011, 2013; Perakis et al., 2009; ; Robillard & Hoey, 2018; Mason, et al., 2012). Digital-based prompting systems can be used to remind people to have their lunch, take medication, or remind them of a family visit (Evans et al., 2015). The key rationale is creating an electronic platform for supporting people with dementia to reduce the need for care staff to constantly remind individuals to carry out certain tasks (Mann et al., 2010; Astell et al., 2019) noted that the costs of these technologies are gradually decreasing which makes them increasingly cost-effective and affordable. "Talking Mats" were introduced as a communication tool that uses a fabric mat and a series of cards to support people to express their views (Murphy et al., 2010). Based on testing and piloting, this tool was found to be effective in enabling individuals to express their views by highlighting the importance of respecting the perspectives of people with dementia themselves.

Environmental and Safety Hazards and AT

There is a growing recognition that residential care homes should be designed and equipped to predict and minimize environmental and health and safety hazards while raising the alarm for help when needed. Several hazards can be identified in residential care homes due to cognitive impairments associated with dementia as shown in Table 2. Despite many AT devices being initially developed to support impaired cognitive function, there was a shift in the emphasis toward environmental safety devices. These ranged from a trip, slip, and fall prevention which could lead to concussion and multiskeletal and head injuries due to impact (Evans et al., 2015). It is estimated that one third of the population in the United Kingdom over 65, and half of the people over 80, fall at least once a year which could lead to head injuries and hip fracture (AgeUK, 2019). Falls are the most common cause of death from injury in people over 65 and cost the NHS over £2 billion a year and over 4 million beds a year (Public Health England, 2016). There are nearly 9 million people in England over 65, and the figure is forecast to rise to 11 million by 2021 (Fenton, 2014). The use of AT devices was advocated by Carswell et al. (2009) and Evans et al. (2015) to reduce and mitigate these risks. These were based on the "observe-monitor-alarm" model drawing healthcare staff attention to potential environmental risks.

Fall prevention sensors and accelerometers were used to predict falls and determine the physiological root of the problem and recommend training or rehabilitation (Amaefule et al., 2020; Mc Ardle et al., 2020). For example, greater flex of hips to compensate weak ankles.

The use of virtual reality and artificial intelligence was explored by Hartin et al. (2016). These have the potential to aid people with dementia in terms of orientation and mobility by providing a remote artificial personal support system to aid in visualizing 3D construct systems and flexible access to environmental information by using haptic, tactile, and vestibular channels to provide a realistic virtual experience (Amaefule et al., 2020). However, using electronic monitoring, communication, and rehabilitation tools raises the question of how much individuals might be prepared to pay for such a system, moving away from consideration of costs to the public purse and privacy issues (Lncioni et al., 2011; 2013; Mann & De Mallo, 2010; Mathotaarachchi et al., 2017; Pilotto et al., 2011) apart from the ethical issues involved in monitoring (Robillard et al., 2018).

The authors argue that ATs might be instrumental in gathering real-time data regarding changes in key behavioral and physiological indicators to assess individual awareness of environmental hazards while navigating and to identify unique individual needs to mitigate risk. This is intertwined, from the point of diagnosis, with monitoring the progression of any underlying health/medical condition and problems emerging or

targeting lifestyle factors that are associated with the risk of developing moderate dementia, delivering interventions, and avoiding unnecessary emergency admissions and hospital stays. The use of ATs equally helps facilitate some independence for people with dementia and leads to further cost saving and reduction in staffing cost (Riley-Doucet et al., 2009), meets their social needs concerning ADL and maintain personal safety, and reduces stress levels by mitigating particular environmental risks (Carrillo et al., 2009; Shabha et al., 2018; Robillard & Hoey, 2018).

Monitoring technologies such as wireless and sensors-based devices can be used to detect any unusual or fluctuating behavior of individuals with dementia and provide continual feedback to caregivers (Döpp et al., 2015; Gitlin et al., 2003). These include, *inter alia*, night-time wandering, and navigation devices nightfall. Night-time wandering is a major problem in residential care homes to alert care staff to the problem (Begum et al., 2013; Hartin et al., 2016; Chaudhury, 2020). While the caregiver's role is still essential, they are being provided with greater potential for awareness and for monitoring from a distance which doesn't resolve the problem. Two interrelated operational problems can be identified as (1) utility and efficacy of ATs devices and (2) ease of use by people with dementia due to gradual decline of cognitive abilities and memory loss. The latter are associated with the aging process which includes visual, auditory, and fine/gross motor coordination problems and other underlying neurological and mobility impairments. These militate against the effective use of ATs leading to wider implications to environmental safety and wayfinding.

Wayfinding, navigation, and orientation. The quality of the visuospatial environment is a critical factor in dementia due to the declining memory function and well-being of individuals; it significantly affects wayfinding, navigation, and orientation in the built environment (i.e., knowing where you are and knowing your destination as you navigate your way out). Cognitive maps constitute the basis for our understanding of spatial relationships and drive our ability to navigate our physical environment. Hoffman (2018) argued that neurodegeneration can lead to the decreased ability to encode and retrieve/recall new information, resulting in spatial memory impairment. In healthy individuals, the cognitive mapping process can be supported or disrupted depending on the environment and external visual cues. Disorientation due to declining cognitive memory makes it difficult for people with dementia to lead an independent life (Moore et al., 2006).

Such a two-way complex process is influenced by (1) the decline in physical and cognitive abilities of the individual with dementia and (2) the gradual decline in the processing of spatial and sensory information provided by the environment through visual, auditory, and tactical senses due to the aging process. Once visual and auditory perceptual processing is compromised, cognitive abilities could be hindered and become significantly limited and reduced. Age-related changes associated with vision loss include presbyopia (far-sightedness), decreased light transmission of the ocular media, and decreased pupil size (Watson, 2001). Other problems include loss in contrast sensitivity, higher sensitivity to glare, delayed recovery from glare, delayed dark adaptation, and reduced visual field and color discrimination were also identified by Rubin et al. (1997). Age-related auditory problems include hearing loss, tinnitus, and hyperacusis which might indirectly impact the navigation of a person with dementia due to being easily distracted and loss of attention particularly in noisy environments.

A higher association between sensory–perceptual decline and cognition was observed by Li and Lindeberger (2002) and Reyes-Ortiz (2005). People living with dementia are more likely to experience added compensatory challenges when faced with difficult visual, auditory, or cognitive tasks while performing ADL leading to confusion (Anstey et al., 2006; Li & Lindeberger, 2002; Reyes-Ortiz, 2005). Visual contrast sensitivity and visual acuity appear to be pivotal to cognitive performance. Lower light contrast leads to a slower encoding of spatial and written information. A moderate to a strong association between visual contrast sensitivity and cognitive performances was found by Anstey et al. (2006), supporting the claim that visual aging is associated with the slower encoding of sensory information which is critical to wayfinding.

A multisensory environment to alleviate cognitive decline was explored by Riley-Doucet et al. (2009), Ward-Smith et al. (2009), and Lorusso and Bosch (2017) to alleviate cognitive and sensory–perceptual problems associated with dementia. While the technology did make a person with dementia calmer and more relaxed (Bowes & Dawson, 2019). This intervention merits further research to assess its potential and efficacy to ameliorate cognitive decline toward improving the sensory experience of people with dementia through visual, auditory, and tactile channels which might be beneficial to aid wayfinding (Barrett et al., 2019; Jakob & Collier, 2017; Murry et al., 2016).

Marquardt and Schmieg (2009) and Marquardt (2011) identified four prerequisites for successful wayfinding (1) cognitive ability to process spatial information; (2) cognitive ability to process sensory information (i.e., visual, auditory, and tactile); (3) physical ability to navigate relying on the self-spatial organization (cognitive maps); and (4) cognitive ability to process, encode, and retrieve/recall sensory information. The authors argue that sensory processing problems due to various visual impartments may exasperate spatial disorientation leading to poor wayfinding and probably related to other negative symptoms of dementia such as wandering or restless walking and poor performance on simple wayfinding goals (Algase et al., 2004). This is an area that merits further analysis and investigation.

Design Typology Versus Wayfinding

Various methods to improve wayfinding have been adopted and implemented in both refurbished and newly designed residential care homes. However, the perception and the design of these facilities are grounded in misconception and limited understanding. Much emphasis was given in the literature to design typology (Marquardt, 2011), signage, and visual cues including furniture layout and point of reference to aid wayfinding (Barrett et al., 2019; Elmståhl et al., 1997).

Design typology and shape of the floor plan claimed to be significant in supporting the spatial orientation and wayfinding of people with dementia, determining which routes can be traveled in the building (Caffo et al., 2014; Fleming & Purandare, 2010). A few studies had examined the effect of the architectural floor plan in care settings on wayfinding success based on care staff observations of the level of confusion and disorientation experienced by people with dementia (Elmståhl et al., 1997; Marquardt, 2011, 2014) and in particular to assess which routes can be found independently and which ones require staff assistance. Faith (2015) investigated four design topologies which include Y, H-, linear, and circuit type plans. Several key problems in wayfinding were identified. These include central areas/hubs in a symmetrical plan or when there is a multiple-choice junction, T-junctions, and long corridors. These problems can be attributed to the decision-making problem by people with dementia when there are alternative routes. Straight corridors were observed by Faith (2015) to facilitate movement and increase walking speed, as such "featureless corridors" lack distractions which cause residents to miss cues, particularly if they are designed in a homogeneous manner, where all doors to adjacent rooms look the same.

Long, narrow corridors are often a result of bedroom wings in long-term care settings and can be confusing and daunting compared with the smaller domestic environment so the size and scale of the building do matter in this respect (Van Buuren & Mohammadi, 2022) as with the length and width of corridors (Passini et al., 2000). This study argues that wayfinding is influenced by a wide range of design characteristics including (1) design layout and typology, (2) internal circulation patterns, (3) traveling distance, (4) length and width of corridors, (5) shape of corridors, and (6) proximities and adjacency of private and communal areas as shown in Table 3. Several design guidelines for a supportive environment for wayfinding can be proposed as follows:

Reducing complex processing which requires higher analytical skills such as reading and interpreting signage and decision making. This is given the gradual decline of well-being and cognitive abilities of people with dementia triggered by the aging process. Most will be limited in the

Table 3. The Relationship Between Design Characteristics and Wayfinding.

Key Design Variables and Characteristics	Wayfinding, Navigation and Orientation	Cognitive Impairments and Triggers	Design Interventions
Descriptive design variables Design typology Design shape Internal circulation patterns Length and width of corridors Shape of the corridor Traveling distance Proximities and Adjacency of private rooms to communal areas Admittance of natural light	Square and rectangular forms (Passini et al., 1998) Multiple-choice junction T-junctions and long corridors (Faith 2015; Marquardt, 2011; Elmståhl et al., 1997) Straight corridors facilitate movement and increase waling speed and wayfinding (Faith 2015; Van Buuren & Mohammadi, 2022) Short corridors and well-articulated space (Passini et al., 2000) Short distance between private and communal facilities	Visuospatial environment **Neurodegeneration to encode and retrieve new information** (spatial memory deficit; Hoffman, 2018) **Lack of cognitive mapping** **Lack of external cue** (Moore et al., 2006) **Visual and perceptual processing problems** due to visual neuropathy and age-related associated vision loss (Waston, 2001; Rubin et al., 1997): • Loss in contrast sensitivity • Higher sensitivity to glare • Delayed recovery from glare • Delayed dark adaptation • Reduced visual field • Color discrimination Auditory environment **Age-related auditory problem** • Hearing loss • Tinnitus • Hyperacusis • Hallucination	Visual cueing via clear signage, simplicity, effective color contrast, and avoid patterns. Cushioning effect via sound absorbent materials for floors, wall, and ceilings. Enhancing spatial visualization by people with dementia to minimize sensory processing providing visual access to all areas in a residential home and hence optimizing spatial awareness. Reducing decision making by judicious planning of corridor and transitional areas such as hallways, lobbies, central hubs, and living areas
Interior design characteristics and features			
• Color contrast between walls, floor, and fittings • Visual cueing and differentiation of kitchen, toilets, bathrooms, and living areas. • Flecks or sparkly specks floors • Shine and dark colors and floor patterns • Spongy and noisy floors • Clear signage and landmarks	Improve wayfinding (Arditi, 2005, Faith et al., 2015; Kelly et al., 2011) Worsen wayfinding and Heightened anxiety cause physical obstruction (Buxton, 2015; Evans et al., 2011)		

Legend
Positive impact
Negative impact

ability to perform higher planning and decision-making tasks or learn new skills. The plan topologies should, therefore, ensure familiarity and clarity of the floor plan to facilitate navigation and orientation for a dementia-friendly setting to people with dementia in a sense that do not require the acquisition of new orientation skills. As a good practice, a clear floor layout is needed together with a well-articulated space configuration to facilitate access, navigation, and orientation.

Reducing complex processing which requires higher analytical skills.

Enhancing spatial visualization by people with dementia to minimize sensory processing difficulties in visualizing and abstracting 3D construct/concept of the spatial situation which they cannot see directly. By providing visual access to all places relevant to them, people with dementia can fully appreciate their settings through visual access to all areas in a residential home and hence optimizing spatial awareness.

Enhancing spatial visualization by people with dementia to minimize sensory processing.

Reducing decision making by judicious planning of corridor and transitional areas such as hallways, lobbies, central hubs, and other areas. An easy transition from source Location A to destination Location B with the least cognitive effort should be facilitated. This is due to the difficulty experienced by individuals with dementia to make a hierarchical decision.

Reducing decision making by judicious planning of corridor and transitional areas such as hallways, lobbies, central hubs, and other areas.

Furnishing, Color, and Lighting Versus Wayfinding

Various internal design interventions were identified to aid wayfinding which include furniture layout, color, lighting, signage, and landmarks. Selection of colors and contrast for walls, floor, and fittings were also examined as useful means for cueing and differentiation (Faith 2015; Kelly et al., 2011). However, these interventions have limited compensatory effect if the design layout is complicated (e.g., constantly changing direction). In a more basic design layout, such compensatory interventions may address adverse design topologies (e.g., changing direction and reinforcing orientation and navigation). The problem of confusion with dementia, due to visual and perceptual processing problems can lead to misconception and distortions of realities. A dark patch on the floor can be mistaken for a step and a glossy and shining surface might be perceived as being wet (Buxton, 2015) which support the claim about higher sensitivity to glare, delayed dark adaptation (Rubin et al., 1997). For instance, changes in the surface can be mistaken for changes in level which potentially lead to tripping and falling or knocking objects around (Evans et al., 2011).

Older people, in general, may also find certain colors harder to differentiate due to the thickening of the lens of the eye (Arditi, 2005; Buxton, 2015; Evans et al., 2011). Dementia-friendly flooring needs to avoid anything that causes anxiety and deters people with dementias from being able to walk safely across the floor without getting distracted or thrown off balance as shown in Figures 2 and 3.

Avoiding flecks or sparkly specks, which people with dementia may try to pick up, as well as shine and dark colors and floor patterns. The latter can be seen as a physical obstruction. This can be aggravated by age-related visual impairments. Spongy and noisy floors are not advised due to trip hazards. Strong colors can work well to achieve higher contrast to mitigate visual acuity problems (Arditi, 2005). Extra benefits can be achieved in terms of visual cueing and landmarks to easily navigate facilities like the kitchen, living room, toilets, and bathroom areas without being confused.

Ameliorating the impact of both visuospatial cognitive decline and sensory–perceptual impairments on wayfinding requires a holistic design strategy and diligent interventions which pay attention to minute details. Through such

Figure 2. Light color cushioned and hard floor to support wayfinding in residential care home. (a) Shows light color cushioned carpet floor to cater for impact in living areas, private rooms, and end corridors; sharp color contrast between floors and walls; judicious use of calm and neutral colors for floors, walls, and furniture. (b) Solid nonslippery laminated floor in living area, corridors, and sport room. Photos provided by Natta Building Company Ltd, UK.

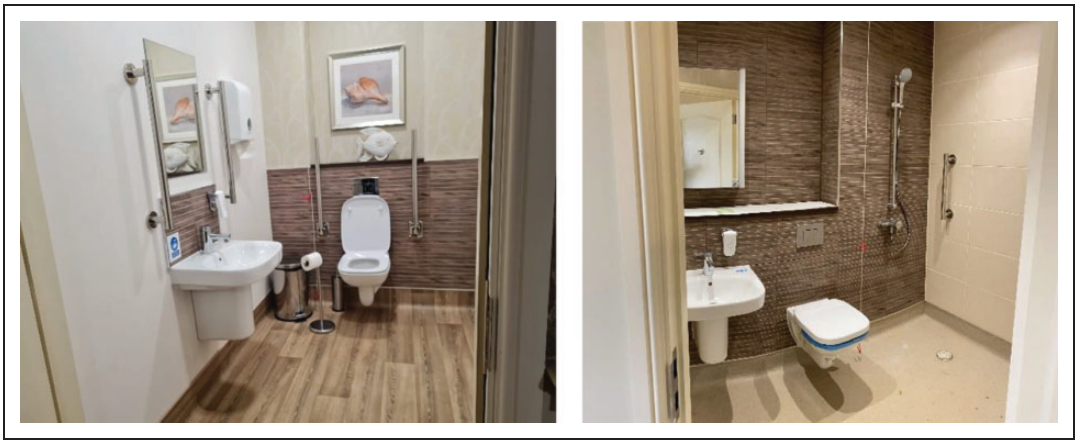

Figure 3. Selection of nonslippery light color floor in bathroom area. Photos provided by Natta Building Company Ltd, UK.

judicious design interventions, daily navigation can be facilitated for self-rewarding experiential dementia living (Carswell, 2009; Diaz et al., 2006; Marquardt, 2011). There is a need for optimizing sensory processing via:

Careful tactical design interventions is needed to address the weakening of sensory processing of people with dementia and visuospatial impairments intertwined with fear and uncertainty caused by an inappropriately designed environment which can be confusing to their safety and well-being as shown in Figure 2. This is particularly true for flooring. The authors argue that the right choice of flooring is particularly important where tactile elements can be incorporated to dispel fear and create a sense of safety while navigating as many are often frail and susceptible to falls. A key prerequisite to successful orientation includes geometrically well-defined spaces incorporating complementary spatial design features including differentiation between floors, walls, and ceiling through color and textures and judicious use of signage.

Careful tactical design interventions.

Limitations

This article is focused on reviewing a broad range of research studies conducted in the field of ATs and wayfinding for people with dementia. There are significant variations in terms of the focus, context, research design and methodologies adopted, quality, and robustness of analysis and findings. However, this review posed several limitations primarily attributed to a wide range of variations in the methodical approaches and qualities of research design and evidence obtained which impacted the validity and credibility of the findings and outcomes of these studies.

Conclusions

Dementia is a devastating neurodegenerative condition affecting both individuals and the families involved. Attempting to design for dementia residential care home environment is an intricate process that should be based on an in-depth understanding of the multidimensional and multifaceted factors associated with the condition both in terms of the causes of impairments, symptoms manifested, and behavioral implications regarding wayfinding to people with dementia.

Addressing the first research question "(1) how can cognitively facilitating AT be made more user-focused to mitigate the impacts of cognitive impairments on environmental safety and wayfinding?" there is an inherent limitation exhibited by ATs interventions which vary in their scope and effectiveness due to practical and operational problems and difficulty of use in addressing the multifaceted aspects of

neurocognitive decline and visuospatial deficit associated with dementia.

Addressing the second research question "(2) how can design intervention and changes in design typology, colors, and texture, and internal finishing aid wayfinding, navigation, and orientation in dementia residential care homes," there is a need to move toward dementia-centered design. This requires a more in-depth analysis of the interrelated sensory, behavioral, and cognitive factors. There is a need to create a therapeutically enhanced environment more attuned to reduce confusion and provide a sense of familiarity and autonomy to people with dementia. Creating a sensory-enriched and cognitively affective care home environment will aid people with dementia in navigating and performing to their highest capacity in everyday activities of living. Spatial orientation "wayfinding" strategies require careful cognitively focused design interventions, strengthened by meaning, emotional connection to places, and familiarity. Based on the current consensus among healthcare, clinicians and built environment professionals involved, there is a need to move toward evidence-based design for dementia. Equally, the importance of creating a sensory enriched environment for dementia to aid cognitive processing cannot be underestimated. This will enhance resilience based on the therapeutic qualities of the living environment and ultimately minimize the overall risk involved to people with dementia. Further research is therefore needed.

Recommendations

The authors recommend that mixed-method, multidisciplinary research is needed in future research investigating AT and wayfinding for people with dementia. This should be based on (1) quantitative data obtained via structured questionnaires and interview involving family, carers, and care service providers; and (2) qualitative data based on real-time participant observation of wayfinding walks of individuals living with dementia combined with conversational style interviews to glean and draw out their perception and experience. No doubt there are various ethical considerations and practical difficulties in obtaining data and evidence and identifying key AT and wayfinding problems from people living with dementia. These include poor short-term memory due to deteriorating cognitive ability and overall debilitating conditions such as vision and hearing loss which makes it difficult to engage and articulate their thoughts and ideas. This approach is more appropriate since it enables cross-validation of factual, perceptual, and experiential data which will provide more in-depth understanding and effectively interpreting dementia users changing needs, operational challenges of ADL experience and perspectives. This allows qualitative data about wayfinding and environmental safety to be collected, analyzed, and interpreted robustly toward creating an evidence-based platform which can be accessed by all professionals involved across the spectrum.

Implications for Practice

- Assisting built environment, professionals in addressing the complexity of sensory processing problems and cognitive impairment associated with dementia through judicious plan typology and circulation pattern to ensure familiarity and clarity of the floor plan to facilitate access, navigation, and orientation.
- Reducing decision making by judicious planning of corridor and transitional areas such as hallways, lobbies, central hubs, and other communal areas.
- Optimizing spatial awareness and enhancing spatial visualization of people with dementia where they can fully appreciate their settings through visual access to all communal areas in the residential care homes.
- Developing a "Safety by Design" system based on careful use of ATs for wayfinding to aid environmental safety and tackling night walk, nighttime wandering and nightfall, and by alerting caregivers about any potential problem.
- Enhancing careful use of signage, landmarks, color, and light contrast between floor and walls intertwined with tactile design interventions of floor finishing to aid wayfinding and to dispel fear and create a sense of safety while navigating.

Acknowledgments

The author would like to acknowledge Dr. Mo May for his enthusiastic assistance in moving this project from initial presentation to manuscript development.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research and/or authorship of this article.

ORCID iD

Ghasson Shabha, FCIBSE, MBIFM, PG Cert Ed., FHEA, IOSH https://orcid.org/0000-0003-3441-8256

References

AgeUK. (2019). *Fall in later life: A huge concern for older people*. Falls later in life (ageuk.org.uk)

Algase, D., Son, G., Beel-Bates, C., Song, J., Yao, L., Beattie, E., & Leitsch, S. (2007). Initial psychometric evaluation of the wayfinding effectiveness scale. *Western Journal of Nursing Research*, *29*(8), 1015–1032. https://doi.org/10.1177/0193945907303076

Algase, D. L., Son, G., Beattie, E., Song, J., Leitsch, S., & Yao, L. (2004). The interrelatedness of wandering and wayfinding in a community sample of persons with dementia. *Dementia and Geriatric Cognitive Disorders*, *17*(3), 231–239. https://doi.org/10.1159/000076361

Alzheimer's Society UK. (2020). *Facts for the media*. https://www.alzheimers.org.uk/about-us/news-and-media/facts-media

Amaefule, C. O., Lüdtke, S., Kirste, T., & Teipel, S. J. (2020). Effect of spatial disorientation in a virtual environment on gait and vital features in patients with dementia: Pilot single-blind randomized control trial. *JMIR Serious Games*, *8*(4). https://doi.org/10.2196/18455

Anstey, K. J., Butterworth, P., Borzycki, M., & Andrews, S. (2006). Between- and within- individual effects of visual contrast sensitivity on perceptual matching, processing speed, and associative memory in older adults. *Gerontology*, *52*(2), 124–130.

Arditi, A. (2005). Enhancing the visual environment for older and visually impaired persons. *Alzheimer's Care Today*, *6*(4), 294–9.

Arthur, P., & Passini, R. (1992). *Wayfinding: People, signs, and architecture*. McGraw Hill Book Company.

Astell, A. J., Bouranis, N., Hoey, J., Lindauer, A., Mihailidis, A., Nugent, C., & Robillard, J. M. Technology and Dementia Professional Interest Area (2019). Technology and dementia: The future is now. *Dementia and Geriatric Cognitive Disorders*, *47*(3), 131–139. https://doi.org/10.1159/000497800.

Barrett, P., Sharma, M., & Zeisel, J. (2019). Optimal spaces for those living with dementia: Principles and evidence. *Building Research & Information*, *47*(6), 734–746. https://doi.org/10.1080/09613218.2018.1489473

Begum, M., Wang, R., Huq, R., & Mihailidis, A. (2013). Performance of daily activities by older adults with dementia: The role of an assistive robot. *IEEE International Conference Rehabilitation Robot*, *2013*, 6650405.

Bentayeb, M., Norback, D., Bednarek M, Bernard, A., Cai, G., Cerrai, S., Eleftheriou, K.K., Gratziou, C., Holst, G.J., Lavaud, F., Nasilowski, J., Sestini, P., Sarno, G., Sigsgaard, T., Wieslander, G., Zielinski, J., Viegi, G., Annesi-Maesano, I. (2015). GERIE Study: Indoor air quality, ventilation and respiratory health in elderly residents living in nursing homes in Europe. *European Respiratory Journal, 45*, 1228–1238; DOI: 10.1183/09031936.00082414

Boger, J., Young, V., Hoey, J., Jiancaro, T., & Mihailidis, A. (2018). *Zero-effort technologies: Considerations, challenges, and use in health, wellness and rehabilitation*. Morgan & Claypool.

Bowes, A., & Dawson, A. (2019). *Designing environments for people with dementia* (1st ed.). Emerald Publishing Limited. https://doi.org/10.1108/978-1-78769-971-720191002

Bryman, A. (2016). *Social research methods* (5th ed.). Oxford University Press.

Buettner, L., Yu, F., & Burgener, S. (2010). Evidence supporting technology-based interventions for people with early-stage Alzheimer's Disease. *Journal of Gerontological Nursing*, *36*(10), 15–19.

Bulat, T., Kerrigan, M. V., Rowe, M, Kearns, W., Craighead, J. D., & Ramaiah, P. (2016). Field evaluations of tracking/locating technologies for

prevention of missing incidents. *American Journal of Alzheimer's Disease and Other Dementias*. https://doi.org/10.1177/1533317515619479

Buxton, P. (2015). How to avoid flooring dementia patients. *RIBA Journal*. https://www.ribaj.com/products/flooring-for-dementia-patients

Caffò, A. O., Hoogeveen, F., Groenendaal, M., Perilli, A. V., Picucci, L., Lancioni, G. E., & Bosco, A. (2014). Intervention strategies for spatial orientation disorders in dementia: A selective review. *Developmental Neurorehabilitation*, *17*(3), 200–209. https://doi.org/10.3109/17518423.2012.749951

Carrillo, M. C., Eric Dishman, E., & Plowman, T. (2009). *Everyday technologies for Alzheimer's disease care: Research findings, directions, and challenges*. Elsevier. https://doi.org/0.1016/j.jalz.2009.09.003

Carswell, W., McCullagh, P. J., Augusto, J. C., Martin, S., Mulvenna, M. D., Zheng, H., Wang, H. Y., Wallace, J. G., McSorley, K., Taylor, B., & Jeffers, W. P. (2009). A review of the role of assistive technology for people with dementia in the hours of darkness. *Technology and Health Care*, *17*(4), 281–304.

Cercas Curry, A., Papaionannou, I., Suglia, A., Agarwal, S., Shalyminov, I., Xu, X., Dusek, O., Eshghi, A., Konstas, I., Rieser, V., & Lemon Alana, O. (2018). Open-domain social dialogue using ontologies and entity linking. *First Proceedings of the Alexa prize*. https://m.media-amazon.com/images/G/01/mobile-apps/dex/alexa/alexaprize/assets/pdf/2018/Alana.pdf(link is external)

Chaudhury, H. (2020). Canada: Supportive environments for people with dementia in long-term care: Education and training methods. In R. Fleming, J. Zeisel, & K. Bennett (Eds.), *World Alzheimer Report 2020: Design, dignity, dementia: Dementia-related design and the built environment* (Vol. 1, pp. 192–201). Alzheimer's Disease International. https://www.alzint.org/resource/world-alzheimer-report-2019/

Cooper, C. (2014). Dementia time bomb set to cost 3 bn by 2030 as people leave work to care for relatives. *The Independent*. https://www.independent.co.uk/life-style/health-and-families/health-news/dementia-timebomb-set-cost-ps3bn-2030-people-leave-work-care-relatives-9655241.html

Dawes, M., Summerskill, W., Glasziou, P., Cartabellotta, A., Martin, J., Hopayian, K., Porzsolt, F., Burls, A., & Osborne, J. (2005). Sicily statement on evidence-based practice. In second international conference of evidence-based health care teachers and developers. *BioMed Central Medical Education*, *5*(1), 1–7. https://doi.org/10.1186/1472-6920-5-1

Daykin, N., Byrne, E., Soteriou, T., & O'Connor, S. (2008). The impact of art, design and environment in mental healthcare: A systematic review of the literature. *The Journal of the Royal Society for the Promotion of Health*, *128*(2), 85–94.

Diaz, K. M., Geboy, L. D., & Weisman, G. D. (2006). *Designing a better day. Guidelines for adult and dementia day services centers*. Johns Hopkins University Press.

Döpp, C. M., Graff, M. J., Teerenstra, S., Olde Rikkert, M. G., Nijhuis-van der Sanden, M. W., & Vernooij-Dassen, M. J. (2015). Effectiveness of a training package for implementing a community-based occupational therapy program in dementia: A cluster randomized controlled trial. *Clinical Rehabilitation*, *29*(10), 974–986.

Elmståhl, S., Annerstedt, L., & Ahlund, O. (1997). How should a group living unit for demented elderly be designed to decrease psychiatric symptoms? *Alzheimer Disease and Associated Disorders*, *11*(1), 47–52.

Evans, J., Brown, M., Coughlan, T., Lawson, G., & Craven, M. P. (2015). A systematic review of dementia focused assistive technology. In M. Kurosu (Ed.), *Human-computer interaction: Interaction technologies. HCI 2015. Lecture notes in computer science* (Vol. *9170*). Springer. https://doi.org/10.1007/978-3-319-20916-6_38

Evans, N., Carey-Smith, B., & Orpwood, R. (2011). Using smart technology in an enabling: A review of using technology to support daily life for a tenant with moderate Dementia. *British Journal of Occupational Therapy*, *74*(5), 249–253.

Evans, N., Harris, N., & Kuppuswamy, A. (2011). A smarter future: Technology to enhance an independent lifestyle for our future selves. *International Journal of Therapy and Rehabilitation*, *18*(12), 495–499.

Faith, V. (2015). *Designing for dementia: an assessment of the impact of the physical environment on wayfinding success for residents in long term care settings* (1st ed.). Queen's University, Belfast.

Fenton, K. (2014, July 7). *Public health matters: The human cost of falls* [Blog post]. Public Health England. https://publichealthmatters.blog.gov.uk/2014/07/17/the-human-cost-of-falls/

Fleming, R., & Purandare, N. (2010). Long-term care for people with dementia: Environmental design guidelines. *International Psychogeriatrics*, *22*(7), 1084–1096.

Gibson, G., Brittain, K., & Robinson, L. (2019). Working with assistive technologies and people living with dementia. In B. Neves & F. Vetere (Eds.), *Ageing and digital technology: Designing and evaluating emerging technologies for older adults*. Springer. 213–227.

Gitlin, L. N., Winter, L., Corcoran, M, Dennis, M. P., Schinfeld, S., & Hauck, W. W. (2003). Effects of the home environmental skill-building program on the caregiver-care recipient dyad: 6-month outcomes from the Philadelphia REACH initiative. *The Gerontologist*, *443*(4), 532–46.

Habib, M. A., Mohktar, M. S., Kamaruzzaman, S. B., Lim, K. S., Pin, T. M., & Ibrahim, F. (2014). Smartphone-based solutions for fall detection and prevention: Challenges and open issues. *Sensors (Basel, Switzerland)*, *14*(4), 7181–7208. https://doi.org/10.3390/s140407181

Hartin, P. J., Nugent, C. D., McClean, S. I., Cleland, I., Tschanz, J. T., Clark, C. J., & Norton, M. C. (2016). The empowering role of mobile apps in behavior change interventions: The gray matters randomized controlled trial. *Journal of Medical Internet Research*, *4*(3), e93. PMID: 27485822. https://doi.org/10.2196/mhealth.4878. PMID: 27485822.

Higgins, J. P. T., & Green, S. (2011). *Cochrane handbook for systematic reviews of interventions* (Version 5.1.0; updated March 2011). The Cochrane Collaboration. http://www.cochrane-handbook.org/

Hoffman, M. (2018, May 1). The cognitive impact of wakeful rest. *Conscious Cities Journal*. No. 5, Conscious Cities Anthology, Human-Centered Design, Science, and Technology. https://theccd.org/article/places-of-pause-the-cognitive-impact-of-wakeful-rest/

Hughes, J. C. (2011). *Alzheimer's and other dementias* (1st ed.). Oxford University Press.

Jakob, A., & Collier, L. (2017). Sensory enrichment for people living with dementia: Increasing the benefits of multisensory environments in dementia care through design. *Design for Health*, *1*(1), 115–133, https://doi.org/10.1080/24735132.2017.1296274.

Kelly, F., Innes, A., & Dincarslan, O. (2011). Improving care home design for people with dementia. *Journal of Care Services Management*, *5*(3), 147–155.

Lancioni, G. E, Perilli, V., Singh, N. N., O'Reilly, M. F., Sigafoos, J., Cassano, G., Bosco, A., Caffò, A. O., Picucci, L., & Picucci, L. (2013). Technology-based orientation programs to support indoor travel by persons with moderate Alzheimer's disease: Impact assessment and social validation. *Research in Developmental Disabilities*, *34*(1), 286–293.

Lancioni, G. E., Perilli, V., Singh, N. N., O'Reilly, M. F., Sigafoos, J., Cassano, G., Pinto, K., Minervini, M. G., & Oliva, D. (2011). Technology-aided pictorial cues to support the performance of daily activities by persons with moderate Alzheimer's disease. *Research in Developmental Disabilities*, *35*(1), 265–273.

Lancioni, G. E., La Martire, M. L., Singh, N. N., O'Reilly, M. F., Sigafoos, J., Cassano, G., Pinto, K., Minervini, M. G., et al (2008). Persons with mild or moderate Alzheimer's disease managing daily activities via verbal instruction technology. *American Journal of Alzheimer's Disease and Other Dementias*, *23*(6), 552–562.

Li, K. Z. H., & Lindeberger, U. (2002). Connections among sensory, sensorimotor and cognitive aging: Review of data and theories. *Neuroscience Biobehavioral Reviews*, *26*(2), 777–783.

Liu, L., Gauthier, L., & Gauthier, S. (1991). Spatial disorientation in persons with early senile dementia of the Alzheimer type. *American Journal of Occupational Therapy*, *45*(1), 67–74.

Lorusso, L., & Bosch, S. (2017). Impact of multisensory environments on behavior for people with dementia: A systematic literature review. *The Gerontologist*, *58*(3), e168–e179.

Mann, W. C., & De Mallo, M. A. F. (2010). Assistive technology use by the elderly in Brazil and the United States. *Topics in Geriatric Rehabilitation*, *26*(1), 62–69.

Mapundu, Z., Simonnet, T., & Van Der Walt, J. S. (2012). A videoconferencing tool acting as a home-based healthcare monitoring robot for elderly patients. *Studies in Health Technology and Informatics*, *182*, 180–188.

Marquardt, G. (2011). Wayfinding for people with dementia: The role of architectural design. *Health Environments Research and Design Journal*, *4*(2), 22–41.

Marquardt, G., & Schmieg, P. (2009). Dementia-friendly architecture: Environments that facilitate wayfinding in nursing homes. *American Journal of Alzheimer's Disease and Other Dementias*, *24*, 333–340.

Marquardt, G., Bueter, K., & Motzek, T. (2014). Impact of the design of the built environment on people with dementia: An evidence-based review. *Health Environments Research and Design Journal*, *8*(1), 127–157.

Mason, S., Craig, D., O'Neill, S., Donnelly, M., & Nugent, C. (2012). Electronic reminding technology for cognitive impairment. *British Journal of Nursing*, *20*(4), 855–861.

Mathotaarachchi, S., Pascoal, T. A., Shin, M., Benedet, A. L., Kang, M. S., Beaudry, T., Fonov, V. S., Gauthier, S., & Rosa-Neto, P. (2017). Alzheimer's disease neuroimaging initiative. Identifying incipient dementia individuals using machine learning amyloid imaging. *Neurobiology Aging*, *59*, 80–90. https://doi.org/10.1016/j.neurobiolaging.2017.06.027

Mc Ardle, R, Del Din, S., Galna, B., Thomas, A., & Rochester, L. (2020). Differentiating dementia disease subtypes with gait analysis: Feasibility of wearable sensors? *Gait & Posture*, *76*, 372–376. https://doi.org/10.1016/j.gaitpost.2019.12.028

McKinstry, B., & Sheikh, A. (2013). The use of global positioning systems in promoting safer walking for people with dementia. *Journal Telemedicine Telecare*, *19*(5), 288–292. https://doi.org/10.1177/1357633X13495481

Monacelli, A. M., Cushman, L. A., Kavcic, V., & Duffy, C. J. (2003). Spatial disorientation in Alzheimer's disease: The remembrance of things passed. *Neurology*, *61*(11), 1491–1497.

Moore, K. D., Geboy, L. D., & Weisman, G. D. (2006). *Designing a better day: Guidelines for adults and dementia day services*. Johns Hopkins University Press.

Murphy, J., Gray, C. M., van Achterberg, T., Wyke, S., & Cox, S. (2010). The effectiveness of the talking mats framework in helping people with dementia to express their views on well-being. *Dementia: The International Journal of Social Research and Practice*, *9*(4), 454–472.

Murray, C., Gilbert-Hunt, S., Berndt, S., & de la Perrelle, L. (2016). Promoting participation and engagement for people with dementia through a cognitive stimulation therapy programme delivered by students: A descriptive Qualitative Study. *British Journal of Occupational Therapy*, *79*(10), 620628.

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, M., McDonald, S., ... Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *British Medical Journal*, *372*, 71. https://doi.org/10.1136/bmj.n71

Passini, R., Joanette, Y., Rainville, C., & Marchand, N. (1995). Wayfinding in dementia of the Alzheimer type: Planning abilities. *Journal of Clinical and Experimental Neuropsychology*, *17*(6), 820–832.

Passini, R., Joanette, Y., Rainville, C., & Marchand, N. (1998). Wayfinding in dementia: Some research finding and a new look at design. *Journal of Architecture and Planning Research*, *15*(2), 133–151.

Passini, R., Pigot, H., Rainville, C., & Tétreault, M. H. (2000). Wayfinding in a nursing home for advanced dementia of the Alzheimer's type. *Environment and Behavior*, *32*(5), 684–710.

Perakis, K., Haritou, M., & Koutsouris, D. (2009). ALADDIN: A technology platform for the assisted living of dementia elderly individuals and their carers. In S. Omatu, M. Rocha, J. Bravo, F. Fdez-Riverola, E. Corchado, A. Bustillo, & J. M. C. Rodríguez (Eds.), *IWANN 2009, Part II Proceeding, LNCS 5518*, 878–881.

Pilotto, A., D'Onofrio, G., Benelli, E., Zanesco, A., Cabello, A., MargelÃ, M. C., & Kilias, D. (2011). Information and communication technology systems to improve quality of life and safety of Alzheimer's disease patients: A multicentre international survey. *Journal of Alzheimer's Disease*, *23*(1), 131–141.

Possin, K. L. (2010). Visual spatial cognition in neurodegenerative disease. *Neurocase*, *16*(6), 466–487. https://doi.org/10.1080/13554791003730600

Public Health England. (2016). *Falls: Applying all our health*. Falls and fractures: Applying All Our Health—GOV.UK (www.gov.uk)

Public Health England. (2016, September 29). *Dementia data and analysis: A guide for health professionals*. Dementia data and analysis: A guide for health professionals—GOV.UK.

Reisberg, B., Ferris, B. H, De Leon, M. J., & Crook, T. (1982). The Global Deterioration Scale for assessment of primary degenerative dementia. *Am Journal of Psychiatry*, *139*(9), 1136–1139. https://www.ncbi.nlm.nih.gov/pubmed/7114305Riley-Doucet.

Reyes-Ortiz, C. A, Kuo, Y. F., DiNuzzo, A. R, Ray, L. A., Raji, M. A., & Markides, K. S. (2005). Near vision impairment predicts cognitive decline: Data from the Hispanic established populations for epidemiological studies of the elderly. *Journal of American Geriatric Society*, *53*(4), 681–686. https://doi.org/10.1111/j.1532-5415.2005.53219.x

Riley-Doucet, C. K. (2009). Use of multisensory environments in the home for people with dementia. *Journal of Gerontological Nursing*, *35*(5), 43–52.

Robillard, J. M., Cleland, I, Hoey, J., & Nugent, C. (2018). Ethical adoption: A new imperative in the development of technology for dementia. *Alzheimers Dementia*, *14*(9), 1104–1113. PMID: 29937247. https://doi.org/10.1016/j.jalz.2018.04.012 PMID: 29937247.

Robillard, J. M., & Hoey, J. (2018). Emotion and motivation in cognitive assistive technologies for dementia. *Computer*, *51*(3), 24–34.

Rubin, G. S, West, S. K., Muñoz, B, Muñoz, B, Bandeen-Roche, K., Zeger, S., Schein, O., & Fried, L. P. (1997). A comprehensive assessment of visual impairment in a population of older Americans: The SEE study: Salisbury eye evaluation project. *Investigative Ophthalmology and Visual Science Journal*, *38*(3): 557–568.

Sackett, D. L., Rosenberg, W. M., Gray, J. A., Haynes, R. B., & Richardson, W. S. (1996). Evidence based medicine: What it is and what it isn't. *British Medical Journal*, *312*(7023), 71–72. https://doi.org/10.1136/bmj.312.7023.71

Shabha, G., Mutingowenda, B., & Gaines, K. (2018). Assistive monitoring and wayfinding strategies. *Care Home Environment*, 21–24. https://content.yudu.com/web/1u0jl/0A40tfs/TCHEVol3Iss6/flash/resources/index.htm

Van Buuren, L., & Mohammadi, M. (2022). Dementia-friendly design: A set of design criteria and design typologies supporting wayfinding. *Health Environment Research Design*, *15*(1), 150–172. https://doi.org/10.1177/19375867211043546

Ward-Smith, P., Llanque, S. M., & Curran, D. (2009). The effect of multisensory stimulation on persons residing in an extended care facility. *American Journal of Alzheimer's Disease and Other Dementias*, *24*(6): 450–455.

Watson, G. R. (2001). Low vision in the geriatric population, rehabilitation and management. *Journal of American Geriatric Society*, *49*(3), 317–330.

World Health Organization. (2019). *Dementia*. http://www.who.int/mediacentre/factsheets/fs362/en/