TECHNISCHE UNIVERSITÄT WIEN

DISSERTATION

Interactive Architecture for Alzheimer's Therapeutic Environment in long-term Healthcare Centers

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Heidi Elnimr

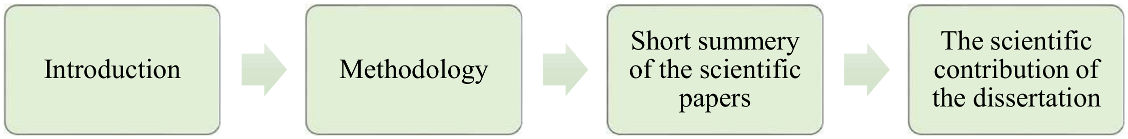
Kurzfassung

Die Alzheimer-Krankheit (AD) ist eine der fortschreitenden Krankheiten, die das Verhältnis des Einzelnen zu seiner Umwelt verändert. Aus der Perspektive von Menschen mit Alzheimer-Krankheit (MmA) stellt sich immer die Frage: "Wie soll ich...? Und: "Wohin...?" MmA fehlen diese Informationen aufgrund des Fortschreitens der Krankheit. Daher ist das therapeutische Umfeld von entscheidender Bedeutung für die Bereitstellung der fehlenden Informationen und die Erfüllung der Bedürfnisse und Anforderungen von MmA. Die in diesem Bericht vorgestellte Studie ist eine kumulative Dissertation, die darauf abzielt, einen Ansatz für die Gestaltung personalisierter interaktiver therapeutischer Innenräume für MmA zu entwickeln, um ihre Selbstorientierungsfähigkeiten bei der Erledigung ihrer täglichen Aufgaben in ihren Zimmern in Langzeitpflegezentren im Rahmen eines interdisziplinären Ansatzes zu unterstützen, der Architektur, Mensch-Computer-Interaktion und Neurowissenschaften kombiniert, um integratives Lernen, kritisches Denken und kreatives Problemlösen einzubeziehen. Damit soll die Lebensqualität von MmA verbessert werden. Dieses Ziel führt zu folgenden Forschungsfragen: (1) Was sind die Schlüsselkomponenten einer therapeutischen Umgebung für MmA? (2) Inwieweit könnte interaktive Architektur die Erfahrung eines therapeutischen Innenraums für MmA in langfristigen Gesundheitszentren verbessern? (3) Welche Rolle spielt das Computational-Design bei der Verbesserung des therapeutischen Umfelds für MmA? Diese Dissertation verfolgt drei Ziele. Das erste Ziel (Elnimr, 2021) ist ein Scoping-Review, um die in diesem Bereich durchgeführte Forschung systematisch abzubilden und Lücken im aktuellen Wissen und in der Forschung zu identifizieren. Das zweite Ziele (Elnimr, 2022) besteht darin, Daten über strukturierte und halbstrukturierte Fragebögen und persönliche Interviews mit Fachleuten zu erhalten, die täglich mit MmA zu tun haben. Zusätzlich zur neutralen Beobachtung eines Bewohners, um die täglichen Bedürfnisse von MmA und die Hindernisse, die sie in ihren Zimmern erleben, zu verstehen. Das dritte Ziel (Elnimr, 2023) ist die Schaffung eines computergestützten Frameworks, der Forschern, Architekten im Gesundheitswesen und Designern bei der Bewertung des therapeutischen Umfelds auf der Grundlage räumlicher Beschränkungen und der Selbstorientierung von PLWADs helfen soll. Die Dissertation zielt darauf ab, eine Strategie für die Implementierung personalisierter interaktiver Innenraumumgebungen für Menschen mit Behinderungen zu entwickeln, um ihre Selbstorientierungsfähigkeiten bei der Erledigung ihrer täglichen Aufgaben in ihren Zimmern in Langzeitpflegezentren zu unterstützen und ihre Lebensqualität zu verbessern. Die Dissertation leistet einen bemerkenswerten Beitrag durch: (1) Annahme und Demonstration der Stärke eines interdisziplinären Forschungsansatzes_ Architektur/ Digitale Architektur, Neurowissenschaften, HCI_; (2) Entwicklung eines computergestützten Frameworks zur Bewertung des therapeutischen Umfelds aus der Perspektive von MmA; und (3) die Bewältigung der ethischen Herausforderungen im Zusammenhang mit der Gerontotechnologie für die Alzheimer-Krankheit in künftigen Studien.

Abstract

Alzheimer's disease (AD) is one of the progressive diseases that changes one's relationship with the surrounding environment. AD as experienced from the perspective of persons living with Alzheimer's disease (PLWAD) is always a matter of "how to..?" Moreover, it is a matter of "where to..?" PLWADs are missing those pieces of information due to the disease's progression. Therefore, the therapeutic environment is essential in providing the missing information and fulfilling PLWADs' needs and requirements. The study presented in this report is a cumulative dissertation that aims to develop an approach to designing personalized interactive indoor therapeutic environments for PLWADs to support their self-orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers within an interdisciplinary approach that links architecture, human-computer interaction, and neuroscience to involve integrative learning, critical thinking, and creative problem-solving. This is done to ultimately increase PLWADs' quality of life. This aim leads to the following research questions: (1) what are the key components of a therapeutic environment for PLWAD?; (2) how far could interactive architecture add to the experience of an indoor therapeutic environment for PLWAD at long-term healthcare centers?; (3) what is the role of computational design in enhancing PLWADs' therapeutic environment? This dissertation targets objectives at three levels. The first objective (Elnimr, 2021) is a scoping review to systematically map the research done in this area and identify gaps in current knowledge and research. The second objective (Elnimr, 2022) is to obtain data via structured and semi-structured questionnaires and face-to-face interviews from professional experts, (such as nurses, psychologists, etc.), who are in daily contact with PLWADs, in addition to neutral shadowing observation of one of the residents to understand PLWADs' daily needs and the obstacles they experience in their rooms. The third objective is to create a computational framework to guide researchers, healthcare architects, and designers in assessing the therapeutic environment based on spatial constraints and PLWADs' self-orientation (Elnimr, 2023). The dissertation aims to strategize the implementation of personalized interactive indoor environments for PLWADs to support their self-orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers to enhance their quality of life. The dissertation makes a noteworthy contribution by: (1) adopting and demonstrating the power of an interdisciplinary research approach (Architecture/ Digital Architecture, Neuroscience, Human-Computer-Interaction (HCI)); (2) developing a computational framework to assess the therapeutic environment through the perspective of PLWADs'; and (3) addressing the ethical challenges surrounding gerontechnology for AD in future studies.

1. Exegesis Structure (Fig.1)



(Fig. 1): illustrates exegesis structure

1.1. Introduction

Alzheimer's disease (AD) is one of the significant causes of disability and dependency among older adults worldwide, affecting memory, cognitive abilities, and behavior, ultimately interfering with one's ability to perform daily activities. AD is considered the most common form of dementia and may contribute to 60–70% of cases (World Health Organization, 2017). Dementia is an umbrella term used to define several diseases that affect memory, cognitive processes, and behavior and have a significant impact on a person's ability to maintain their independence. Dementia is the seventh leading cause of mortality globally (World Health Organization, 2017). As mentioned in the World Alzheimer's Disease International 2020 Report (World Alzheimer Report 2020, 2020), the impact of AD is not only significant financially but also represents substantial human costs to countries, societies, and families and individuals in particular. To put the cost of this disease into perspective, if AD represented a country's economy, it would be the 18th largest factor in terms of economic impact. If AD were a company, it would be the most ‘profitable’, exceeding Walmart, with USD 414 billion (World Health Organization, 2017; 2021 Alzheimer's disease facts and figures, 2021; 2023 Alzheimer's disease facts and figures, 2023).

Furthermore, previous studies (Bowes, A. and Dawson, A., 2019; Marquardt et al., 2014) and the World Alzheimer's Disease International 2020 Report (World Alzheimer Report 2020, 2020) stated the importance of the built therapeutic environment for PLWADs' health status. The therapeutic environment has either a negative or a positive impact on PLWADs and has no neutral effect (Zeisel, 2000). Hence, there is a need to understand in depth PLWADs' needs, problems, daily activities, and the architectural barriers considered obstacles to achieving their daily activities in their room at long-term healthcare centers to enhance their therapeutic environment. Moreover, a therapeutic environment is an environment that is supportive of each individual. Therefore, applying one therapeutic environment design to different residents is inadequate because each resident's health status might differ. In addition, each resident has a different identity, background, habits, and symptoms.

Primary research implied three main aspects of designing a user-friendly therapeutic environment (Feddersen and Lüdtke, 2014). These include: (1) considering PLWADs as end-users; (2) considering what is essential about the environments one lives in; and (3) PLWADs' identity, i.e., knowing PLWADs' background, hobbies and habits, etc. (van Steenwinkel et al., 2014; Van Steenwinkel, I., Van Audenhove, C., Heylighen, A., 2012; Wasana de Silva, 2019). In addition, the vital aspect of the ten principles reported in the World Alzheimer's Disease International 2020 Report (World Alzheimer Report 2020, 2020) emphasizes the importance of designing supportive environments, allowing PLWADs to make decisions and accomplish activities independently. The ten principles are (1) unobtrusively reduce risks; (2) provide a human scale; (3) allow people to see and be seen; (4) reduce unhelpful stimulation; (5) optimize helpful stimulation; (6) support movement and engagement; (7) create a familiar place; (8) provide opportunities to be alone or with others; (9) link to the community; and (10) design in response to vision for a way of life.

Therefore, the study provided in this dissertation aims to develop an approach to designing a personalized interactive indoor therapeutic environment for PLWAD to support their self-orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers. The dissertation aims to strategize the implementation of interactive indoor environments for PLWADs to support their self-orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers to enhance their quality of life. This aim leads to the following research questions:

(1) What are the key components of a therapeutic environment for PLWAD?

(2) How far could interactive architecture add to the experience of an indoor therapeutic environment for PLWAD at long-term healthcare centers?

(3) What is the role of computational design in enhancing PLWADs' therapeutic environment?

Due to the complex nature of AD, it was challenging to answer the dissertation questions from only the architectural perspective. Hence, designing a therapeutic environment that caters to PLWADs' needs and abilities revealed the importance of combining and going cross-disciplinary (Architecture, Neuroscience, and Human-Computer-Interaction (HCI)) to create an interactive, personalized therapeutic environment with a positive impact on PLWAD. Meanwhile, although the dissertation is interdisciplinary in character, a targeted discipline has been addressed in each objective. Moreover, each targeted discipline was combined with the architecture discipline (Elnimr, 2021, 2022, 2023). Furthermore, in some cases, this involves a selection of design approaches, design targets, and related vital parameters. In other cases, this involves selection, combination, and/or developing technology.

Moreover, the interdisciplinary research reinforced the dissertation's overarching objective: how to support architects and designers in "designing" an interactive, personalized therapeutic environment; its interior and its technologies match the needs of PLWAD and enhance their self-orientation abilities?

Based on what was mentioned previously, the interdisciplinary research model contains the following:

(1) The architecture/ digital architecture discipline provides the computational design processes for concrete designs and defines the architectural barriers in PLWADs' therapeutic environment. Moreover, digital architecture allows architects to consider each resident's specific needs. For instance, an architect could use digital tools to design a healthcare residency room that considers a resident's unique needs with mobility issues. Likewise, an architect could use digital tools to design a residential space specifically tailored to a resident's needs with a particular mental health condition. Digital architecture is essential for architects who want to create spaces that promote healing and well-being for PLWADs. With the help of digital tools, architects can create customized designs that are both functional and aesthetically pleasing while ensuring that they promote their users' needs, safety, and independence.

(2) The neuroscience discipline provides an understanding of PLWADs' behavior to detect anomalies in their movements/ behavior and their interaction with their surrounding therapeutic environment. PLWAD can exhibit various behavioral anomalies, making it difficult for architects to provide adequate therapeutic environment design with a positive influence. However, neuroscience research offers valuable insights that can deepen architects' understanding of these behaviors and enable the development of more effective therapeutic environment design and a higher quality of life for PLWAD.

(3) The Human-Computer-Interaction (HCI) discipline provides suitable assistive technology (AT) that caters to PLWADs' abilities. The field of HCI has been at the forefront (Jheng and Pai, 2009; Moyle et al., 2018) of developing AT that caters to PLWADs' unique skills and needs. HCI has sought (Ienca et al., 2017; Klimova et al., 2018) to create specialized hardware, software, and user interfaces that enable PLWADs to interact with their surrounding therapeutic environment using computers and other electronic devices in ways that are tailored to their physical, sensory, and cognitive capabilities.

This dissertation targets objectives at three levels to answer its questions (Fig.2).

First Objective

A scoping review

Interactive architecture as a therapeutic environment for people with Alzheimer's disease, a scoping review (2021)

Second Objective

Understand PLWADs' daily and the barriers they experience in their rooms

A Study of Architectural Barriers and the Potential Role of Assistive Technologies in Long-term Healthcare Centres for People with Alzheimer's (2022)

Third Objective

Create a computational framework

Assessing Alzheimer's Therapeutic Environment Digitally Through People with Alzheimer's' Perspective: A Computation-Based Approaches Framework (2023)

(Fig. 2): illustrates the three objectives of the dissertation

The first objective (Elnimr, 2021) was a scoping review to systematically map the research done in this area and identify gaps in current knowledge and research. The scoping review has three main goals:

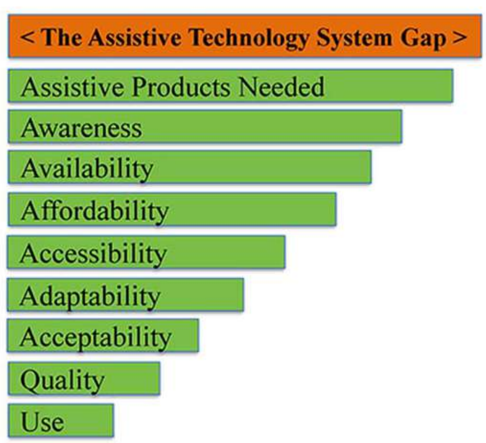
(1) Elaborating on the significance of creating a therapeutic environment for PLWAD and determining the criteria for a therapeutic environment with positive outcomes for PLWAD. Positive outcomes, such as reducing anxiety and behavioral/psychological symptoms, and improving comfort and well-being;

(2) Recognizing the most recent technological solutions for interactive therapeutic environments in long-term healthcare centers to improve PLWADs' quality of life;

(3) Identifying the gaps in the AT, including implemented place, which types of AT have been integrated into the residents' rooms, the purpose of their use, and if the residents use them individually or with the assistance of caregivers.

Based on a preliminary scoping review, the key research questions were: (1) Is there a correlation between the therapeutic environment and PLWADs' improvement? (2) What are the key system characteristics of a therapeutic environment with a positive outcome for PLWAD? (3) What is the use of AT? (4) What types of AT have been used in PLWADs' rooms at long-term healthcare centers? (5) Are the residents using the AT individually or with the caregivers' assistance? (6) What aspects should healthcare architects and designers consider while designing a therapeutic environment for PLWAD?

The answers to those questions have been reflected in the scoping review (Bowes, A. and Dawson, A., 2019; John Zeisel, 2003; Malkin, 1992; Ron Smith, 2016; van Hoof et al., 2017; Zeisel, 2000) have confirmed a positive correlation between the therapeutic environment design (especially when healthcare architects consider PLWAD as end-users) and PLWADs' improvement. Moreover, including interactive architecture in PLWADs' environments improved their physical and cognitive rehabilitation (such as, memory retention, attention, and problem-solving), and their self-esteem (Dalton, 2017; Fasilis et al., 2018; Hofmann et al., 2003; Marquardt et al., 2014; McCullough, 2005; Moyle et al., 2018; Yates et al., 2019). Moreover, the scoping review revealed a few gaps concerning the integration of AT in residents' rooms. Other limitations include a lack of studies on the effects of architectural factors on AT efficiency (James R. Benya, 2010). In addition to the AT system gaps (Fig.3), which had been mentioned in the Alzheimer's Association International Conference (AAIC) 2019 (AAIC 2019 Press Office, 2019).



(Fig. 3): illustrate assistive technology system gap according to Alzheimer's Association International Conference (AAIC) 2019 in Los Angeles.

The second objective (Elnimr, 2022) was to understand the daily needs of PLWADs, the barriers they experience in their rooms, to determine potential architectural barriers, and the AT type and the purpose of its usage, by obtaining data via structured and semi-structured questionnaires and face-to-face interviews from the professional experts who are in daily contact with PLWADs, in addition to neutral shadowing observation of one of the residents. The study was conducted at one of the long-term healthcare centers for PLWAD in Vienna, Austria. The key research questions reflected in this study during the sequential procedure were: (1) What was the health status of PLWAD? (2) Were the PLWADs aware of their surroundings and to which degree? (3) What were the PLWADs' daily needs in their room? (4) Were they achieving their daily activities individually or with caregivers' assistance? (5) Did they have a daily routine? (6) What barriers did they face to achieving their daily activities individually? (7) What was the PLWADs room's equipment? (8) What architectural barriers does the PLWAD face when moving in the room or using AT? (9) What AT is currently used in PLWADs' rooms and which purpose do they serve? (10) What design concept is capable with PLWADs' needs? (11) How to enhance/ modify the existing therapeutic environment?

The pivot of the answers was the participants' experiences in how AD changes one's relationship with the surrounding environment and the possible alternative solutions to enhancing PLWADs' quality of life. Understand how a person–space–assistive technology relationship challenges PLWADs in performing their daily activities. Moreover, the PLWADs' self-disorientation was the biggest challenge they faced during all the activities they had to achieve. Additionally, the second objective revealed another layer of AT use due to COVID-19 restrictions. The COVID-19 pandemic emphasized the need for decision-support tools in Alzheimer's care to help researchers continue collecting and analyzing their research data, the architects in built-environment decision-making processes; and neurologists to follow up PLWADs' health status. Therefore, the third objective proposed a framework based on computational design as an alternative solution for the regular shadowing observation by the researcher.

The third objective was a computational framework to guide researchers and designers in assessing PLWADs' therapeutic environment based on spatial constraints and PLWADs' self-orientation (Elnimr, 2023). The key research questions were: (1) How to digitalize the as-built for a post-construction old building? (2) What is the criteria for selecting the Internet of Things (IoT) sensors-based monitoring motion within the context of PLWAD? (3) How to determine the optimal sensors' placement? (4) What is the analyzing criteria for PLWADs' movement in their rooms at the long-term healthcare center? (5) What is the movement anomaly definition within the context of PLWAD behavior? (6) How to display the analyzed data output in the Building Information Modelling (BIM) system? (7) What is the ethical consideration for installing IoT- technology-based monitoring in PLWADs' rooms at long-term healthcare centers?

The dissertation adopts a design methodology in its approach to exploring the potential use of AT to assess the existing therapeutic environment for PLWAD and enhance it. The following section, “Methodology,” will explain each method used for each objective.

1.2. Methodology

AD is a progressive neurodegenerative disorder that affects memory, thinking, and behavior, and is the main cause for the development of dementia. The therapeutic environment plays a crucial role in managing AD. This study aims to explore the creation of a personalized interactive therapeutic environment for PLWAD through their perspective using digital architecture. The following section illustrates the research philosophy, design, approach, data collection and analysis to achieve the study's aim.

Research philosophy

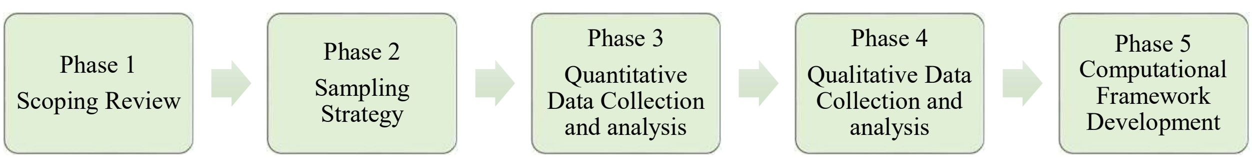
Due to the complex nature of AD in humans who experience the therapeutic environment differently requires cross-disciplinary collaboration (namely, Architecture, Human-Computer Interaction, and Neuroscience); to attain the dissertation aim, questions, and objectives. Therefore, the dissertation combines two research philosophies: interpretivism and pragmatism. The starting point for interpretivism is that knowledge in the human and social sciences cannot conform to the natural science model because there are features of human experience that cannot objectively be "known." This might include emotions; understandings; values; feelings; subjectivities; socio-cultural factors; historical influence; and other meaningful aspects of human beings (Scauso). Hence, the interpretivism philosophy's main aim is to understand individuals' lives and experiences and empathetically identify reasons for why they act the way they do. As a result, the main aim of Interpretivism is appropriate with the dissertation objectives to understand from PLWADs' perspective how AD changes one's relationship with the surrounding environment and to determine the architectural barriers to create a therapeutic environment with a positive outcome on PLWAD. Furthermore, the interpretive approach is based on naturalistic data collection approaches such as interviews and observations. Although primary data generated in interpretivism studies cannot be generalized; it can be associated with a high level of validity because data in such studies tend to be trustworthy and honest (Farrow, R., Iniesto, F., Weller, M. & Pitt., R., 2020).

While the research philosophy of Pragmatism accepts concepts to be relevant only if they support action, Pragmatics recognizes that there are many different ways of interpreting the world and undertaking research, that no single (Żegleń and Conant, 2002) point of view can ever give the entire picture, and that there may be multiple realities. Moreover, Pragmatism takes a practical and problem-solving approach to research; it emphasizes the use of mixed methods and acknowledges the value of using multiple research methods, such as qualitative, quantitative, and action research methods. Pragmatists are concerned with finding practical solutions and generating helpful knowledge that can be applied to real-world situations (Farrow, R., Iniesto, F., Weller, M. & Pitt., R., 2020). Pragmatism provides a guiding epistemological framework anchored in the inquiry process and practical solutions, and it is appropriate for problem-solving during the research processes due to the COVID-19 pandemic restrictions. As this philosophy has three main principles: (1) an emphasis on actionable knowledge; (2) recognition of the interconnectedness between experience, knowing, and acting; and (3) inquiry as an experiential process (Kelly and Cordeiro, 2020). These principles strengthen each stage of the research process, from project design and data collection to data analysis, conclusions, and dissemination. According to Dewey (Dewey and Hickman, 2007; Kelly and Cordeiro, 2020), all conscious human actions involve some inquiry or assessment in response to a problem or obstacle. This inquiry or assessment is followed by adaptation and altered behavior in response to the problem. Pragmatist management researchers can be compared to architects. In the same way, architects use whatever materials and methods are needed to build the building they schemed on paper; pragmatists use whatever combination of methods necessary to find answers to research questions. At the same time, it has to be noted that pragmatists do not have to use multiple methods; instead, they use a method or a combination of methods that advances specific research in the best possible manner.

Research design and approach

Due to the essential role of the therapeutic environment in the management of AD and how each person living with AD experience the therapeutic environment differently, the main aim of this study is to explore the creation of an interactive personalized therapeutic environment for PLWAD using digital architecture for improving their self-orientation abilities; hence, the dissertation adopted an exploratory research design plan to achieve its aim and objectives. Furthermore, the underlying premise in grounded theory is that every human interaction involves a problem and a process to solve (Brink and Wood, 1998); hence, the researcher used the exploratory research design: (1) to document the therapeutic environment impact from the perspective of professional experts, caregivers, and PLWAD; (2) there is a literature deficiency about how PLWADs' are self-orientated individually in their room at the long-term healthcare center; as well as the architectural barriers considered obstacles to achieving their daily activities; and (3) the exploratory research's vital characteristics, flexibility, pragmatism, and the particular, which are capable with the complex nature of AD (Casula et al., 2021).

The exploratory research involved multiple methods for data collection. That is the use of these three approaches for data collection, namely: questionnaire, face-to-face interviews, and shadowing observation, to meet the doctrine of exploratory research design and to satisfy the researcher's curiosity as well as the desire for a better understanding of how a person–space–AT relationship challenges PLWADs in performing their daily activities in their rooms at the long-term healthcare center. A mixed-methods study with a sequential design was conducted to understand in-depth the PLWADs' space, needs, and potential role of AT (Creswell and Plano Clark, 2018; Delamont, 2020; Palinkas et al., 2015). The principle for combining quantitative and qualitative data is that neither method is sufficient by itself to examine specifics of circumstances, such as a complex topic of how AD changes a person's interaction with space. Combining quantitative and qualitative data provided a complete understanding of the research problem rather than either approach by itself (Creswell, 2017). The study was conducted in five phases (Fig. 4):

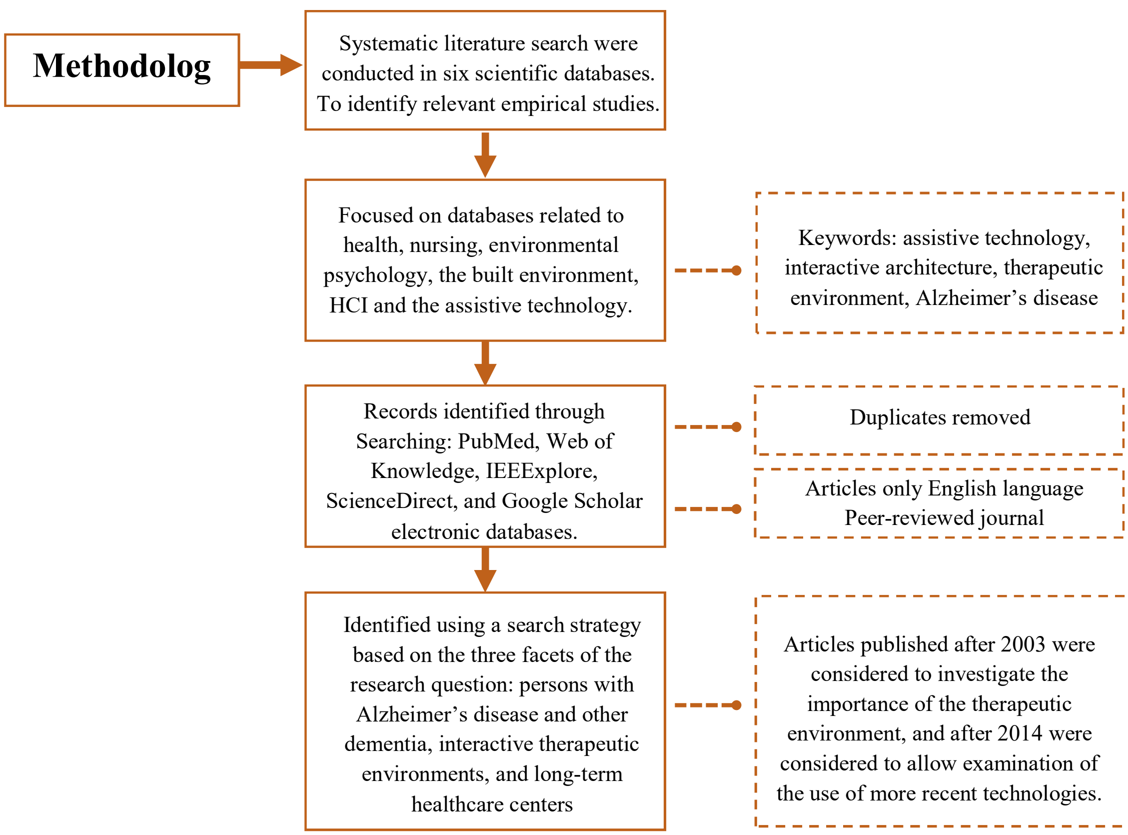


(Fig. 4): illustrate the four phases of the research design

Phase 1: Scoping Review

In this phase, a comprehensive scoping review of the literature was conducted to (1) clarify the importance of implementing a therapeutic environment for PLWAD and identifying the characteristics of a positive outcome for these residents; (2) identifying the latest advances in technological solutions for interactive therapeutic environments in long-term healthcare centers for improving the PLWAD's quality of life. The focus is on virtual environments (VEs) as AT tools; and (3) identifying the gaps in the AT-implemented place, looking at which types of AT has been integrated into the residents' rooms, the purpose of their usage, and whether the residents are using them individually or with caregivers' help.

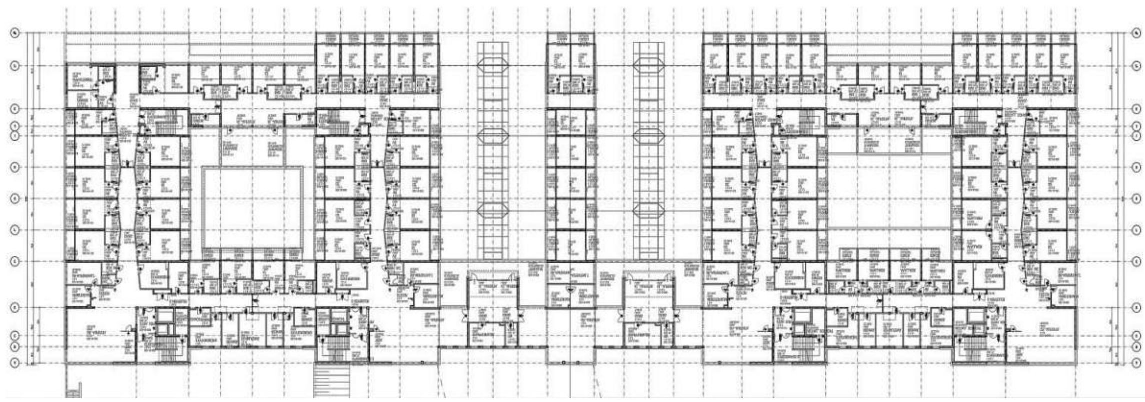
The literature review represented an embedded study, collecting and analyzing quantitative and qualitative information. It involves a mixed research synthesis by using quantitative research approaches to synthesize quantitative-based works and qualitative research approaches to synthesize qualitative-based works. The review is organized into two parts: (1) searching the literature and selecting relevant work and (2) categorizing the selected works and their use. In the first part, a systematic literature search was conducted in six scientific databases to identify relevant empirical studies. A focus was on the health, nursing, environmental psychology, the built environment, HCI, and AT databases. Therefore, a literature search was performed in PubMed, Web of Knowledge, IEEExplore, ScienceDirect, and Google Scholar electronic databases, using the following keywords: assistive technology, interactive architecture, therapeutic environment, virtual environment, multisensory stimulation, multisensory environment, and augmented reality. The keywords were combined with the terms "dementia" and "Alzheimer's" to identify papers on the topic and pilot studies. Published studies were next identified using a search strategy based on the three facets of the research question: persons with Alzheimer's disease and other dementias, interactive therapeutic environments, and long-term healthcare centers. Only English-language peer-reviewed journal articles published after 2003 were considered in investigating the importance of the therapeutic environment. Articles published after 2014 were mainly considered to examine the use of more recent technologies. Eligible articles examined the effects of no immersive, semi-immersive, and/or fully immersive virtual, augmented, or mixed reality interventions using head-mounted devices on participants' quality of life, depressive symptoms, social interaction, enjoyment, and acceptability. In the second stage of the review, the retrieved VR studies and applications were categorized according to the classification in (Fig. 5). The scoping review included peer-reviewed articles, books, and other relevant sources.



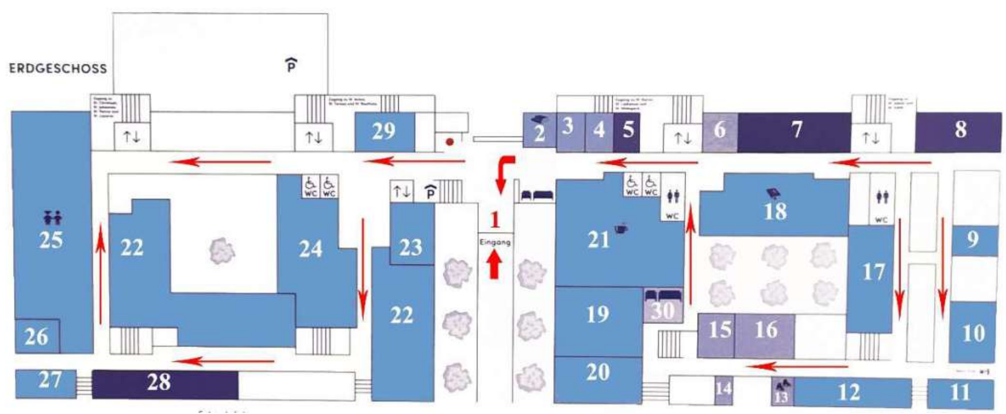
(Fig. 5): illustrates a flowchart of the scoping review methodology

Phase 2: Sampling Strategy

Due to the dissertation's main aim and objectives, the study occurred at a long-term healthcare center in Vienna, Austria. The healthcare center was built in 2005. The structure of the building is divided into two main wings (Fig. 6), the east and the west wing. The building has four floors, each one containing 12 wards for people with different care needs, while the ground floor (Fig. 7) contains the treatment and therapy rooms on the west of the central entrance hall, and on the east is a restaurant, event rooms, the chapel, library, hairdresser and the administration area. In addition to the therapy area, there is a kindergarten with an outdoor area. The healthcare institution had about 300 residents. The number of residents and the professional experts working there; the variation in the residents' room occupancy (single and doubled), and the use of AT were the characteristics of selecting this center for the study.



(Fig. 6): Floor plan of the Alzheimer's center (1st floor)



1. Entrance
2. Library
3. Hairdresser
4. Residents' service point
5. Administration office
6. Conference Room
7. Nursing Director
8. Institute Director
9. Management Director
10. Quality Management
11. Communication
12. Technical Director
13. Consultation Room 1
14. Consultation Room 2
15. Conference Room 1
16. Conference Room 2
17. ICT Service
18. Church
19. Seminar Room 1
20. Seminar Room 2
21. Restaurant
22. OT room
23. X-Ray
24. Medical Control Room
25. Kindergarten
26. Cardinal Schönborn room
27. Ignatius Nascher room
28. Medical Director
29. Technical Room
30. Paris Salon

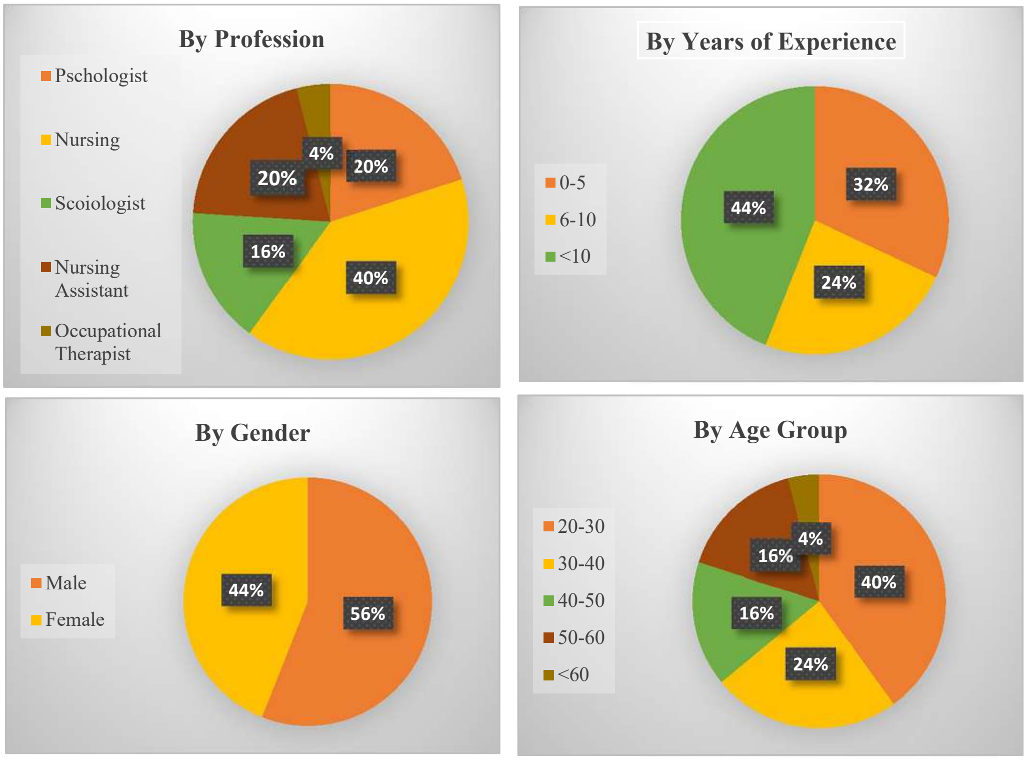
(Fig. 7): Floor plan of the Alzheimer's center (ground floor)

As mentioned previously, the study adopted an exploratory research plan with a sequential design, quantitative followed by qualitative; therefore, a multi-sampling was used. Stratified random sampling technique for the quantitative data and for more data-oriented from the insights gained in the quantitative data, a convenience sampling technique for the qualitative data was used. The researcher used stratified random sampling to be sure that all the professional experts with different subgroups; (such as psychologists, nurses and nursing aides, etc.) were included and participated in the collected sample. While simple random sampling and systematic sampling might not adequately capture all these groups, particularly relatively rare ones. The following criteria characterized the stratified random sampling technique: (1) active working in the long-term healthcare center (the case study); (2) a period of experience caring for PLWADs; (3) in daily contact with PLWADs; (4) completed professional training related to healthcare; (5) speaks the German language.

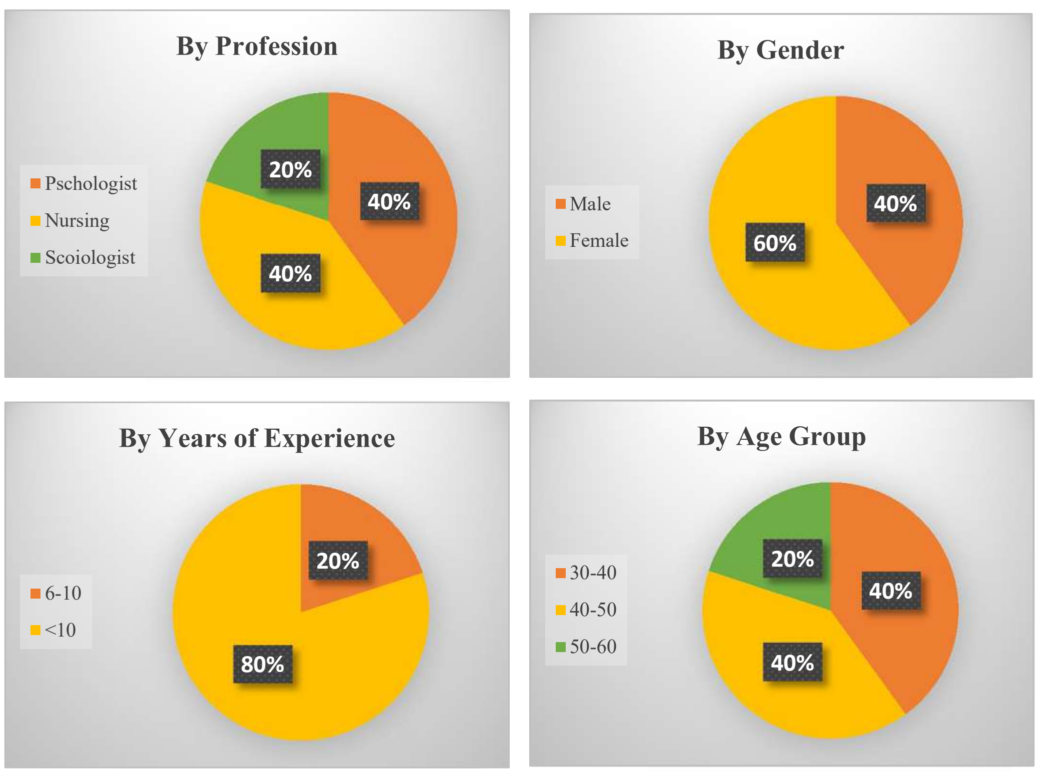
Furthermore, due to the COVID-19 restrictions, which were considered the most significant difficulty encountered during the research study (Elnimr, 2022), and the need to continue collecting the qualitative data, the researcher selected convenience sampling for more oriented data. Convenience sampling is a qualitative research sampling strategy that involves selecting participants based on their accessibility and availability to the researcher. Convenience sampling is the most common type of non-probability sampling, which focuses on gaining information from participants (the sample) who are 'convenient' for the researcher to access and who match the participants' criteria. At the same time, quota sampling and snowball sampling might not be adequate in this study, as quota sampling is used in investigating traits of a particular subgroup and relationships between the subgroups, snowball sampling, on the other hand, is used in the study of deviant behavior and in situations where the population is hard to reach.

The following criteria characterized the convenience sampling technique: firstly, the face-to-face interview participants' criteria: (1) active working in the long-term healthcare center (the case study); (2) at least eight years of experience caring for PLWADs; (3) in daily contact with PLWADs; (4) completed professional training related to healthcare; (5) speaking the English language. Secondly, the shadowing observation participant criteria included: (1) PLWAD is in the early stage of AD, (2) single room occupancy, (3) living in a long-term healthcare center for at least two years, and (4) having no disabilities (for instance, blindness).

A total of 30 professional experts participated in the questionnaire and the face-to-face interviews. Emails were sent to the responsible person at the long-term healthcare center with information about the study and the questionnaire form. A total of 25 professional experts participated in the questionnaire (Fig. 8). Five individuals were interviewed (Fig. 9). The variation between the two languages is due to not all professional experts working in long-term healthcare center speaking English. Due to COVID-19 restrictions, only one PLWAD was shadowed. This male patient was 78 years old, in the early stage of AD, and stayed in a single room. He was shadowed during three time periods on different weekdays from 09:30 am to 12:30 am, from 1:30 pm to 4:15 pm, and from 5:30 pm to 8:00 pm.



(Fig. 8): illustrates the participants (the professional experts) in the questionnaire (quantitative data)



(Fig. 9): illustrates the participants (the professional experts) in the face-to-face interview (qualitative data)

Phase 3: Quantitative Data Collection

In this phase, a questionnaire was developed based on the findings from Phase 1, to explore the experience of PLWADs through experts' opinions. The questionnaire (in the German language) was administered to a sample of active caregivers and professional experts working in the Alzheimer's long-term healthcare center (the case study) and in daily contact with PLWADs. The participants, who matched the criteria, filled out a hard copy survey. The questionnaire, in total contained 118 questions (Qs) and was divided into two parts:

(1) PLWADs' health status and their daily needs, information about the use of the AT, and facility information, for instance, the equipment in each room for single and double room occupation.

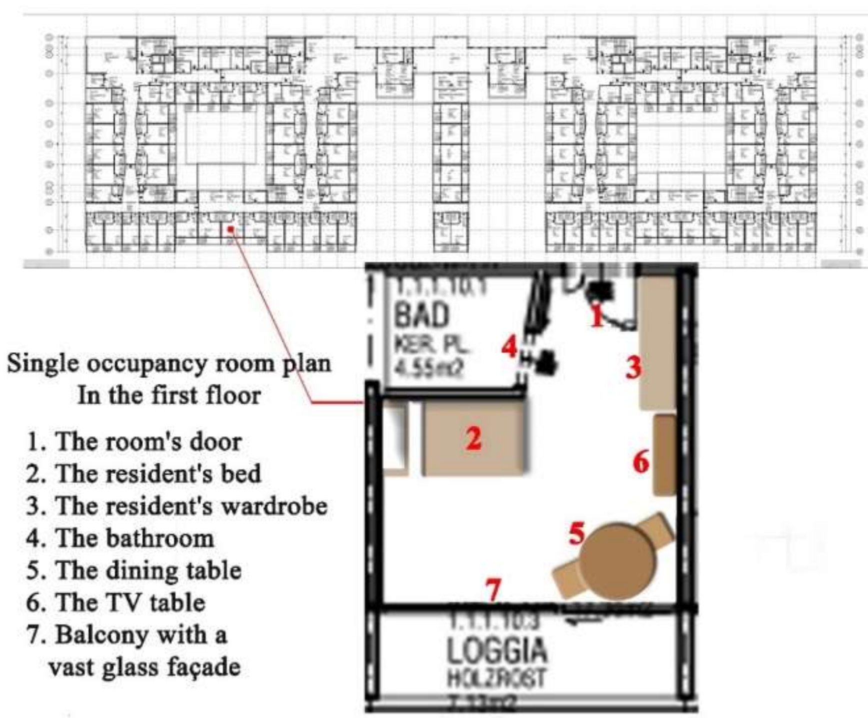
(2) Participants' information (profession, age, years of experience, etc.), their opinions about the use of AT, and the barriers which residents (PLWAD) face in their daily tasks in their room.

The participants answered all questions related to (1) facility information in total (n= 91Qs) as follows; building areas contained (n= 15Qs); building entrance equipment contained (n= 10Qs); social areas equipment; living room and dining room contained (n= 19Qs); training and therapy room equipment contained (n= 13Qs), PLWADs' single occupancy room equipment contained (n= 17Qs) and PLWADs' double occupancy room equipment contained (n= 17Qs), (2) PLWADs health status and their daily needs and actives contained (n= 9Qs), (3) the barriers that PLWADs face in their daily tasks in their room contained (n= 3Qs), and (4) the participants' information contained (n= 8Qs). Furthermore, AT had in total of (n= 11Qs) divided into two parts as follows; firstly, the existing AT in the facility (Q1- Q6), all participants answered the first part; secondly, participants' opinions and knowledge of AT (Q7- Q11), only (n= 8P) answered the second part of AT. Since the data and selected cases contain sensitive personal information, maintaining participant confidentiality and privacy is essential. Confidentiality was addressed during the data collection, data cleaning, and dissemination of the research results. The participants' and organizations' names were replaced with pseudonyms.

Phase 4: Qualitative Data Collection

This phase contained two stages: (1) face-to-face interviews; and (2) shadowing observation.
Concerning the face-to-face interviews were with active caregivers and professional experts working in the Alzheimer's long-term healthcare center (the case study) and in daily contact with PLWADs, to explore the role of five factors ("therapeutic environment," "assistive technology," "PLWADs' self-disorientation," "PLWADs' daily routine in their room, and "coping and support"). The semi-structured interviews were developed based on the findings from Phase 3; the questions employed a blend of closed- and open-ended questions, often accompanied by follow-up why or how questions. During each interview, notes were made in the margin. These notes contained verbatim extracts from the transcript. Interviews were verbatim transcribed. The interviews took place at the healthcare center. Each interview was followed by taking pictures (by the researcher) to illustrate what the interviewed person talked about. Since the data and selected cases contain sensitive personal information, maintaining participant confidentiality and privacy is essential. Confidentiality was addressed during the data collection, data cleaning, and dissemination of the research results. The participants' and organizations' names were replaced with pseudonyms.

The second stage is the shadowing observation, which is considered the key to creating a personalized therapeutic environment with a positive outcome for the PLWADs in their rooms at long-term healthcare centers. User shadowing observation is a qualitative research method that collects rich data about the PLWADs' behaviors in their familiar therapeutic environment (Goodrich et al., 2022; Liberati, 2017; Shaw et al., 2014; van der Weele and Bredewold, 2021). This research method prioritizes the users' interaction. It is an old research method (Alasuutari et al., 2008) with a fresh beginning in user experience design concepts (UX) and design thinking framework. It can potentially gather critical evidence for researchers to create, develop, and improve the existing therapeutic environment for PLWADs in long-term healthcare centers. There are three types of shadowing observation (Quinlan, 2008): (1) Naturalistic (no-interference), where the researcher only observes the participants for a fixed period in their natural surroundings; (2) controlled, which is typically a structured observation, where the researcher designs an activity and observes it being carried out; and (3) participatory, where the researcher achieves the activity being observed to gain a firsthand perspective. The researcher chose the naturalistic shadowing observation approach to explore in-depth the natural way PLWADs' self-orientation in their room and if the room layout/ equipment considers an architectural barrier. Combining observation and debriefing helps to grasp the participant's perspective and gives a "voice" to PLWADs concerns and experiences. The researcher drew the room's plan with the actual dimensions and the existing equipment (Fig. 10). The researcher paid close attention to nonverbal reactions, for instance, PLWAD's body language taking notes with them. He was shadowed during three time periods on different weekdays from 09:30 am to 12:30 am, 1:30 pm to 4:15 pm, and 5:30 pm to 8:00 pm. In the case study, the focus points for observation included the following: (1) Was the PLWAD aware of his surroundings? (2) What were the PLWADs daily activities in his room? (3) What were the PLWADs daily needs in his room? (4) What was the PLWADs room's equipment? (5) What architectural barriers does the PLWAD face when moving in the room or using AT? (6) What type of AT did the PLWAD use?



(*Fig. 10):* illustrates the floor plan of a typical resident's room in the Alzheimer's center

Quantitative and qualitative data analysis

The quantitative and qualitative data were integrated by comparing the findings from each phase (Creswell, 2017; Creswell and Plano Clark, 2018; Gournelos, 2019). The quantitative data from Phase 2 was analyzed using descriptive analysis to identify the critical components of a therapeutic environment for PLWAD. The qualitative data from Phase 3 was analyzed using thematic analysis (Braun and Clarke, 2006) to identify patterns and themes in the interview data (Fig. 11). The overall result from the text was the participants' experiences in how AD changes one's relationship with the surrounding environment and the possible alternative solutions to enhancing PLWADs' quality of life. Understand how a person–space–AT relationship challenges PLWADs in performing their daily activities. The focus was on knowing PLWADs' daily needs, activities, and challenges, the other supportive solution to enhancing their quality of life from the professional experts' perspective, the AT, and the potential architectural barriers.

Phase	Procedure	Product
Quantitative Data Collection	• Hard copy questionnaire contained 118 questions • 25 Participants	• Numeric data
Quantitative Data Analysis	• Familiarization • Constructing initial thematic codes • Indexing and sorting • Reviewing data extracts • Data summary • Using Nvivo software	• Descriptive Statistics • Missing data • Creating preliminary codes relating to a person– space– AT
Interview Protocol Development	• Forming the participants' criteria • Developing interview questions	• Participants (N = 5) • Interview protocol
Qualitative Data Collection	• Individual in-depth face-to-face interviews • Using semi-structured questions. • Shadowing observation by the researcher in the patient's room	• Interviews were verbatim transcribed • Image data (photo taken by the researcher • Narrative case study
Qualitative Data Analysis	• Coding and thematic analysis • Within-case and across-case theme development • Cross-thematic analysis • Using Nvivo software • Analyzing patient's movements in their room	• Codes and themes • Similar and different themes and categories • Defining the architectural barriers to the patient self-orientation
Integration of the Quantitative and Qualitative Results	• Interpretation and explanation of the quantitative and qualitative results	• Discussion • Conclusion • Future research

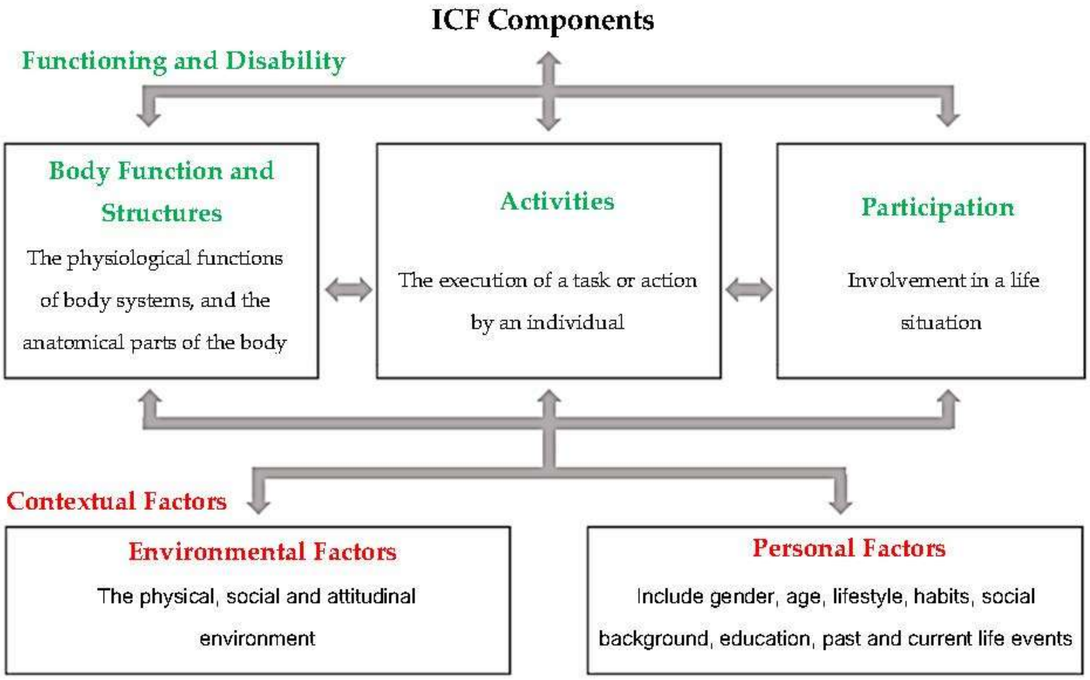
(*Fig. 11*)*:* illustrates the quantitative and the qualitative data process

NVivo (QSR International Pty Ltd., 2020) was used for data analysis for the questionnaire forms and the interviews. The transcript reading, note-making, and listed topics were used as codes in NVivo. These codes were either exact words or sentences from the transcripts. The criteria used to identify the codes are as follows: (1) familiarization to create preliminary codes relating to how a person–space–assistive technology relationship challenges PLWADs in performing their daily activities were identified, (2) constructing initial thematic codes; consisted of five main categories, with several sub-themes for each; assistive technology, architectural aspects, values or beliefs, objects, and places, (3) indexing and sorting process was to find out "what parts of the data are about the same thing and belong together," after indexing, data were sorted so that material with similar content could be viewed as a whole; (4) reviewing data extracts aimed to review the indexed data to determine other potential ways of organizing the data to create more coherent sets; and (5) data summary and display reduced the material to a more manageable level. The codes served to gain an improved understanding of PLWAD's experiences through professional experts' knowledge and the potential role of integrating interactive architecture into an indoor therapeutic environment for PLWAD at healthcare centers. The codes were not used to structure this article. Instead, the subheadings in this article reflect the topics that emerged from the questionnaire and interview responses, focusing on how a person–space–AT relationship challenges PLWADs in performing their daily activities.

Phase 5: Computational Framework Development

In this phase, the findings from Phases 1, 3, 4, and formal knowledge based on previous studies' results (Bouchard et al., 2014; Colombo et al., 2017; Feddersen and Lüdtke, 2014; Gayathri and Easwarakumar, 2016; Goldberg, 2009; Richardson and Domingos, 2006), cross-disciplinary, digital architecture, and neurosciences were combined to develop the assessment technique criteria of the proposed framework: (1) object; (2) time; (3) space; and (4) duration. The computational framework adopted a system theory that focused on the interactions and on relationships between PLWADs' self-orientation and their surrounding therapeutic environment, which is, in this study, their rooms at long-term healthcare centers in order to understand the architectural barriers considered as obstacles to achieving their daily activities individually, based on the International Classification of Functioning, Disability and Health (ICF) as a rationale model, to create the five-stages of the assessment framework. System theory's main components include the following (Fig. 12):

- Environment: PLWADs' rooms
- Inputs: body function and structures, activities, participation, and personal factors.
- Process: using IoT technology, and machine learning to detect the anomaly in the PLWADs' movement.
- Outputs: will be displayed in the BIM system to make a correlation between PLWADs' self-disorientation and the room layout and equipment to determine the architectural barriers.



(*Fig. 12):* illustrates system theory's main components

The proposed framework used the user experience design concept (UX) and the design thinking framework to evaluate PLWADs' resident rooms. In the UX design concept and the design thinking framework, the essential trigger for effective decision-making is in-depth knowledge of users. Within this context, the proposed framework aims to collect real-time quantitative data about PLWADs' movements in their rooms at long-term healthcare centers via IoT sensor-based monitoring with a comprehensive analysis via computational tools and presents the output into a BIM system, that aid decision-makers in investigating, analyzing, improving, and assessing the therapeutic environment through PLWADs' perspective. The proposed framework-structured approach will enable healthcare architects/designers to (1) digitalize old building architecture plans using BIM; (2) strategize IoT sensor selection; (3) recognize PLWAD's activities and detect anomalies; and (4) integrate IoT real-time data into the BIM system. The proposed framework supports three types of professionals: (1) architects in decision-making processes, (2) researchers in collecting/analyzing accurate data for shadowing observation, and (3) neurologists in following up PLWAD's health statutes.

1.3. Short summary of the scientific papers

- First Paper: Submitted on 09.2020- accepted and published on 07.2021

Interactive architecture as a therapeutic environment for people with Alzheimer disease, a scoping review.

The first paper (Elnimr, 2021) is a scoping review that represents an embedded study by collecting and analyzing both quantitative and qualitative information and serves to: 1. Clarify the effects of the therapeutic environment attributes on the well-being of PLWAD, with commentary on the relevance and usefulness of the available research in the field of architectural design and on the relative paucity of credible, relevant design research; 2. Identify the importance of using AT_ as an assistive tool_ to improve the remembering process for

PLWAD, as well as state general issues around AT provision that need to be explored in detail, such as; improving access, personalized care, analysis of limitations, ethical considerations, and future developments, additionally; scanning the latest technological solutions for interactive therapeutic environments in long-term healthcare centers for improving the PLWADs' quality of life; and 3. Identify gaps in AT-implemented places, looking at which types of AT have been integrated into the residents' rooms, the purpose of their usage, and whether the residents are using them individually or with caregivers' help. It also introduces the fundamental visions of research cross-discipline benefits, namely: Architecture_HCI_ Environmental Psychology. This emerges the necessity for a three-pronged approach to designing environments that maximize PLWAD/therapeutic environment fit to adequately address functional and psychosocial congruence issues.

The first paper concluded the main design aspects that should be considered by healthcare architects and designers and elucidated the positive impact of AT use on PLWADs' outcomes, as well as the issues that might happen to PLWAD while using some types of AT, such as head-mounted displays. Moreover, the first paper highlighted the future studies that are needed to improve the interactive therapeutic environment, such as: 1. The necessity to explore the potential integrating strategies of AT to promote daily activities in the PLWADs' rooms at healthcare centers and the architectural factors that could affect ATs' efficiency; 2. The need for future studies to be designed to improve residents' self-orientation in their rooms by using AT individually as assistive tools to motivate and orient them to do specific daily activities, which may differ from one resident to another; and 3. The need for more research focusing on the implementation of interactive therapeutic environments in multiple residence rooms at long-term healthcare centers, the use of AT to stimulate PLWAD in carrying out their daily activities, and the effect of architectural factors on the ATs' efficiency.

- Second paper: submitted on 07.2022- accepted on 11.02022- published on 02.2023
  A Study of Architectural Barriers and the Potential Role of Assistive Technologies in Longterm Healthcare Centres for People with Alzheimer's

While the vital question for the architects to properly design for such a paradigm is the requirement for "person-centered design," particularly in healthcare design, it is essential first to identify the characteristics and needs of the person who stands at the center of the design model, PLWAD are the actual clients. Therefore, the second paper (Elnimr, 2022) was done at an Alzheimer's long-term healthcare center in Vienna, Austria, using a mixed methods study with a sequential design to examine: (1) The daily activities that PLWADs perform in their residence rooms to understand potential architectural barriers considered obstacles to achieve these daily activities individually; and (2) The AT used in PLWADs' rooms at long-term healthcare centers. The second paper identified the following four themes and followed by a summarized description of each theme: (1) PLWADs' orientation in space because all participants _the professional experts_ mentioned disorientation in place as the main observed barrier for PLWAD; (2) Occupational therapy (OT) because it is an effective therapy for PLWAD and the physical environment, influences OT activities; (3) AT and its potential role; and (4) The architectural barriers in the PLWADs' rooms.

The summarized description of the four themes was followed by a broader discussion comparing the current case-study _PLWAD's room layout and equipment_ to the Occupational Therapy Practice Framework (OTPF), as well as to the main focal aspects for designing a user-friendly therapeutic environment that significantly supports the spatial orientation for PLWADs which were suggested in previous studies. Moreover, it stated the relevance and usefulness of the UX for designing a friendly therapeutic environment with a positive outcome; and recommended using the AT as a connection tool to adopt the UX design concept in PLWADs' rooms (in the existing building) to support their self-orientation/ to create a supportive environment for OT activities in the PLWADs' room.

By analyzing the collected data, the second paper revealed the following research gaps:

(1) There is a knowledge gap regarding the PLWADs' needs in their residence rooms and the room layout and equipment.

(2) A knowledge gap regarding supportive AT in the long-term healthcare center applied in a specific room, not in the residents' rooms, because of: (a) lack of awareness from the caregivers; (b) low budget, as most of the time the companies offer the expensive devices; (c) a need to study each resident individually, which is challenging due to the nursing shortage, and the ethical consideration.

(3) A knowledge gap regarding the categorization of AT according to (a) the center budget; (b) how it could help in motivating the residents to do a specific activity in their rooms; and (c) what supportive AT helps the residents to enhance their independence in their rooms.

Furthermore, from the insight gained from this paper, this study recommended the shadowing observation as an essential research method to understand in-depth PLWADs' needs and the architectural barriers they are facing in their rooms; however, due to the Covid-19 restrictions, a reflective question was exposed: What is the role of computational design/ digital architecture in continue the shadowing observation?

- Third paper: submitted on 06.2023- accepted on 08. 2023- published on 09.2023
  Assessing Alzheimer's Therapeutic Environment Digitally Through a People with Alzheimer's' Disease Perspective: A Computation-Based Approach Framework

Based on the insights gained in the exploratory research (Elnimr, 2022), and since epidemics prevented the continual and extensive shadowing observation, there was a need to develop a framework based on computation-design to help collect and analyze quantitative data and support decision-making processes. The exploratory research raised three main issues: (1) the necessity of utilizing BIM in facility management at the post-construction stage; (2) AT has a dual use, firstly, using IoT sensors-based monitoring for shadowing observation helps continuity collecting data mainly during the pandemic time to identify the residents' needs and problems to enhance the design thinking of the therapeutic environment. Secondly, as an assistive tool to achieve a specific activity; and (3) the necessity of using computation-design-based decision-support approaches. Hence, the third paper (Elnimr, 2023) proposed a framework-based computation-designs approach to assess the existing therapeutic environment for PLWAD using BIM-IoT sensors-based monitoring. The proposed framework used the UX and the design thinking framework to evaluate PLWADs' resident rooms. The third paper described comprehensively the five main steps of transferring old postconstruction building to a smart building as follow: (1) The first step is digitalizing old building architecture plans using BIM; (2) selecting IoT sensors-based monitoring; (3) detecting the anomaly in the PLWADs' movement; (4) integrating IoT sensor data into the BIM system (environmental data); and (5) the ethical consideration.

The paper highlighted the difference between the previous framework in the same field and the one proposed here; the proposed framework attempts to improve the therapeutic environment at Alzheimer's long-term healthcare center by dual processes in solving design challenges using design thinking framework and computational design technologies. Furthermore, the proposed framework evaluates each resident's room from each resident's perspective, abilities, and health status, in addition to the recognition systems focusing primarily on the constraints of spatial aspects within using BIM and IoT sensors-based monitoring. These differences are the main novelty of this proposed framework. Moreover, a reflective question was exposed from the insight gained from this paper: How far could the contribution cross-disciplinary enhance the ethical consideration concerning gerontechnology for Alzheimer's disease?

1.4 The scientific contribution of the dissertation

This dissertation aims to enhance the quality of life for PLWAD residing in long-term healthcare centers by developing an approach to designing a personalized interactive indoor therapeutic environment for them that supports their self-orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers, in other words, strategizing the implementation of interactive indoor environments for PLWADs to support their self-orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers to enhance their quality of life. The dissertation makes a noteworthy contribution by: (1) adopting and demonstrating the power of an interdisciplinary research approach, namely_ Architecture/ Digital Architecture, Neuroscience, and HCI_; (2) developing a computational framework to assess the therapeutic environment through PLWADs' perspective; and (3) the vision to address the ethical challenges surrounding gerontechnology for Alzheimer's disease in future studies.

The integration of an interdisciplinary research approach enables a comprehensive understanding of the problem, namely_ Architecture/ Digital Architecture, Neuroscience, and HCI_; this method enables researchers to explore and analyze complex problems, such as AD, from multiple perspectives, leading to a more nuanced and informed understanding of the subject matter at hand. By combining the insights and expertise of experts in diverse fields, researchers can gain valuable insights that are only possible through a single-discipline approach; additionally, it enables researchers to reach a wider audience and communicate diverse viewpoints, and it encourages researchers to confront questions that traditional disciplines do not ask while opening up new research areas. This approach is particularly relevant in Architecture/ Digital Architecture, Neuroscience, and HCI, where the interaction between the built environment, human behavior, and technology is complex and multifaceted, especially in the context of AD, and the end-user is the PLWAD. As such, an interdisciplinary research approach is invaluable for advancing knowledge and developing innovative solutions that meet the needs of a rapidly changing world. Additionally, multidisciplinary research offers the opportunity to open new research areas, tackle complex problems, and cover investment in research by opening the use of knowledge, tools, methodology, and solutions generated in one discipline to other disciplines.

While the computational framework provides a structured methodology for collecting, organizing, and analyzing real-time quantitative data, the framework developed in this dissertation provides a novel approach to assessing PLWADs’ therapeutic environment from their perspective, which can significantly impact their overall health outcomes. The proposed framework is based on a combination of sensor data (IoT technology), machine learning algorithms, and a Building Information Modelling (BIM) system to collect, analyze, and display real-time quantitative data about PLWADs’ self-orientation and behavior and display the output in the BIM system to improve PLWADs' therapeutic environment design. The integration of these technologies enables healthcare architects and designers to gain a deeper understanding of PLWADs’ self-disorientation, needs, behavior, and the architectural barriers faced by PLWAD to make informed decisions to enhance PLWADs' therapeutic environment. By using this framework, professionals in the healthcare industry can access detailed insights, including information on therapeutic environment factors such as room equipment. This data can be used to optimize the design of the therapeutic environment and improve the overall quality of care provided to PLWAD.

Moreover, by continuously monitoring and analyzing PLWADs’ self-orientation and behavior, the system developed in this dissertation can identify patterns, trends, and potential areas of concern, allowing healthcare professionals to proactively optimize the design of the therapeutic environment and improve the overall quality of care provided to PLWAD. In overview, this innovative solution is a game-changer for architects, healthcare professionals, and researchers who are dedicated to improving the lives of PLWAD. By harnessing the power of IoT, machine learning, and BIM systems, this system enables them to leverage real-time quantitative data and advanced analytics to create more effective and personalized therapeutic environments that promote better health outcomes and enhance the quality of life for PLWAD.

Furthermore, the dissertation sheds light on the complex ethical considerations and practical challenges that arise during the development of the computational framework. By exploring the range of issues involved, including privacy concerns, the need for informed consent, and the potential for technology to exacerbate existing inequalities, this study provided an overview of the key ethical and social challenges that must be addressed in this field. Additionally, implementing IoT technology-based monitoring in the rooms of PLWAD necessitates thoroughly considering the ethical implications. In particular, the issues of privacy and data ownership are essential and must be addressed with great care. Using IoT technologies generates new and extensive amounts of real-time quantitative data; to whom that data belongs remains a subject of serious inquiry. It is essential to preserve the confidentiality of sensitive data and prevent exposing them in any personally identifiable way. Ensuring the safety of PLWAD, involving them in decision-making processes, and obtaining informed consent from them and their family members are crucial steps in addressing these ethical considerations. Failure to adequately address these concerns can result in legal repercussions and, more importantly, cause significant harm to the monitored individuals. Thus, it is vital to approach this matter with a high degree of professionalism, expertise, and sensitivity to the needs of PLWAD.

This research paves the way for future studies to explore these issues in greater depth to develop more targeted solutions that can better address the needs and concerns of PLWAD. This vision demands more attention and focus, as it is essential to ensure that the progress made in this field is ethical and safe. Further research and exploration in this area are warranted to continue advancing the development and implementation of ambient assistive technology-based monitoring in the context of PLWADs' therapeutic environments. When considering the challenges and ethical considerations around the use of gerontechnology for monitoring PLWADs' behavior, it is essential to recognize the potential benefits of cross-disciplinary contributions in enhancing ethical considerations. Gerontechnology can significantly improve PLWADs' quality of life; however, it raises concerns about privacy, autonomy, and dignity. This makes it essential to consider the ethical implications of this technology carefully. Experts from different fields, such as psychology, healthcare, and technology, can collaborate to design practical and ethical technologies. This can involve developing clear guidelines and standards for the use of gerontechnology in Alzheimer's contexts and creating ethical frameworks for evaluating the impact of these technologies. Therefore, it is vital to reflect on the potential impact of cross-disciplinary contributions on ethical considerations surrounding gerontechnology for Alzheimer's. By working together, experts can ensure that this technology is used effectively and ethically and that PLWAD can benefit from its potential without compromising their dignity, autonomy, or privacy.

Considering the challenges and ethical implications surrounding gerontechnology for AD, a reflective question was exposed: How far could the contribution cross-disciplinary enhance the ethical consideration concerning gerontechnology for Alzheimer's disease? It is essential to reflect on the potential impact of such contributions concerning ethical considerations.

Overall, the dissertation on creating a personalized interactive therapeutic environment for PLWAD using a computational framework to assess the PLWADs' therapeutic environment contributes significantly to the healthcare, healthcare architecture, digital architecture, and technology field. The framework proposed in this dissertation has the potential to improve PLWADs' self-orientation abilities, increase the efficiency and effectiveness of healthcare.

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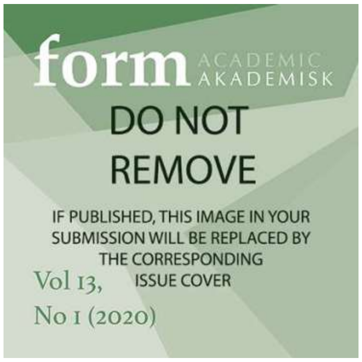

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Interactive architecture as a therapeutic environment for people with Alzheimer disease, a scoping review

ABSTRACT
As the global population ages, the number of people suffering from Alzheimer's disease (AD) increases. AD is the most common cause of dementia. In recent years interactive architecture has been developed to enhance the lives of people coping with this disease. This article presents an extensive literature review from existent research projects how assistive technology (AT) has been used as a physical and cognitive rehabilitation aids to AD and other dementia patients. The review served to identify gaps in AT implemented place. That revealed the following findings: (1) a notable improvement in both physical and cognitive rehabilitation when integrating AT in patients' therapeutic environments, (2) a positive effect for caregivers when patients used AT individually, and (3) a lack of clarity due to limited studies on the use of AT for daily activities in residents' rooms at healthcare centres. However, further studies are necessary to explore the AT potential integrating strategies to promote daily activities in the residents' rooms at healthcare centres, and the architectural factors that could affect ATs' efficiency.

Keywords:
Assistive technology, Alzheimer's disease, interactive architecture, therapeutic environments, virtual environment.

Overview

This review is part of a cumulative doctoral dissertation comprising three substantial articles and an exegesis. The dissertation is on an interdisciplinary topic consisting of architecture, human-computer interaction (HCI), and environmental psychology. Developing this research through interdisciplinary studies creates a powerful learning experience that emphasizes integrative learning, critical thinking, and creative problem solving. The aim of this dissertation is to develop the implementation of interactive indoor environments for persons living with Alzheimer disease (PLWAD) to support their orientation abilities in performing their daily tasks in their rooms at long-term healthcare centers in order to increase their quality of life (QoL). This aim leads to several related research questions: To what extent can interactive architecture add to the experience of an indoor therapeutic environment for people with Alzheimer's at long-term healthcare centers? What are the key system characteristics of integrating assistive technology (AT) as an assistive tool in residents' rooms at these centers? What kind of contributions could the use of virtual environments (VEs) in their rooms offer to

PLWAD? What are the architectural factors that could affect VEs' efficiency? What are the barriers to adopting VEs in residents' rooms? Which VEs could be used to motivate and orient the residents to do specific daily activity in their rooms (e.g., for toileting)? How can VEs be integrated in both single and multiple occupancy rooms? How do PLWADs react to VEs? Studying residents' orientation in their rooms, how do they act before and after the use of VEs? What is the effect of the use of VE?

To answer these research questions, this dissertation targets objectives at three levels. The first objective is a scoping review to systematically map the research done in this area, as well as to identify any existing gaps in knowledge. The second objective is to study different assistive technology systems scenarios (which are used to motivate and orient residents' in their rooms to do a specific daily activity) through the user experience design concept, to investigate various aspects of using interior elements as information displays, taking into consideration the residents' as an end user. The third objective is to create a framework that can guide the researchers and designers to use interactive architecture in long-term healthcare centers for people with Alzheimer's.

Introduction

Alzheimer's disease (AD) is the most common type of dementia and account for between 50% and 75% of all cases (Alzheimer's disease and Dementia 2017). Cognitive scientists have defined AD as a progressive, chronic disease that severely impairs cognitive functions, including memory, reasoning, linguistic ability, depth perception, and mobility (Alzheimer's association 2018; National Institutes of Health, National Institute on Aging 2017; Alzheimer's disease International). Van Hoof, Demiris, and Wouters (2017) provided an accurate definition of AD that gave a narrower perspective: precisely, it is the loss of necessary knowledge about "how to," including how to carry out the various tasks of daily living and how to interact appropriately with the environment. This definition provides an initial approach to resolving the larger problem at hand here. Therefore, prior understanding of the transition between disease stages is necessary (Mayo Clinic Staff). This transition may take several years, and patients in different stages of the disease have different requirements. Table 1 summarizes the familiar symptoms of AD over its three stages.

Stage	Activities Affected by Alzheimer's disease	Alzheimer's disease Symptoms
I. Preclinical	Memory, speech, complex organization, social skills, judgment and logical thinking, mobility, senses.	A person may seem to be healthy but has increasing difficulty making sense of the world around them. Short-term memory is impaired, all skills and senses worsen, but substitutes may be used to eliminate problems.
II. Moderate	Memory, speech, complex organization, social skills, judgment and logical thinking, mobility, senses.	More intensive supervision and care become necessary, which can be difficult for many families. The ability to take care of oneself is lost, as is independent judgment. Orientation deteriorates.
III. Severe	Cognitive ability to achieve anything complex (including dressing oneself), memory, mobility (often bed-bound).	People in this stage of AD cannot communicate and are completely dependent on others for their care. They lose the ability to walk, sit, and swallow and have increasing difficulty communicating.

Table 1: Alzheimer's Symptoms (Alzheimer's Society, 2018b; Mayo Clinic Staff; Msw, 2015)

These cognitive problems have attracted substantial attention to the design and development of special care units for people living with Alzheimer disease (PLWAD). These units must provide a supportive environment for daily activities and increase PLWAD's physical and mental independence. The loss of self-esteem linked with dependency in daily activities can be a devastating experience for PLWAD (Yates et al., 2019).

PLWAD need support to engage in activities that provide multisensory stimulation, as they may be incapable of accessing this type of stimulation by themselves. An adequate level of sensory stimulation helps to relieve stress and boredom. All the senses—sight, touch, taste, smell, sound, and movement—need stimulation. The senses related to movement can be divided into proprioception (the sense of where the body is in space) and vestibular awareness (awareness of velocity and direction of movement (Fowler, 2008).

Dementia-friendly design integrates the key principles that support maximum independent functioning without inducing anxiety (Parke, B., Friesen, K., 2007). In incorporating these principles, architectural design aims to improve PLWAD's vision and recognition by removing distracting objects, directing their attention to environmental cues, and highlighting key features in the surrounding environment. Virtual environment (VE) technologies can assist in this endeavor.

VE technologies are now a viable alternative to conventional rehabilitation methods. They have diverse properties and capabilities in patients' physical and cognitive rehabilitation—from conventional 2D graphic displays that provide no immersive or semi-immersive virtual reality (VR) scenarios to more advanced approaches, such as head-mounted displays and 3D smart TV technologies, with realistic multisensory interaction devices and neurophysiological feedback capacity. Such approaches are considered to be the most promising developments, as this review highlights. Additionally, it is desirable that these VR applications for PLWAD be easily and affordably transferable to in-home and nursing home environments (García-Betances et al., 2015).

Methods

The goal of the literature review is to inform primary research by (1) clarifying the importance of implementing a therapeutic environment for persons living with Alzheimer's disease (PLWAD) and identifying the characteristics of a positive outcome for these residents; (2) identifying the latest advances in technological solutions for interactive therapeutic environments in long-term healthcare centers for improving the PLWAD's quality of life. The focus is on virtual environments (VEs) as assistive technology (AT) tools, (3) identifying the gaps in the AT-implemented place, looking at which types of AT have been integrated into the residents' rooms, the purpose of their usage, and whether the residents are using them individually or with caregivers' help. The literature review represents an embedded study, by collecting and analysing both quantitative and qualitative information. It involves a mixed research synthesis, by using quantitative research approaches to synthesize quantitative-based works and qualitative research approaches to synthesize qualitative-based works. The review is organized into two parts: (1) searching the literature and selecting relevant work and (2) categorizing the selected works and their use. In the first part; a systematic literature search was conducted in six scientific databases to identify relevant empirical studies. A focus was on the databases related to health, nursing, environmental psychology, the built environment, HCI and assistive technology. Therefore, a literature search was performed in PubMed, Web of Knowledge, IEEExplore, ScienceDirect, and Google Scholar electronic databases, using the following keywords: assistive technology, interactive architecture, therapeutic environment, virtual environment, multisensory stimulation, multisensory environment, and augmented reality. The keywords were combined with the terms "dementia" and "Alzheimer's" to identify papers on the topic, as well as pilot studies. Published studies were next identified using a search strategy based on the three facets of the research question: persons with Alzheimer's disease and other dementia, interactive therapeutic environments, and long-term healthcare centers. Only English-language peer-reviewed journal articles published after 2003 were considered in investigating the importance of the therapeutic environment. Articles published after 2014 were particularly considered to examine the use of more recent technologies. Eligible articles were those that examined the effects of no immersive, semi-immersive, and/or fully immersive virtual, augmented, or mixed reality interventions using head-mounted devices on participants' quality of life, depressive symptoms, social interaction, enjoyment, and acceptability. In the second stage of the review, the retrieved VR studies and applications were categorized according to the classification in Figure 1.

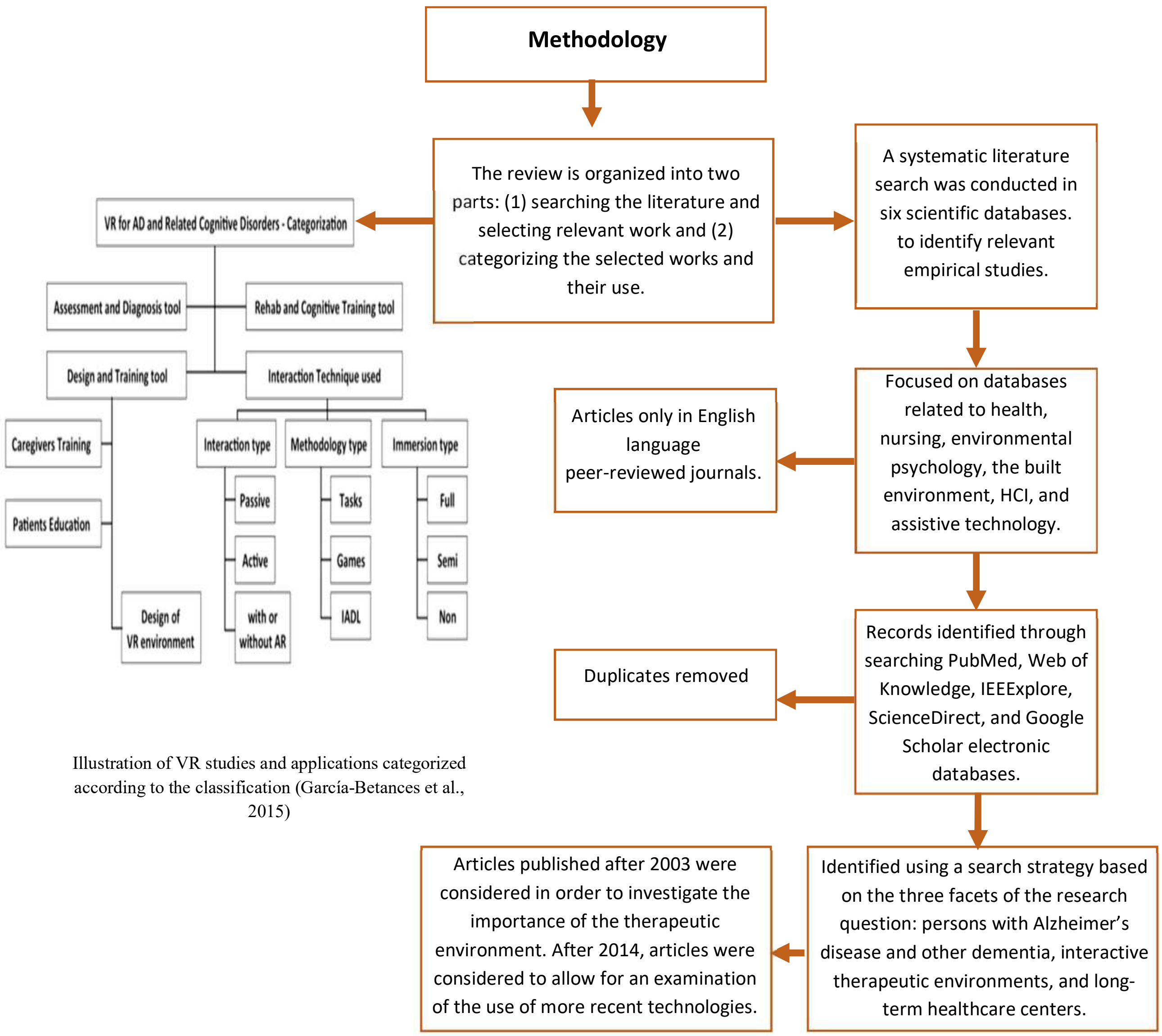

Figure 1: Flowchart of the literature search on Interactive architecture as a therapeutic environment for people with Alzheimer's disease

Results

This section outlines the results of the literature review. Numerous studies have confirmed a positive correlation between the therapeutic environment design (especially when healthcare architects consider patients as end users) and patient improvement (Bowes, A. M. and Dawson, A., 2019a; John Zeisel, 2003; Malkin, 1992; Marquardt et al., 2014; Ron Smith, 2016; van Hoof et al., 2017; Zeisel, 2000). Including interactive architecture in patients' environments improved their physical and cognitive rehabilitation and their self-esteem (Marquardt et al., 2014; McCullough, 2005; Yates et al., 2019). VEs play an important role in the improvement of PLWAD's physical and cognitive rehabilitation, including in such areas as memory retention, attention, and problem solving (Dalton 2017; Fasilis et al. 2018; Hofmann et al. 2003; Moyle et al. 2018). However, there are some gaps concerning the integration of VEs in residents' rooms. Other limitations include a lack of studies on the effects of architectural factors on VEs' efficiency, including illumination (day and artificial light), materials (ordinary and smart materials), and the room area (James R. Benya, 2010). In addition, the role of VE integration in rooms with multiple residents in healthcare centers remains unclear (Dalton, 2014).

1. THERAPEUTIC ENVIRONMENT ROLE

Recently multiple studies (John Zeisel, 2003; Marquardt et al., 2014; Ron Smith, 2016; Zeisel, 2000) have acknowledged the relation between therapeutic environments and patient improvement. Many researchers highly recommend considering the patient as an end user in the design process, as this contributes to a more supportive therapeutic environment (McCullough, 2005). The research literature in this field has grown rapidly in recent years. For instance, Bowes and Dawson (2009) have systematically identified, examined, and evaluated studies on designing environments for people with dementia (PwD). (Marquardt et al., 2014) indicated that specific design interventions improve outcomes for PwD, except in the area of their cognition.

(John Zeisel, 2003) examined indications of the most appropriate treatments for PLWAD in order to better understand the therapeutic environment (environment, behavior/communication, and medication). Other research has focused on the use of technology in the therapeutic environment for PLWAD and other types of dementia. One study (Topo, 2009) suggested that universal design principles can be a helpful starting point, but these must be supplemented with dementia-specific knowledge. This requires that PwD be involved in the design process and implies that it is essential for technologies to be thoroughly tested in a real-world environment and not solely in laboratory conditions. Another study (Dalton, 2017) described a framework for a smart home environment that aims to comprehensively address issues of environmental fit, in particular for people with dementia. This includes a means of sensing the user affect as a factor in the system management of a smart personal living space and generating environmental responses that adapt to changing user needs. The overall intention is to maximize environmental congruence for the user, both functionally and psychosocially, by factoring in adjustments based on changing patient status.

2. INTERACTIVE TECHNOLOGIES

Using interactive technology in everyday life can help PLWAD maintain their independence, keep safe, and stay active and involved (Alzheimer's Society, 2019). This technology can assist individuals in the process of remembering, including the receiving, encoding, storing, and retrieving of memories. Memory problems can be caused by difficulties at any of these stages. A useful way to improve the process of remembering is to establish a daily routine and break it into smaller steps (Alzheimer's Society, 2018d). Assistive technology (AT) can play an important role in this process. AT refers to devices or systems that help maintain and improve a person's ability to function in everyday life. Such technologies can assist with many difficulties, including problems with memory and mobility. AT includes a broad range of items, ranging from electronic pill boxes to “smart home” systems (Alzheimer’s Society, 2018c). This section focuses on the main developments in AT and locating evidence as to whether AT can improve the well-being of PLWAD.

2.1. Interactive technology effectiveness and issues

Recent literature reviews (Clay et al., 2020; D'Cunha et al., 2019; García-Betances et al., 2015; Koumakis et al., 2019; Mohamad Nadim ADI and Mais M. ALJUNAIDY, 2020; Montana et al., 2019; Sánchez et al., 2013; Strong, 2020) and position papers have addressed AT for PwD and PLWAD from a broad perspective. Generally, these publications discuss a range of topics to advance research and bring to market evidence-based solutions that are usable and effective in patients’ everyday lives. While AT has potential benefits to offer PwD (Alzheimer’s Society, 2018c), there are still a number of general issues around its provision that need to be explored in detail. These include improving access, personalized care, analysis of limitations, ethical considerations, and future developments.

A conference paper confirmed the lack of standards for relating quality of life (QoL) to AT (Jason Hayhurst, 2017). A number of ATs, including virtual reality (VR) and augmented reality (AR), have been reported to enhance the QoL of PLWAD. However, It can be difficult for PLWAD and care personnel to evaluate the products available to them (Jason Hayhurst, 2017). Therefore, in future research, technology-based QoL metrics would support the objective assessment of the impact of AR and VR.

“Interaction design must serve the basic human need for getting into place. Like architecture, and increasingly as a part of architecture, interaction design affects how each of us inhabits the physical world” (AAIC 2019 Press Office, 2019). Experts have stated that while some technology tools can be helpful for PLWAD, others do not work as promised. James Hendrix, director of global science initiatives at the Alzheimer’s Association, stated that *“there exist hundreds of products and computer apps to help PLWAD, but very few are clinically proven*” (Alzheimer’s Society, 2019).

Several studies that examined the use of AT for PLWAD have shown promising results. For example, a case study of night-time wandering (Kenfack Ngankam et al., 2020b) showed the importance of context awareness architecture for ambient assisted-living applications. Another study presented and reflected on recent findings on how PwD experience and manage their daily lives through their own initiative, including their use of technology (Topo, 2009). Yet another study evaluated a novel kind of interactive computer-based cognitive training in AD for rehabilitation and therapeutic interventions (Hofmann et al., 2003).

2.2. Virtual environments as cognitive aids for people with Alzheimer’s

VEs are a promising technology that can be used for cognitive assessment and intervention (AAIC 2019 Press Office, 2019). VR immerses the user in a dynamic VE in which they carry out cognitive and sensorimotor activities while interacting with virtual stimuli. The use of interaction in VEs provides new approaches to the treatment of memory deficits in elderly individuals (Corriveau Lecavalier et al., 2020). Recent literature (Clay et al., 2020; D'Cunha et al., 2019; Sánchez et al., 2013; Strong, 2020) has shown the effectiveness of VEs in improving patients’ performance on several tasks in physical and cognitive rehabilitation, using immersive, semi-immersive, and no immersive options. These tasks include reminiscence activities, such as using an interactive touchscreen device to involve discussing events and experiences from the past and aims to evoke memories, stimulate mental activity and improve a person's well-being. As well as spatial cognitive tasks, and enjoyable leisurely activities.

In addition, several pilot studies have shown promising results in the use of VR technologies as cognitive aids for PLWAD. One study (Fasilis et al., 2018) examined the effect of computerized cognitive rehabilitation and interactive computer-based training on potential cognitive enhancement and rehabilitation in persons with mild dementia. This study found a relative improvement in patients' cognitive functions, including those related to problem solving, rigid thinking, and attention. Another pilot study (Optale et al., 2010) implemented a VR training intervention to try to reduce cognitive decline and improve memory functions. (Moyle et al., 2018) measured and described the effectiveness of a VR forest on engagement, apathy, and mood states of PwD and explored the experiences of staff, PwD, and their families. A study by (Manera et al., 2016) tested the feasibility of using highly realistic image-based rendered VR with people with mild cognitive impairment and dementia. The researchers designed an attentional task to train selective and sustained attention and tested VR and paper versions of this task in a single session. The above studies demonstrate that VR-based training can be a tool for improving adherence to cognitive training among PLWAD.

Using both VR and AR, (Jason Hayhurst, 2017) addressed several technology design issues with VEs, the first being the consideration of the stakeholders. AT often involves a level of technical intervention, either to set up the application or to use it, which requires that caregivers or family members be able to use such applications to support PwD. Furthermore, the designers of AT need to follow a user-centred approach rather than a one-size-fits-all approach. Any intervention using AR or VR must be designed considering the specific needs of the individual with dementia, as their needs may differ depending on how their dementia is affecting them. AR and VR could be developed to support VEs that are context-aware of PwD, thus resulting in a more immersive adoption of any intervention.

3. VIRTUAL ENVIRONMENTS AND ALZHEIMER'S-FRIENDLY BUILDING DESIGN

VEs stimulations can be used in various scenarios for health facility design. These include immersive, semi-immersive, and no immersive scenarios. Most research related to VEs and AD has focussed on enhancing the specific skills that tend to decline over the course of the condition, including spatial navigation (Jiang and Li, 2007; Montana et al., 2019; Pengas et al., 2012; White and Moussavi, 2016). The results are promising and suggest that VR training can facilitate neuro-rehabilitation and promote brain plasticity[2] processes. Applications of virtual buildings and rooms can both evaluate and rehabilitate the spatial memory of patients in different cognitive impairment phases.

Other studies have focused on creating multisensory spaces to enhance cognitive skills (Duchi et al., 2019b; Goodall et al., 2019). This stimulation of sight, touch, hearing, balance, and smell is expected to lead to a reconnection with reality for PwD, resulting in an improvement in their overall well-being and QoL. In addition, it can help patients improve their relationships in their social and personal environments, since the aim is to provide an atmosphere of wellness and relaxation for the patient and the specialist.

(Eisapour et al., 2018) created two VR environments using the Oculus Rift head-mounted display and Oculus touch controllers with the goal of increasing accessibility to exercise for PwD. This research demonstrates the promising potential of VR exergames[3] for PwD. However, future studies are needed to expand the available tasks, increase the available environments, and examine their clinical impact.

Suggestions have been made for dementia-friendly room designs, but the effectiveness of these in improving the safety of dementia patients has not yet been tested (Dalton, 2014, 2017). The author noted that the ideal environment for PwD should be adaptable to compensate for the loss of cognitive function and to decrease the patient's susceptibility to stress of environmental origin, so that the room environment becomes prosthetic or compensatory. This research used Barris's model of environment, including the following aspects: (1) objects; (2) tasks, meaning any series of actions that satisfy internal motives to explore and be competent; (3) groups, since the care setting architecture can either advance or limit connections to the

[2] **Brain plasticity** is the ability of the brain to modify its connections or rewire itself. Without this ability, any brain, not just the human brain, would be unable to develop from infancy through to adulthood or to recover from brain injury.
[3] **Exergames** is a portmanteau of 'exercise' and 'gaming'), or gamercising, is a term used for video games that are also a form of exercise.

greater physical and social context; and (4) culture, referring to family culture, as the design context is a conscious recognition of the user's or resident's expectations. (Dalton, 2014, 2017) suggests that congruence in the architectural environment of care can be supported by the incorporation of real-time sensing and actuation. In such an environment, affect becomes a consideration in the management of environmental response, thus creating a feedback loop that promotes salutogenesis[3].

Discussion

AD is a progressive disease, the symptoms of which differ from person to person (Alzheimer's association, 2018; Alzheimer's Disease International; National Institutes of Health, National Institute on Aging, 2017). In all cases (Alzheimer's Society, 2018d), the problem is on of "how to," as AD and other kinds of dementia often make performing the activities of daily living difficult. Tasks may be done halfway, poorly, or not at all (Msw, 2015). Therefore, healthcare designer should focus on the remembering process when designing AD-patient-friendly buildings. The improvement of patient outcomes depends on the therapeutic environment, as several pilot studies have shown theoretically and practically.

As(Ron Smith, 2016) mentioned, the effects of environments can be either positive or negative; only no environment is neutral. One of the first authors to describe the therapeutic environment effect (Malkin, 1992) listed the following recommendations: (1) reduce or eliminate environmental stressors, (2) provide positive distractions, (3) enable social support, and (4) give patients a sense of control. These factors all influence the effect of the therapeutic space on patient outcomes. In addition, (John Zeisel, 2003; Zeisel, 2000) concluded that for positive therapeutic environment outcomes, specifically for PLWAD, healthcare architects should first classify the relevant symptoms and their treatment. A useful classification scheme of Alzheimer's symptoms includes the behavioral, functional, cognitive, and physical manifestations. By identifying AD's relevant symptoms, architects can design the space to help reduce one or more of them.

(John Zeisel, 2003; Zeisel, 2000) recommendation leads to another aspect of the space: the service to the PLWAD who could be served by the space itself. Considering the PLWAD as an end user will lead to a positive outcome (McCullough, 2005). (Bowes, A. M. and Dawson, A., 2019a) provided a foundation for the further development of practical design work on environments that enable people with dementia to live better. They concluded that there is currently disparate work available on a range of design items, prototypical technologies, and interventions, and that research is needed to consolidate findings and identify the core principles to guide design. In addition, they considered the environment not only as facilitating and supporting good care but also as having a positive role to play in itself.

(Dalton, 2017; Topo, 2009) proved that patients had better outcomes when AT was integrated into their therapeutic environments, which increased their autonomy and independence. AT can be used in daily activities that exercise the remembering processes (AAIC 2019 Press Office, 2019; Alzheimer's Society, 2019; Alzheimer's Society, 2018d), and a daily routine divided into small steps can improve patient outcomes. As previously discussed, there are still a number of general issues around the provision of AT that need to be explored and addressed in greater detail (Alzheimer's Society, 2018c). These include the following:

1. *Improved access*. This issue encompasses two points: (1) A lack of public awareness and information, means that PLWAD and their carers do not know what to ask for. (2) A lack of professional awareness, means that there is also a need for Alzheimer's advisers and other memory services staff to receive AT awareness training.

2. *Personalized care.* It is very important that AT is personalized to the individual and not part of a 'set menu' or 'Alzheimer's package'. PLWAD experience various symptoms that require

different responses. In addition, the most appropriate AT will depend on an individual's lifestyle and circumstances, which change over time. This confirms the theory that 'no one design can fit all'.

3. *Limitations.* AT should not be treated as an 'amend solution' for PLWAD or used as a replacement for human interaction and caring for them. Rather, AT should be seen as complementing an individual's care and support to enhance their QoL. The AT design process should include PLWAD to produce technological aids that are 'fit for purpose' without being overly complex or requiring extensive training. The key to some of the issues around AT for people with AD and caregivers is how reliable off-the-shelf technical solutions are. For example, for some PLWAD telecare is of use only if it is backed up with human care, support, and training. How useful AT is also depends strongly on the external environmental factors that are in place. For example, adequate lighting can be a significant factor in determining whether PLWAD are able to navigate around their home or environment.

4. *Ethical considerations.* To fully realize the beneficial effects of the technology, particular attention should be paid to aspects of care planning including assessment, installation, and obtaining consent.

5. Future developments. The proper promotion of AT benefits requires strong local and national leadership, with advocates explaining the ways in which AT can bring benefits to PLWAD and their carers. AT can play an important role in several daily life activities of PLWAD (Hofmann et al., 2003; Kenfack Ngankam et al., 2020b; Topo, 2009), as it has been shown training improved the task performance of PLWAD substantially, and they appeared to like this approach. New interactive media, therefore, may yield interesting opportunities for rehabilitation and therapeutic interventions (Hofmann et al., 2003).

One promising form of AT is VEs, which are considered effective rehabilitation tools for PLWAD (AAIC 2019 Press Office, 2019; Corriveau Lecavalier et al., 2020). As previously mentioned, recent literature (Clay et al., 2020; D'Cunha et al., 2019; Sánchez et al., 2013; Strong, 2020) has proved the effectiveness of VEs in improving patients' performance on several tasks through the use of immersive, semi-immersive, and no immersive scenarios. These tasks include reminiscence activities and spatial cognitive tasks that involve enjoyable, leisurely activities. Some people have argued that PLWAD will not enjoy or interact with VEs, but research has shown that PLWAD have indeed enjoyed and interacted well with VEs. Additionally, there was some improvement in their QoL and memory function after using VEs in some tasks such as path finding, problem solving, and tasks to stimulate attention (Fasilis et al., 2018; Jason Hayhurst, 2017; Manera et al., 2016; Moyle et al., 2018; Optale et al., 2010).

Although the use of VEs in patients' physical and cognitive rehabilitation has improved outcomes, there are still some problems that need to be solved. For instance, the set-up and use of some devices, such as headsets, tablets, and screens, requires a level of technical intervention. This requires that caregivers have the ability to use such applications to support PLWAD in their use of them. A further problem is that caregiver intervention of this type will not help PLWAD become more self-sufficient. Moreover, not all VE designs fit all patients. Instead, designs are required that consider PLWAD as end users with individually specific needs (McCullough, 2005).

The use of VEs for AD has developed recently in the architecture field. VEs have been used in various ways in architectural design to improve AD patient outcomes, and several studies have shown their benefits for these patients. The four main factors in the use of VEs are as follows: (1) the PLWAD as an end user, (2) the space the VE will be integrated into, (3) the type of VE, and (4) the assistive service that the technology will provide to the PLWAD. Table 2 illustrates this categorization.

Reviewed studies of virtual environment (VE) use to enhance specific skills for people with dementia and Alzheimer's					
Author-Year	VE Type	VE Usage Aim	Place of Implementation	Assessment Primary Outcomes	Disadvantages/Barriers
(Eisapour et al. 2018)	Head-mounted displays	Increasing accessibility to exercise	Special room	Positive	Needs caregiver help, not safe to use individually, in some cases causes cyber-sickness
(Dalton 2014)	Bio sensing	Increasing cognitive function and decreasing patient stress	Patients single rooms	Not tested	Not tested
(Duchi et al. 2019)	VR glasses	Increasing cognitive function	Patients rooms	Positive	Patients forgot to wear the VR glasses
(Goodall et al. 2019)	Projector, biosensing	Embracing a user-centred design approach throughout the development and implementation of the intervention; stimulating sight, touch, hearing, balance, and smell	Special room	Positive	---------
(White and Moussavi 2016)	Head-mounted displays, VR app	Way-finding	Not specified	Positive	Needs caregiver help, not safe to use individually
(Mrakic-Sposta et al. 2018)	Head-mounted displays, VR app. virtual reality (VR)based program combining aerobic exercise and cognitive training	physical and cognitive training	Special room	Positive	Needs caregiver help, not safe to use individually

Table 2: Reviewed studies of VE usage to enhance specific skills for people with dementia and Alzheimer's

The table can be summarized as follows. (Eisapour et al., 2018) investigated physical rehabilitation for PwD using VR exergames in a special room under caregivers' supervision. The duration of this rehabilitation was three weeks, and was provided to six persons living with dementia. The researchers created two VEs using an Oculus Rift head-mounted display and Oculus touch controllers. An evaluation compared the virtual programs with human/therapist-guided exercise in terms of the subjective enjoyment, comfort, and difficulty level of the activities. The evaluation showed positive outcomes in the PLWAD's physical rehabilitation that exceeded those gained from ordinary guided exercise.

Another study (Dalton, 2014) suggested using VEs to enhance PLWAD's QoL in addition to assisting with cognitive rehabilitation by integrating biosensors in the residences' single-occupancy rooms at Alzheimer's healthcare centers. The author used Barris's model of the environment, looking at the aspects objects, tasks, groups, and culture. The 'My Room' concept envisioned patient rooms designed to include a comprehensive embedded responsive system, with multiple networked sensors, allowing continuous activity-aware and contextualized sensing of a user's psycho-physiological state. This suggestion has not been tested in real life. The key characteristics of the My Room model are summarized in Figure 2.

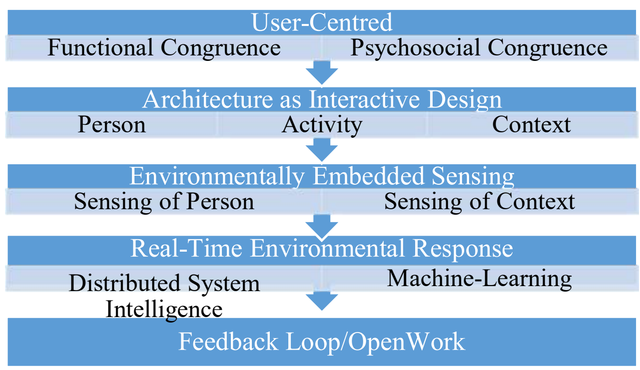

Figure 2: System characteristics of an adaptive salutogenic room (Dalton, 2014)

(Goodall et al., 2019) examined physical and cognitive rehabilitation in addition to QoL for PwD by using an immersive VE that combined VR and AR in a special room that was automatically adaptable to the personal memories and individual preferences of the users. The design of the space is shown in [Figure 3]. The researcher combined multisensory stimulation with physical activity and techniques from reminiscence therapy and Montessori methods. This stimulation of sight, touch, hearing, balance, and smell was expected to lead to a reconnection with reality for the PwD. The researcher used a projector to display information onto a large wall. The VE combined an AR game to improve the patient's balance and physical activity and integrated an interactive touchscreen device showing family photographs from the individual's life story to improve the patient's sense of touch. In addition, an integrated sound system with familiar music and background soundscapes was used to motivate and enhance the patient's cognitive rehabilitation. To complete the scene for the patients, an olfactory dispensary system released familiar scents.

This case study demonstrated the effectiveness of the VE use in two areas. First, it had a positive outcome on patients' physical and cognitive rehabilitation and improved their QoL. Second, it had a positive effect on both the formal and informal caregivers. The improvement in caregiver coping and relief from stress, in turn, increased the quality of informal caregivers' visits to PwD and enhanced the quality of their relationships. In this study, patients used the VE without caregivers' help, and it was safe to be used individually.

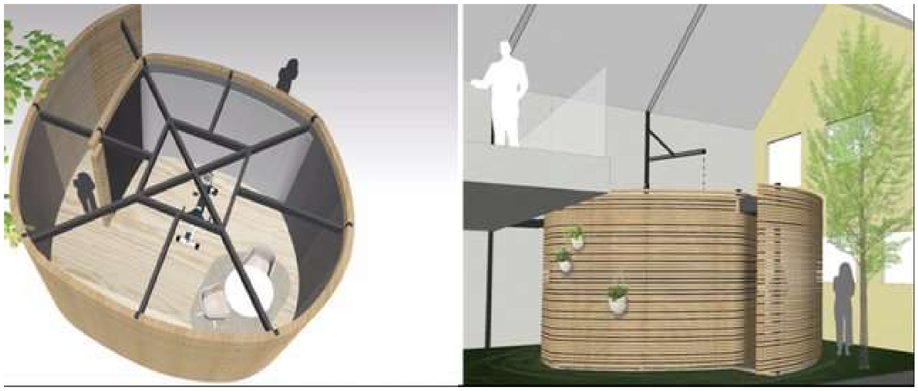

Figure 3: Architectural sketches of the SENSE-GARDEN space (left: interior, right: exterior Goodall et al., 2019)

Other studies by (Mrakic-Sposta et al., 2018; White and Moussavi, 2016) that investigated patients' cognitive rehabilitation, specifically for spatial cognitive tasks, suggested that PLWAD are able to transfer information about the environment obtained from the VE to real life. The study used a cognitive treatment program based on spatial navigation in a VE, having a man with early-stage AD navigate to targets in a symmetric, landmark-less virtual building. The treatment took place in a special room under a caregiver's supervision. The study proved that an individual in the early stages of AD could learn to navigate in a simple VR navigation environment, suggesting that such treatments might benefit other people with AD.

The use of head-mounted displays and computer applications, however, comes with disadvantages. In particular, it will not increase patients' self-esteem, as it must be done under caregiver supervision and in specific spaces. In addition, some studies have confirmed that head-mounted displays can cause cyber-sickness and anxiety for seniors with AD or other forms of dementia (Nesbitt and Nalivaiko, 2020; Pot-Kolder et al., 2018).

By analyzing the previous table through the four main aspects of the positive therapeutic environment outcomes which are; (1) reduce or eliminate environmental stressors, (2) provide positive distractions, (3) enable social support, and (4) give PLWAD a sense of control. Had been found that the use of fully immersive systems will not develop a therapeutic environment with a positive outcome. As there's a lack on aspects one and four. In this sense, display screens and semi-immersive systems, are more comfortable to use. Although, (Goodall et al. 2019) had all the aspects of the effective therapeutic environment, but the system had been integrated into a special room without any window. As the lack of sufficient exposure to bright light during the day can negatively affect the health and well-being of residents in Alzheimer's and other dementia healthcare centers (Hanford and Figueiro, 2013; Konis et al., 2018; Torrington and Tregenza, 2007)

This leads to the identification of the main research gap, which relates to the orientation of PLWAD in their rooms by having them use VEs as assistive technology tools to guide them in performing specific daily activities (e.g., toileting, dressing, self-care, etc.), which differ from one patient to another.

The next step of the dissertation will be divided into two parts: (1) observing the PLWAD's orientation in their rooms at healthcare centers and (2) studying assistive technology as an assistive tool to motivate and orient them in performing specific daily activities through the design of experience concept and using a mixture of qualitative and quantitative methods, including (1) data collection through a survey and interviews by professionals at an Alzheimer's long-term healthcare center in Vienna, Austria, as well as through observing residents; (2)

analysis of the collected data; and (3) developing a simulation for the residents' orientation in their rooms to create a narrative scenario for their orientation, and to discover the influence of architectural elements on the efficiency of the assistive systems. The survey will address the following questions: what are the residents' needs in their rooms? What are their daily activities during the day and night? What type of assistive technology are they using? What are the reasons for this usage? Where do they use each type and when? At which stage of AD do they use them? How do they interact with the assistive technology? What are the architectural barriers while using the assistive technology in their rooms? From a survey completed by professionals (n = 25) and interviews held with specialists (n = 5) in an Alzheimer's long-term healthcare center in Vienna, Austria, the following daily activities were chosen to be investigated in the current study: (1) orient to bed, (2) orient to toilet [Figure 4], (3) orient to wardrobe, and (4) orient to dining table.

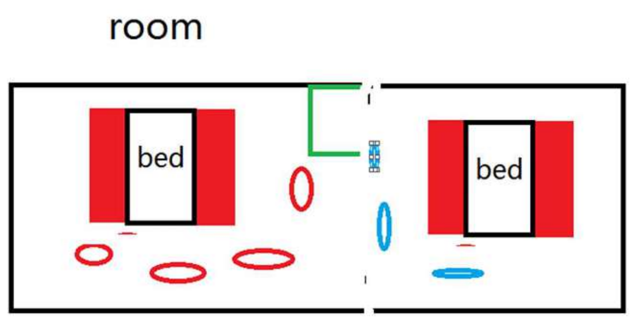

Figure 4: illustrate sketch of the residents' movement to the toilet door in one of the doubled room at the healthcare canter, Vienna, Austria.

Conclusion

This literature review of 55 articles, with a focus on interactive architecture in the therapeutic environment for PLWAD, confirmed that including interactive architecture in residents' environments enhanced their rehabilitation and self-esteem (Clay et al., 2020; D'Cunha et al., 2019; Sánchez et al., 2013; Strong, 2020). The main problem for PLWAD is the process of remembering "how to." Every patient experiences a different situation, however, which confirms the theory that "no one design fits all." Therefore, healthcare architects and interior designers need to consider PLWAD as end users. In general, the reviewed articles highlighted the importance of the therapeutic environment and its relation to outcomes in PLWAD. They identified the main design aspects that should be considered by healthcare designers, as follows: (1) reducing or eliminating environmental stressors, (2) providing positive distractions, (3) enabling social support, and (4) giving a sense of control. In addition, the versatile uses and positive effects of adopting ATs in the therapeutic environment were also apparent, including improving QoL, facilitating rehabilitation, and enhancing socialization. The studies confirmed that PLWAD are able to interact with ATs and that they enjoy using them.

Immersive, semi-immersive, and no immersive VEs have a positive impact on PLWAD outcomes, but some issues with VEs (using VR or AR) remain problematic. One issue is that most ATs require the intervention of caregivers, which, overall, does not help to increase patients' self-esteem. Additionally, some studies found that head-mounted displays can cause cyber-sickness and anxiety for some patients. The literature shows that PLWAD have difficulty with way-finding, but that they can learn their way if the environment is supportive(Cushman et al., 2008; Taillade et al., 2013). VR applications for the early detection of dementia, including VR Practice, VR Park, and VR Games, have been developed to assess the spatial memory of early-stage dementia patients (Wen et al., 2018). Researchers have used VR and AR in the spatial domain by applying different devices for different purposes. Some have used head-mounted displays with biosensors, while others have used VR glasses and interactive projectors with biosensors in dedicated rooms. Experiments have indicated that all these devices have some effectiveness, but this varies from one patient to another, depending on their condition.

There is a need for future studies to be designed with the aim of improving residents' orientation in their rooms by their using VEs individually as assistive tools to motivate and orient them to do a specific daily activities, which may differ from one resident to another. Moreover, there is a need for more research focusing on the implementation of interactive environments in multiple residence rooms at long-term healthcare centers, the use of VEs to stimulate patients in carrying out their daily activities, and the effect of architectural factors on the efficiency of VEs.

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A Study of Architectural Barriers and the Potential Role of Assistive Technologies in Long-term Healthcare Centres for People with Alzheimer's

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Abstract: Alzheimer's disease (AD) changes a person's relationship with space. While research exists on how an interactive therapeutic environment can enhance the quality of life for people living with Alzheimer's disease (PLWAD), PLWADs as end-users are not sufficiently studied. This paper examines (1) the daily activities that PLWADs need to perform to understand potential architectural barriers and (2) assistive technology (AT) used in PLWAD rooms at long-term healthcare centers. A questionnaire (n = 25) and interviews (n = 5) with five professional experts in daily contact with PLWADs were conducted for this study, together with an observation of one resident in his room at a selected healthcare center in Vienna, Austria. Three interrelated aspects emerged from the analysis: (1) orientation of PLWADs in space, (2) occupational therapy, (3) assistive technology, and (4) potential architectural barriers. PLWADs generally prefer therapeutic environments that let them control their lives. Occupational therapy enhances the ability of PLWADs to remember how to perform daily activities. AT can serve as a tool in interactive indoor therapeutic environments and occupational therapy. The results of this study show that healthcare designers should consider PLWADs as end-users when designing interactive therapeutic environments, especially by employing user experience design concepts.

Keywords: Assistive technology, orientation, Alzheimer's disease, therapeutic environments, interviews, occupational therapy, UX design concept.

2. Introduction

AD is a progressive disease that affects people's life, especially concerning the performance of daily activities, including self-care, for instance. AD accounts for 60-80% of dementia cases (Alzheimer's Society, 2018b). A more precise definition of AD is the problem of "how-to" (Engineer et al., 2018). Spatial disorientation, a decline in orienting ability, a lack of motivation to begin activities (including self-care), capacity to persist with activities, and withdrawal from social activities are among the earliest symptoms of AD that emerge at some time in PLWAD's disease (Alzheimer's Disease and Dementia, 2017; Coughlan et al., 2018; Forstmeier and Maercker, 2015; Kirste et al., 2014)

Although there is no cure of AD yet, it is useful to develop supporting solutions that can help reduce AD's progress through "Occupational Therapy" (OT). Occupations are part of life, defining people's identity and bringing meaning to life (Canadian Association of Occupational Therapists, 2013). OT aims to enable PLWAD to participate in everyday life activities by engaging in the activities they want to, need to, or are expected to do, for instance: personal hygiene, communicating, moving around, and eating. Furthermore, OT applies purposeful activity, therapeutic exercise, special equipment, skills training, and environmental modifications to support their occupational engagement to enhance PLWAD's independence in daily activities (WFOT Member Organisations, 2013).

Assistive technology (AT) has potential benefits for PLWADs and is tailored to each individual's needs (Alzheimer's Society, 2018a). This includes solutions such as IPad, an interactive projector (using the kinetic system), or a digital calendar alarm day clock with a non-abbreviated day and month alarm clock, which helps reduce the disorientation in time for PLWADs. Using AT as an assistive tool in OT improves PLWAD's independence outcomes, while also reducing caregiver stress (Dooley and Hinojosa, 2004).

Most PLWADs who live in long-term healthcare centers experience that this is not the environment in which they used to live (Fleming et al., 2020; Marquardt et al., 2014). A feeling of comfort and security, according to Bollnow's concept, occurs in protective environments where one feels at home and able to self-orient (Wasana de Silva, 2019).

Supporting PLWAD's ability for self-orientation is essential for therapeutic environmental design (Jensen and Padilla, 2017; Marquardt, 2011). PLWAD-friendly architectural concepts can support daily activities, independence, and quality of life. Designers can develop improved solutions by considering the fundamentals of PLWAD's environments (Feddersen and Lüdtke, 2014) , aiming to ease the process of self-orientation and performing daily activities. This is especially important in long-term healthcare centers, the environment where patients stay for a long time (Bowes, A. M. and Dawson, A., 2019b; Marquardt et al., 2014; Yates et al., 2019; Zeisel, 2000).

According to recent studies (Jheng and Pai, 2009; Pai and Jan, 2020), PLWADs may form a cognitive map after repeated movement in a specific environment which serves orientation and navigation. This article examines in greater depth PLWADs' movement and daily activities in their rooms at a long-term healthcare center. The goal is threefold: (1) to elucidate the relationship between PLWADs spaces and assistive technology as an assistive tool, (2) to uncover architectural barriers that present obstacles to PLWAD's self-orientation and (3) to explore the role of AT in addressing these obstacles. This involves the following questions: (1) What are PLWAD's daily activities in their rooms at the healthcare center? (2) What architectural barriers present obstacles to PLWAD's self-orientation? (3) How can AT support PLWAD's self-orientation in their room? The answers to these questions are expected to inform better designs of a friendly interactive therapeutic environment for PLWADs.

3. Methods:

Study Design

A mixed methods study with sequential design (Shiyanbola et al., 2021) was conducted to enable an in-depth understanding of the PLWADs space, needs, and potential role of AT (Creswell and Plano Clark, 2018; Palinkas et al., 2015; Ward and Delamont, 2020). This involved quantitative data collection and analysis, followed by qualitative data collection and analysis. The principle for combining quantitative and qualitative data is that neither method is sufficient by itself to examine specifics of circumstances, such as a complex topic of how AD changes a person's interaction with space. The combination of quantitative and qualitative data provides a complete understanding of the research problem than either approach by itself (Creswell and Plano Clark, 2017). Data was acquired through a quantitative questionnaire (in the German language) followed by qualitative face-to-face interviews (in the English language) with caregivers and professional experts (Baldwin and Bick, 2021) at an Alzheimer's healthcare center in Vienna, Austria. The healthcare center was built in 2005. The structure of the building is divided into two main wings (Fig. 4), the east and the west wing. The building has four floors, each one containing 12 wards for people with different care needs, while the ground floor (Fig. 1) contains the treatment and therapy rooms on the west of the central entrance hall, and on the east is a restaurant, event rooms, the chapel, library, hairdresser and the administration area. In addition to the therapy area, there is an independent 2-group kindergarten with an outdoor area. Furthermore, a qualitative narrative study was conducted using shadowing observation for one of the center's residents in single-room occupancy. Among other qualitative methodologies, shadowing characterizes itself by (1) combining observation and interaction and (2) focusing on a single perspective within a larger social situation (van der Weele and Bredewold, 2021). Due to COVID-19-related access limitations to the center, observing only one patient in the early stage of AD was possible.

This study design, consisted of three steps: (1) quantitative data is collected and analyzed first, (2) qualitative, text data is collected and analyzed second in the sequence, which helps elaborate on the quantitative results obtained in the first stage, (3) and a qualitative narrative study using shadowing observation for a resident in his room. In this study, the quantitative data elaborated a broad vision of PLWADs' health status, needs, and daily activities, highlighting the case study facilities and professional experts' awareness of AT use and purposefully selecting the informants for the second stage. Then, a qualitative interview approach was used to identify the most common barriers fronted by PLWADs in their daily life at the center and professional experts' knowledge about the AT, tested in the first stage. Furthermore, the shadowing observation (van der Weele and Bredewold, 2021) explored the architectural barriers PLWADs face in their rooms while doing their daily activities. While the quantitative data and results comprehensively picture the study problem, the qualitative data and its analysis refined and explained the quantitative results by exploring the participants' views on persistence in more depth (van der Weele and Bredewold, 2021).
The study's priority (Creswell and Plano Clark, 2017; Liamputtong, 2019; Ward and Delamont, 2020)was given to the qualitative approach because it focused on in-depth explanations of the results obtained in the first quantitative stage and involved extensive data collection from multiple sources. The quantitative and qualitative methods were connected when selecting five participants for qualitative case studies and developing the interview protocol based on the results from first phase. The quantitative and qualitative methodologies' results were integrated (Creswell, 2017; Gournelos, 2019) during the discussion of the outcomes of the entire study.

Since the data and selected cases contain sensitive personal information, maintaining participant confidentiality and privacy is essential. Confidentiality was addressed during the data collection, data cleaning, and dissemination of the research results. The participants' and organizations' names were replaced with pseudonyms.

3.1 Participants:

A total of 30 professional experts (Table 1, 2) participated in the survey. Emails were sent to the responsible person at the long-term healthcare center with information about the study and the questionnaire form. The target participant in this study's quantitative questionnaire and the qualitative interview were active professional experts working in the Alzheimer's long-term healthcare center (the case study), and in daily contact with PLWADs. The professional experts' statuses varied regarding position, years of experience, age, and gender. Criteria for selecting the participants in the first stage, the quantitative questionnaire, included: (1) active working in the long-term healthcare center (the case study); (2) a period of experience caring for PLWADs; (3) in daily contact with PLWADs; (4) completed professional training related to healthcare; (5) speaks the German language. A total of 25 professional experts participated in the survey (Table 1). Criteria for selecting the participants in the second stage, qualitative interview, included: (1) active working in the long-term healthcare center (the case study); (2) at least 8 years of experience caring for PLWADs; (3) in daily contact with PLWADs; (4) completed professional training related to the healthcare; (5) speaking the English language. Five individuals were interviewed (Table 2). The variation between the two languages is due to not all professional experts working in long-term healthcare center speaking English. However, the shadowing observation participant criteria included: (1) PLWAD is in the early stage of AD, (2) single room occupancy, (3) living in a long-term healthcare center for at least two years, and (4) having no disabilities (for instance, blindness). Due to COVID-19 restrictions, only one PLWAD was shadowed. This male patient was 78 years old, in the early stage of AD, and stayed in a single room. He was shadowed during three time periods on different weekdays from 09:30 am to 12:30 am, from 1:30 pm to 4:15 pm, and from 5:30 pm to 8:00 pm.

Table 1. Questionnaire Respondents

Number of Respondents (n = 25, %)			
Position	Psychologist Nurse Sociologist Nursing Assistant Occupational Therapist	5 10 4 5 1	**20%** **40%** **16%** **20%** **4%**
Years of experience	0-5 6-10 >10	8 6 11	**32%** **24%** **44%**
Age-Range	20-30 30-40 40-50 50-60 >60	10 6 4 4 1	**40%** **24%** **16%** **16%** **4%**
Gender	Male Female	14 11	**56%** **44%**

Table 2. Interviews Participants

Interviews				
Participant	**Age-Range**	**Years of experience**	**Gender**	**Position**
Interviewee 1	50-60	35	Female	Nurse
Interviewee 2	40-50	16	Male	Nurse
Interviewee 3	30-40	18	Female	Psychologist
Interviewee 4	30-40	8	Female	Psychologist
Interviewee 5	40-50	17	Male	Sociologist

3.2 Data collection

Quantitative and qualitative were used based on a topic list (Liamputtong, 2019). The themes of the topic lists were derived from a scoping review (Elnimr, 2021), resulting in four topics lists divided into a structured and semi-structured section with a focus on:

(1) The PLWADs health status and daily needs.

(2) What assistive technology is currently in use in PLWADs rooms, and which purpose do they serve?
(3) Draw out general opinions and experiences of how to motivate the PLWADs to do a specific activity.
(4) Draw out the architectural barriers PLWADs face in their rooms while doing their daily activities.

Interviews were directed, though not determined, by a prepared interview guide based on an extensive literature study. The use of semi-structured interviews made it possible for participants to influence the focus of the interview and for the researcher to adjust the interview course to each participant's situation. Interviews were verbatim transcribed (Gournelos, 2019; Ward and Delamont, 2020).

Quantitative data collection

The first step entailed sending the questionnaire to the professional experts to explore the experience of PLWADs through experts' opinions. The participants, who matched the criteria, filled out a hard copy survey. The questionnaire in total contained 118 questions (Qs), and was divided into two parts:

(1) PLWADs health status and their daily needs (Oakley et al., 1992), information about the use of the assistive technology (AT), and facility information, for instance, the equipment in each room for single and double room occupation.

(2) Participants' information (profession, age, years of experience, etc.), their opinions about the use of assistive technology, and the barriers which patients face in their daily tasks in their room.

The participants answered all questions related to (1) facility information in total (n= 91Qs) as follows; building areas contained (n= 15Qs); building entrance equipment contained (n= 10Qs); social areas equipment; living room and dining room contained (n= 19Qs); training and therapy room equipment contained (n= 13Qs), PLWADs' single occupancy room equipment contained (n= 17Qs) and PLWADs' double occupancy room equipment contained (n= 17Qs), (2) PLWADs health status and their daily needs and actives contained (n= 9Qs), (3) the barriers that PLWADs face in their daily tasks in their room contained (n= 3Qs), and (4) the participants' information contained (n= 8Qs). Furthermore, AT had in total of (n= 11Qs) divided into two parts as follows; firstly, the existing AT in the facility (Q1- Q6), all participants answered the first part; secondly, participants' opinions and knowledge of AT (Q7- Q11), only (n= 8P) answered the second part of AT.

Qualitative data collection

The interview structure was based on the quantitative results from the first stage of the study. From this step, new questions emerged. These included, for instance, inquiry into the professional experts' knowledge about assistive technology. The next step comprised of interviews with the professional experts who matched the participants' criteria (Table 2). During each interview, notes were made in the margin. These notes contained verbatim extracts from the transcript. The face-to-face interviews were semi-structured questions that employed a blend of closed- and open-ended questions, often accompanied by follow-up why or how questions. Questions aimed to explore the role of five factors ("therapeutic environment," "assistive technology," "PLWADs' self-disorientation," "PLWADs' daily routine in their room, and "coping and support"). The interviews took place at the healthcare center. Each interview was followed by taking pictures (by the author) to illustrate what the interviewed person talked about.
Finally, the shadowing observation (Quinlan, 2008) is a qualitative narrative study to explore in-depth PLWADs' self-disorientation in their room and if the room layout/ equipment considers as an architectural barrier. In the case study, the focus points for observation included the following:

(1) Was the PLWAD aware of his surroundings?

(2) What were the PLWADs daily activities in his room?
(3) What were the PLWADs daily needs in his room?
(4) What was the PLWADs room's equipment?
(5) What architectural barriers does the PLWAD face when moving in the room or using assistive technology?
(6) What type of assistive technology did the PLWAD use?

The participant with the first AD stage was shadowed for three hours during each observation. The objective of the author was to observe and record manually on an observation sheet with the room plan using different colors and symbols and taking notes in a table (Fig. 2), and not to participate in the activities actively. The natural (no-interference) approach had been chosen to observe the natural way PLWADs' self-orientation was performed in his room. Combining observation and debriefing helps to grasp the participant's perspective and gives a "voice" to PLWADs concerns and experiences. The author drew the room's plan with the actual dimensions and the existing equipment (Fig. 2). The researcher paid close attention to nonverbal reactions, for instance, PLWAD's body language taking notes with them. He was shadowed during three time periods on different weekdays from 09:30 am to 12:30 am, from 1:30 pm to 4:15 pm, and from 5:30 pm to 8:00 pm.

3.3 Data Analysis

NVivo (QSR International Pty Ltd., 2020) was used for data analysis for the questionnaire forms and the interviews. The transcript reading, note-making, and listed topics were used as codes in NVivo. These codes were either exact words or sentences from the transcripts. The criteria used to identify the codes are as follows: (1) familiarization to create preliminary codes relating to how a person–space–assistive technology relationship challenges PLWADs in performing their daily activities were identified, (2) constructing initial thematic codes; consisted of five main categories, with several sub-themes for each; assistive technology, architectural aspects, values or beliefs, objects, and places, (3) indexing and sorting process was to find out "what parts of the data are about the same thing and belong together," after indexing, data were sorted so that material with similar content could be viewed as a whole; (4) reviewing data extracts aimed to review the indexed data to determine other potential ways of organizing the data to create more coherent sets; and (5) data summary and display reduced the material to a more manageable level. The codes served to gain an improved understanding of PLWAD's experiences through professional experts' knowledge and the potential role of integrating interactive architecture into an indoor therapeutic environment for PLWAD at healthcare centers. The codes were not used to structure this article. Instead, the subheadings in this article reflect the topics that emerged from the questionnaire and interview responses, focusing on how a person–space–assistive technology relationship challenges PLWADs in performing their daily activities.

3.4 Ethics

Approval for this study was obtained from the center by signing an informed consent form that explained the study's aims and what participation would entail (Creswell, 2017). Participants approved the use of obtained data. All participants were informed about the study and their rights in written form, and all gave written consent to participate. All data was handled confidentially, and the results were presented in a non-identifiable way at a group level in the present study. In presenting the findings using specific quotations, it was explicitly considered if this could lead to the identification of a participant via deductive disclosure. For this reason, additional details in the direct quotations were removed. Only the researcher can trace the quotations included in this article based on the participant code.

4. Results:

The overall result from the text was the participants' experiences in how AD changes one's relationship with the surrounding environment and the possible alternative solutions to enhancing PLWADs' quality of life. Understand how a person–space–assistive technology relationship challenges PLWADs in performing their daily activities (Table 3). The focus was on knowing PLWADs' daily needs, activities, and challenges they face, the other supportive solution to enhancing their quality of life from the professional experts' perspective, the assistive technology, and the potential architectural barriers.

Table 3. The coloration between the three research methods

Theme/ Subtheme		Questionnaire from (n= 25)	Interview (n= 5)	Shadowing Observation (n=1)	Convergence
1. PLWADs (Person)	**Health status**	- Having difficulty performing tasks - Losing or misplacing objects	- Need help performing an activity - Forgetting objects, places	- Aware of his surroundings - Knows the colors - Knows what he wants - Do not know where to go to do a specific activity.	Typical symptoms of AD early stage, each symptom may differ with each resident.
	Fundamental daily needs	- Self-hygiene, dressing, eating, and sleeping	- Self-hygiene, dressing, and sleeping - Eating sometimes in the residents' rooms or dining room, depending on the PLWADs' status.	- Self-hygiene, dressing, and sleeping in his room. - Eating in the dining room with other residents.	- Three fundamental activities for all PLWAD - Interviews and Shadowing were more precise for the activity timing and place.
	Daily activities	- Diversity in participants' answers; reading, watching TV, etc.	- Diversity in participants' answers, depending on the PLWADs' identity and hobbies.	- Watching TV. In his room after breakfast. - Imitating he was fishing, as it was his hobby while watching TV. - Sitting in the garden evening. - Sometimes sitting in the living room afternoon.	- Depending on PLWADs' identity and hobbies - Interviews and Shadowing were more precise for the activity timing and place.
	Daily challenges	- Disorientation - Forgetting how to do the activities - Anxiety	- Disorientation in Place, cannot find their rooms - Disorientation in Time. -Loss of Motivation, sometimes, not with all residents	- Self-disorientation in his room - Lack of displayed information, for instance on the doors - Prefer to be guided than to choose between options (he waited the nurse to guide	Disorientation in place - Self-disorientation in PLWADs' room - Prefer to be guided

				him to the bathroom)	
2. Facility information (Place)	**The Healthcare center in general**	- Identifying of the existing spaces, each room area and equipment	- PLWADs in the early stage of AD are allowed to use the stairs alone - PLWAD are not allowed to use the elevator alone - The building had four floors, each had a different level of Alzheimer's/ dementia - Two gardens exist, one at the building entrance, and the other on the rooftop - All the rooms had a glass facade - All the social activity on the ground floor, e.g., hairdresser, OT room, Restaurant, etc. (Fig. 1) - Each floor had a small living room for residents and a nursing station		- All the PLWADs' activities exist on the ground floor - There are daily three main routes in the PLWAD's room
	PLWADS' rooms	- Single room occupancy: Rooms' area and equipment - Double room occupancy: rooms' area and equipment	- Taking photos of each room (the single and double occupancy) - Explanting the PLWADs' daily movement	- Three main routes started at 9.00 am; 1. From the bed to the bathroom; 2. From the bathroom to the wardrobe; 3. From the wardrobe to the room's door - The same three routes reversed at 8.00 pm	
3. Assistive technology	**Usage Purpose**	- PLWADs' safety - Rehabilitation	- Monitoring PLWAD in their rooms - PLWADs' safety - Sensor bar on the PLWADs' bed (Fig. 2)	- Sensor bar on the resident bed (Safety and monitoring at night time) - The nurse call button the resident	- AT used for PLWADs' safety and monitoring at nighttime

			- Sensor carpet under the bed at nighttime - The nurse call button in each room (Fig. 3) -Paro-Robot stimulates communication and has a calming effect on PLWAD	did not use when he was confused about the doors	- Using, e.g., IPad for rehabilitation under caregiver supervision - PLWAD forgot to use the nurse call button when needed help - PLWAD interacts significantly with IPad and Paro-Robot more than the nurse call button
	Implemented place	- Special room - PLWADs' rooms	- OT rooms - PLWADs' rooms	-PLWADs' rooms	
	Participants' opinion and knowledge	- Only eight participants answered this part - Lack of knowledge about the AT - It is a helpful tool for PLWADs' safety - Useful for rehabilitation	- Lack of knowledge about what already exists in the market - Companies offer only the expensive one - Covering the lack of nursing, especially at the night time - PLWAD interacting with it perfectly, e.g., Paro - There is a plan to implement more AT in the next five years		**Only the questionnaire and the interview** - Lack of knowledge concerning AT devices and systems - Need to implement AT because of lack of nursing
4. Coping and support		- OT - Daily routine - Social activities in the group	- OT in a particular room - Motivating the residents - Adding signs/ symbols on the residents' rooms door - Using some types of AT, like IPad, Paro, etc - Daily routine	- OT two times per week - Physiotherapy in his room - Adding figures related to his hobby on the room wall	- OT is essential for PLWAD - Motivating is needed sometimes - Daily routine improve PLWADs' performance
5. Architectural barriers			- All the rooms' doors have the same color, confusing the residents. - Lack of privacy in double rooms occupancy	For Single Occupancy room: - The doors face each other, confusing the resident with which one to use. - The doors have the same color without any	**Only the interview and shadowing** - Rooms doors have the same color - Hidden corner in the PLWADs' rooms

		- Artificial lighting is not sufficient, annoying the residents	clarification signs or symbols. - The resident cannot see his room at once because of the hidden corner	- Doors are facing each other in the PLWADs' room - Lack of displayed information for each door

The following four themes identified in the structural analysis and followed by a summarized description of each theme are (1) PLWADs' orientation in space because all participants mentioned disorientation in place as the main observed barrier for PLWAD; (2) occupational therapy because it is an effective therapy for PLWAD and the physical environment, influences OT activities; (3) assistive technology and its potential role, and (4) architectural barriers in the PLWADs rooms.

4.1 PLWADs' orientation in space

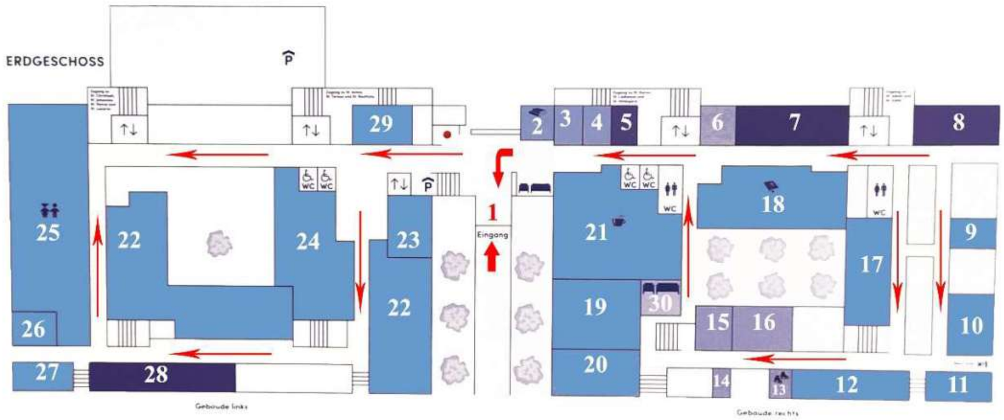
The expert participants were asked to identify the most common barriers encountered by PLWADs in their daily life at the center. All participants mentioned disorientation as the main observed barrier for patients and discussed it from different perspectives. According to one of the experts, all PLWADs have problems with orientation: "there is no difference in disorientation problem when they are in the early or intermediate stage of Alzheimer's disease" *(P5)*. Half of the experts said orientation in space is a challenge in general*:* "losing their way back to their rooms" *(P4)*, while others pointed towards orientation in time, losing the sense of day and night time, or self-orientation to do a specific activity.

"(PLWADs) are suffering from self-disorientation to do a specific activity, especially in their room. This might differ depending on the patients' case; some know what they want, but forget where to do it, while others head to the place and forget what they have to do" *(P2).* According to one interviewee, there are two different types of self-disorientation: PLWAD needs information on how to do a specific activity and where to go to do a specific activity. This information is required in PLWAD's rooms because caregivers are not always there. If PLWADs can access this information, they can act independently, which may increase their self-esteem and quality of life.

Different answers were given by the expert participants regarding how they solved disorientation problems. Solutions differ "depending on the patient's case" *(P1).* Some residents find a solution for finding their way back to their room by hanging a unique sign or element or "putting their photo on the front door, to find their room easily" *(P1).* In this way, PLWADs were able to overcome some disorientation problems in locating their room. On the other hand, according to the interviewees, there was no clear solution for solving the disorientation problems inside PLWAD's rooms. PLWADs are frequently unable to orientate in their rooms and therefore often cannot act independently.

4.2 Occupational Therapy

"Occupational therapy" (OT) was mentioned in several professional participants' answers when asking what alternative supportive methods are used in the healthcare center to enhance PLWADs' daily activities. It was a question of: "stimulate activities," work on memory." Some of the participants had more precise objectives directly aimed at achieving an essential activity, such as "take PLWADs for a wash" *(P1, 4)* or "making a family photo album." *(P5)*. Overall, the professional participants mentioned that OT had several aspects; one is related to "everyday life activities" *(P2, 3, 4)*, and other activities are "individualized" *(P5, 1,3)* depending on the PLWAD health status. Some participants expressed their disappointment; although the OT is an effective method to enhance PLWADs' quality of life, it is not done daily and only in a "specific room" *(P 2, 3)* (Fig.1), not in the PLWADs' rooms. They added; because of several reasons, for instance, "lack of occupational therapist" or "unsupportive environment" *(P 4,5)* like the PLWADs' room.



1. Entrance
2. Library
3. Hairdresser
4. Residents' service point
5. Administration office
6. Conference Room
7. Nursing Director
8. Institute Director
9. Management Director
10. Quality Management
11. Communication
12. Technical Director
13. Ice skating
14. Consultation Room
15. Conference Room 1
16. Conference Room 2
17. ICT Service
18. Church
19. Seminar Room 1
20. Seminar Room 2
21. Restaurant
22. OT room
23. X-Ray
24. Medical Control Room
25. Kindergarten
26. Cardinal Schönborn room
27. Ignatius Nascher room
28. Medical Director
29. Technical Room
30. Paris Salon

(Fig. 7): Floor plan of the Alzheimer's center (ground floor)

4.3 Assistive technology

AT as an assistive tool for PLWAD can serve different purposes such as, for instance, safety, monitoring, rehabilitation, socializing, etc. According to the experts' answers, AT is mainly used in two ways: firstly, for residents' safety in their rooms, and secondly, for occupational therapy.

"Due to nursing shortage" *(P1)* the caregivers use AT to monitor the residents' movement in their rooms during their sleeping time. If the residents get out of their bed, "a sensor bar (Fig. 2) or sensor-carpet" *(P1, P4)* are used to detect the PLWADs movement" *(P5).*

Furthermore, when the residents need assistance from a caregiver, they use the nurse call button (Fig. 3). However, there is a problem concerning the nurse call button, as the residents "forget to press the button" *(P4)* most of the time.

Caregivers also use AT in some activities in occupational therapy (OT). Assistive technology includes, for instance, using an IPad and an interactive projector to improve cognitive, mobility, and communication skills. Brain-boosting games and apps have been shown to improve multi-tasking ability, memory, and focus, gradually integrating into daily activity. Another kind of AT used in OT is the "Paro-robot" *(P5, P2)* which helps PLWADs become more engaged and relaxed. PLWADs have improvements in positive emotions and behaviors when interacting with Paro-robot.
From the participants' experience, there exists a lack of awareness about available and suitable types of AT. Furthermore, they pointed towards technical problems regarding specific types of AT, for instance, that sensors "do not work" *(P3)* due to "daylight reflection, or furniture that was accidentally moved in front of it" *(P1,P5).*

Fig. 2: The sensor-bar to detect the residents' movement if they get out of the bed.

Fig. 3: The nurse call button

4.4 Architectural barriers

This section outlines the results of the questionnaire, the interview, and PLWAD observation to identify architectural barriers that might prevent the implementation of an interactive friendly therapeutic environment in PLWAD's room.

Room layout and equipment

The studied long-term healthcare center offers single occupancy rooms (one resident per room) and double occupancy rooms (two residents per room). The surface area of the single occupancy room is approx. 28m^2 while the double occupancy room is approx. 39m^2, including the bathroom (Fig. 4). The expert participants stated that living in a single or double room "depends on the residents' desire and needs." *(P3,P5).* Each room has seven main elements: (1) door, (2) bed, (3) wardrobe, (4) bathroom, (5) dining table, (6) TV table, and (7) balcony with large windows (Fig. 5).

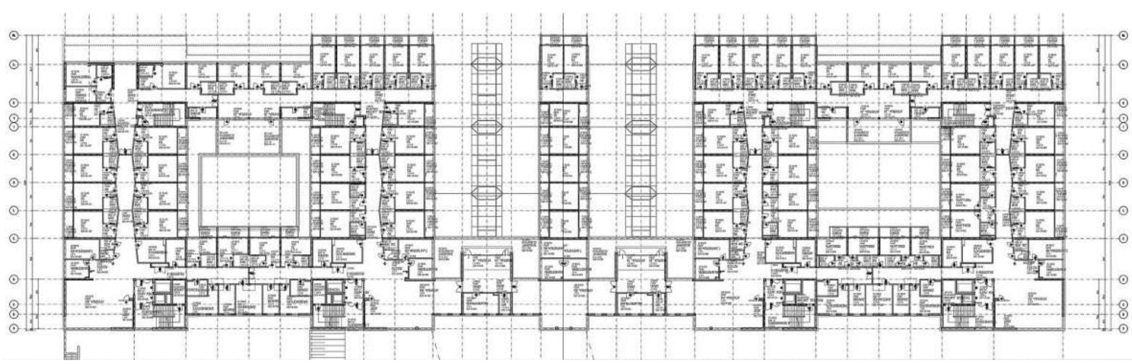


Fig. 4: Floor plan of the Alzheimer's center (1st floor)

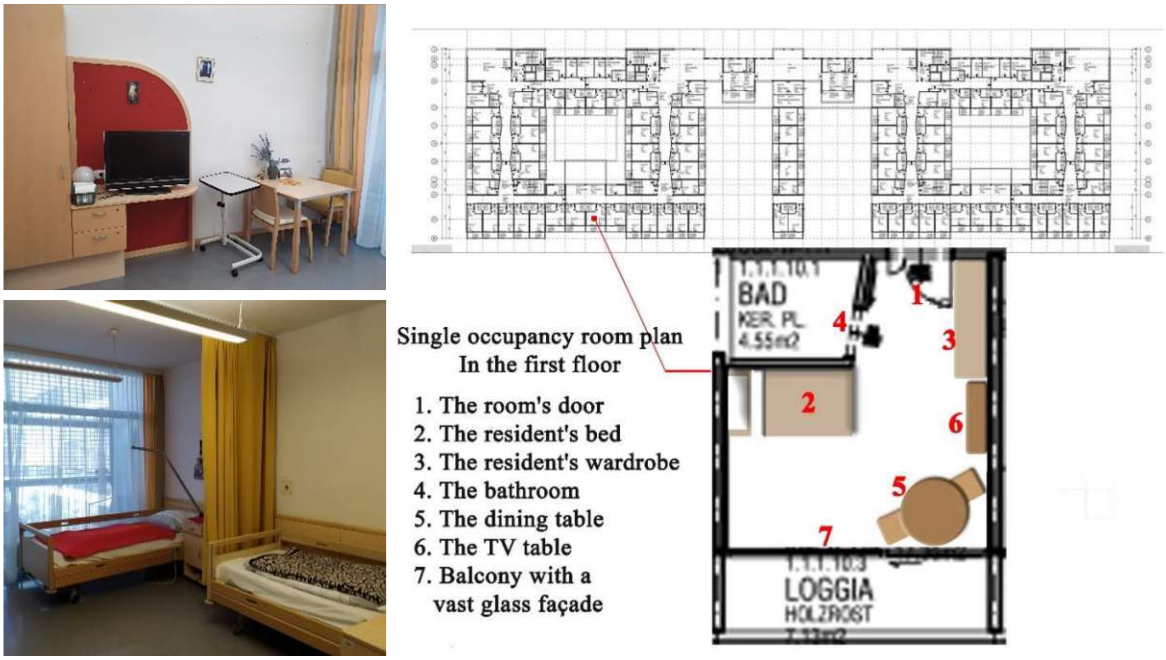
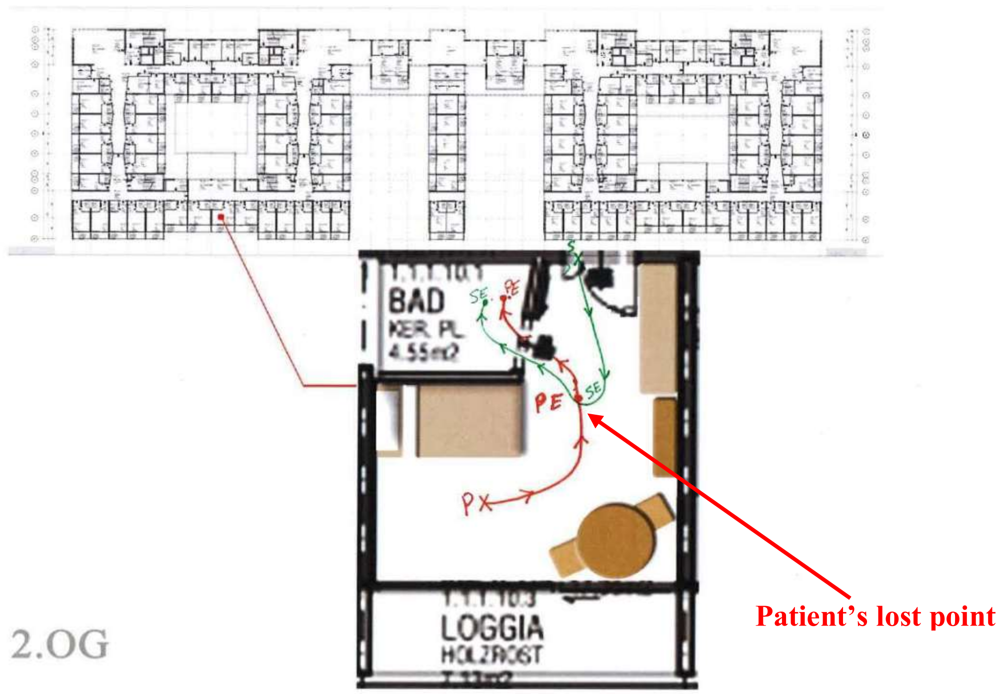


Fig 5: Floor plan and images of a typical resident's room in the Alzheimer's center

Each resident has seven main paths related to the seven main room elements. Four of them are related to daily activities, such as: (1) getting out of the bed (element no. 2), (2) toileting (element no. 4), (3) dressing (element no. 3), and (4) eating (element no. 5). Expert participants clarified that eating in the resident's room "is not a routine" *(P1,P3).* As a result, the PLWADs main daily activities in their rooms are getting out of bed, self-care, and dressing.

The residents need to be oriented inside their room in relation to "three paths" *(P3)*: (1) from the bed to the bathroom, (2) from the bathroom to the wardrobe, and (3) from the wardrobe to the room's door. This sequence establishes the "daily routine" *(P2,P4)* for all residents. While this sequence might sound simple to an average person, it is a complicated sequence for PLWADs. Based on the questionnaire responses and the interviews, there exists no displayed information that would help clarify these three paths to PLWADs. Furthermore, the observation of a PLWAD in his room pointed to additional architectural barriers. During the observation time, the resident was sitting in his wheelchair, watching TV while imitating fishing, which was his favorite hobby. When finishing the imagined fishing activity, the resident moved in his wheelchair, heading directly to somewhere inside his room. Then he stopped in confusion, facing three doors in front of him: (1) the room door, (2) the bathroom door, and (3) the wardrobe door (Fig. 6, Fig. 7). When the nurse entered the room, he expressed the wish to wash his hands after fishing. The nurse then guided the resident to the bathroom, where he washed his hands without the nurse's help. The resident knew what he wanted but did not know how to get to the bathroom. In this case, the location of the doors in the room acted as an architectural barrier. All three doors are located in one corner of the room and face each other without any displayed information, thereby leading to the resident's confusion.



Symbols:

X - starting position, ——— - movement, O - stop, 1, 2, 3 - change of space, E - end position,

▫ - change of floor, P - patient, V - visitor, S - medical staff

Fig. 6: The point where the observed resident became disoriented in his room shown on the room's floor

Fig. 7: The three doors that made the resident disoriented in the corner of his room: 1. The room's door, 2. The bathroom door, 3. The wardrobe door

Therefore, self-orientation seems to be an essential aspect of a person's well-being or ill-being. In the context of care for PLWADs,' it was valuable to investigate the PLWADs' daily needs, activities, and movement in their room. Consequently, the new research questions emerge: How can the therapeutic environment afford the feeling of coming or being home, supporting PLWADs' self-orientation in their room using AT? Considering the PLWADs as end users of the therapeutic environment raises several sub-questions: which essential activities in PLWADs' room need self-orientation supported by AT? Which design concepts are suitable for designing a friendly therapeutic environment with a positive outcome? How would an OT be beneficial in the healthcare-building industry? How could the AT help to improve the shadowing-observation method in case of epidemics?

5. Discussion:

From the professional experts' answers and the observation, it is clear that PLWADs are missing information that can help them achieve basic activities independently in their rooms and often also motivation to perform the activity (Forstmeier and Maercker, 2015; Nathan Herrmann, 2017). One of the biggest challenges PLWADs face was disorientation, which was addressed by medical staff in both the questionnaire forms and the interviews. The disorientation problem for PLWADs is divided into two categories:

(1) Disorientation in the building in general;
(2) Disorientation in the residents' rooms;

Caregivers addressed the first problem by adding different items and signs on the PLWADs room doors to make it easier for them to find their rooms. In contrast, there were no clear solutions for disorientation inside PLWADS rooms, whether single or double occupation. It is evident from the first problem solution that the caregivers considered the residents as end-user. Because every PLWAD has a different interaction with the surrounding environment, the caregivers usually find out what suits each of them and apply related solutions to the residents' room door. Moreover, the professional experts addressed the importance of the OT to maximize PLWADs' independence with a specific activity (Crystal Jo, 2018). OT might assist PLWAD in relearning the activity in a new way or adapting to the environment. Furthermore, OTs are trained to consider how the physical environment influences PLWADs' activities. According to the Occupational Therapy Practice Framework (OTPF) (Occupational Therapy Practice Framework: Domain and Process-Fourth Edition, 2020) the physical environment can support or present barriers to engaging in meaningful activities. OTPF states that OT practitioners acknowledge that for PLWAD to achieve full inclusion, they must engage comfortably with their environment (American Occupational Therapy Association, 2014). OT uses way-finding programs to overcome PLWADs' disorientation (Letts et al., 2011). However, Making rooms easy to navigate is an essential therapeutic environmental modification that supports OT (Corvol et al., 2018). Observation shows that the current layouts of PLWADs rooms are not easy to navigate. In the observation described in this article, the PLWAD got lost in his room when he faced three doors, all located in one corner in front of him without any displayed information regarding where these doors lead to. In architectural terms, this means rooms without a well-considered spatial arrangement that can be perceived at a glance are not beneficial. Spaces that turn a corner or are otherwise hard to visualize are unsettling and may cause anxiety (Coughlan et al., 2018; Feddersen and Lüdtke, 2014; Marquardt, 2011, 2014).

Moreover, these studies (Coughlan et al., 2018; Feddersen and Lüdtke, 2014; Marquardt, 2011, 2014) have identified the optimal layout plan that significantly supports the spatial orientation for PLWADs as follows: (1) PLWADs should have visual access to all the spatial that are related to them, and they should be able to oversee their entire immediate living environment; (2) PLWAD should be guided and directed rather than required to choose from several options to self-orientation, and (3) Improve architectural legibility; by considering the fundamentals of PLWAD's environments, aiming to ease the process of self-orientation and performing daily activities. By comparing the OT rooms' layout (Fig. 1) and the PLWADs' rooms' layout (Fig.5), it is clear that those aspects had been applied and considered only for the OT rooms' layout.

Preliminary research suggested three main focal aspects for designing a user-friendly therapeutic environment (Feddersen and Lüdtke, 2014). These include: (1) considering PLWADs as end-users, (2) considering what is fundamental about the environments one lives in, and (3) PLWADs individual characteristics, i.e., knowing PLWADs hobbies, background, habits, etc. (van Steenwinkel et al., 2014; Van Steenwinkel, I., Van Audenhove, C., Heylighen, A., 2012; Wasana de Silva, 2019). Recent studies show the importance of a friendly therapeutic environment and the positive outcome on the PLWADs when designers consider them end-users (Fleming et al., 2020; Jensen and Padilla, 2017).

Depending on the previous aspects; User Experience Design Concepts (UX) are suitable for designing a friendly therapeutic environment with a positive outcome. UX focuses on understanding users' needs, abilities, limits, and what they value (Garrett, 2011). UX enhances the quality of the user's interaction with spatial characteristics because the design depends on seven main factors: (1) useful, (2) usable, (3) desirable, (4) findable, (5) accessible, (6) credible, and (7) valuable. By applying these primary factors, spatial characteristics can be converted into a sense of space to provide orientation and help PLWADs feel safe and comfortable.
How to adopt the UX design concept in PLWADs' room (in the existing building) to support their self-orientation/ to create a supportive environment for OT activities in the PLWADs' room? AT can provide a connection between the PLWADs' OT and their surrounding environment to create an interactive therapeutic environment that supports PLWADs' self-orientation (Fig. 8) (Smallfield and Heckenlaible, 2017). AT is any device or system that enables PLWADs to accomplish tasks they would otherwise be unable to perform or improves the ease and safety with which the task can be performed (Alzheimer's Society, 2018b). AT includes a wide variety of devices that, according to their purpose, can be divided into three main groups: (1) supportive technology for helping PLWAD to complete tasks, (2) responsive technology for managing risk and raising the alarm, and (3) preventative technology for preventing harm and raising the alarm. Several studies examined the effectiveness of applying the three groups of AT in PLWADs therapeutic environments (Duchi et al., 2019a; Ienca et al., 2017; Kenfack Ngankam et al., 2020a; Klimova et al., 2018).

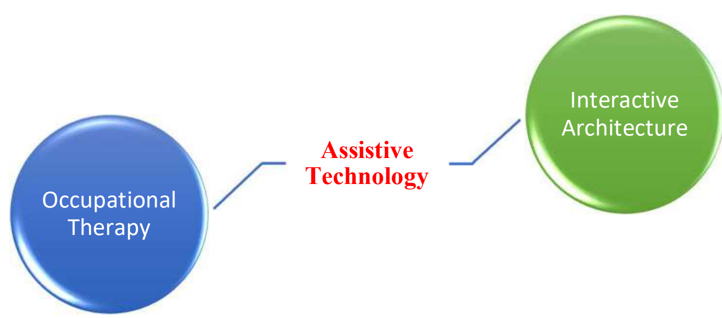


Fig. 8: Illustrate the relation between the Occupational therapy, Assistive Technology and the Interactive Architecture

The three AT groups can be applied in the PLWADs' rooms to partially solve the residents' disorientation problem. This can be done as follows: (1) supportive AT can display information, showing the route, for instance, to the toilet, wardrobe, or the bed, (2) responsive AT can raise alarm, and (3) preventative AT can be of use when the resident does not follow the displayed information. In the current case study, these three groups could be applied to reveal the hidden corner in the PLWADs' room as follows:

(1) The resident will get out of bed in the morning, the sensor will detect his movement and start displaying information guiding the resident to the bathroom's door, for instance, using interactive projection (PLWAD wearing a sensory bracelet, projector, radar, and computer in the nursing station).

(2) When the resident reaches the bathroom door, he will face three doors in front of him/her; the following information will emphasize the bathroom door. The way of displaying the information might differ according to the PLWAD's identity and his/her response to his/her surrounding, as some might interact with color or figures, symbols, etc.

(3) If the PLWAD does not respond to the displayed information, the responsive and preventative AT will raise the alarm in the nursing station according to the sensors' signals.

This study revealed the following research gaps:

(1) a knowledge gap regarding the PLWADs' needs in their residence rooms and the room layout and its equipment;

(2) a knowledge gap regarding supportive AT in the long-term healthcare center applied in a specific room, not in the residents' rooms, because of: (a) lack of awareness from the caregivers, (b) low budget, as most of the time the companies offer the expensive devices, (c) a need to study each resident individually, which is challenging due to the nursing shortage, and the ethical consideration;

(3) a knowledge gap regarding the categorization of AT according to (a) center budget, (b) how it could help in motivating the residents to do a specific activity in their rooms, and (c) what supportive AT helps the residents to enhance their independence in their rooms.

5.1. Study limitations

Due to COVID-19-related access limitations to the long-term healthcare center, it was possible to observe one patient staying in single-room occupancy. Further research could explore the daily activities and the resident self-orientation in the double room occupancy to define the architectural barriers. Conflicts in the self-care activities, privacy, and whether the room equipment creates a barrier to residents' movement should be explored further. Results are valid for long-term healthcare on an institutional basis. The study only focused on persons with Alzheimer's disease, not other types of dementia. Limited generalization of the result from interviews (as it is a qualitative method and there were only 5 participants).

6. Conclusions:

This study examined the problems experienced by PLWADs when performing their daily activities and navigating their rooms in long-term healthcare centers. Therapeutic environments have many prospects to improve PLWAD's well-being that could be significantly improved by specific insights in architectural and other barriers resulting from the design of PLWADs rooms, as well as advantages that can result from equipping the rooms with AT. OT is one of the supportive therapies that help PLWAD engage in daily activities. Previous research showed that recollection effectively maintains and improves AD patients' cognitive functions because it helps clarify blurred memories (Graff et al., 2006; Kim, 2020). According to OTPF (Occupational Therapy Practice Framework: Domain and Process-Fourth Edition, 2020), the environment directly impacts PLWAD's ability to do something. Therefore, this study recommends the following: (1) shadowing observation is essential to understand in-depth PLWADs' needs and the architectural barriers they are facing in their rooms; (2) UX design concept is suitable for designing a friendly, supportive environment with a positive outcome for PLWADs; (3) AT helping reveal the missing information for PLWAD to enhance their self-orientation in their rooms, (4) AT reshaping the therapeutic environment according to PLWADs' needs and activity, and (5) AT could help in creating a supportive environment for OT activities.

Further research should explore the daily activities and the residents' self-orientation in the double room occupancy to further define the architectural barriers, explore problems and conflicts experienced in self-care activities and privacy, and analyze whether PLWADs' movement and the room's equipment unintentionally create barriers. This will help build informed design strategies that can improve PLWADs' lives by considering them as end-users. Based on the insights gained in the research described in this article, and since epidemics may continue to make such studies difficult by preventing the necessary continual and extensive observation, further studies should explore the AT's potential to collect data about PLWADs' movements in their rooms at the long-term healthcare center.

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Article

Assessing Alzheimer's Therapeutic Environment Digitally through a People with Alzheimer's' Disease Perspective: A Computation-Based Approach Framework

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Abstract: People living with Alzheimer's disease (PLWAD) are impacted by their surroundings, and their performance improves in therapeutic environments designed to meet their specific individual needs, are adjustable in terms of their health status, and are created to accommodate their abilities. A literature review of the field revealed scarce knowledge in using a combination of building information modeling (BIM) and the Internet of Things (IoT) for the purpose of understanding the daily needs and self-orientation ability of PLWAD, as well as the architectural barriers they face in their rooms in long-term healthcare centers. In this context, this paper proposes a framework based on computational design approaches to assess the existing therapeutic environment for PLWAD using BIM–IoT sensors-based monitoring. The proposed framework used the user experience design concept (UX) and the design thinking framework to evaluate the resident rooms of PLWAD. The UX design concept and the design thinking framework core allow for the adoption of user-centered methods to provide a comprehensive image of the issues that affect PLWAD in their therapeutic environment. The proposed framework-structured approach will enable healthcare architects/designers to (1) digitalize old building architecture plans using BIM; (2) strategize IoT sensor selection; (3) recognize the activities performed by PLWAD and detect any anomaly; and (4) integrate IoT real-time data into the BIM system. The proposed framework supports three types of professionals: (1) architects in decision-making processes, (2) researchers in collecting/analyzing accurate data for shadow observations, and (3) neurologists in following up the health statuses of PLWAD.

Keywords: computational design; design thinking; software architecture design; smart homes; IoT technology; BIM system; wireless sensor networks

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1. Introduction

Alzheimer's disease (AD) is becoming more prevalent as the world's population ages [1]. AD is considered the most common form of dementia and may contribute to 60–70% of the dementia cases [2]. Worldwide, approximately 46.8 million people are living with Alzheimer's disease [1–3]. To put the cost of this disease into perspective, if Alzheimer's disease represented a country's economy, it would be the 18th largest factor in terms of economic impact. If AD were a company, it would be most profitable, exceeding Walmart, with USD 414 billion [1,3]. Since AD causes cognitive decline, people suffering from deteriorating memory, language, and other thinking abilities require constant care for the rest of their lives. A smart therapeutic environment can provide new opportunities to the care of people living with Alzheimer's disease (PLWAD). Smart therapeutic environments are characterized by sensors and devices embedded in everyday life activities [4]. Ambient assistive technology can provide assistance in making decisions regarding the performance of the daily activities of PLWAD and by guiding residents [5]. However, to enable the ambient assistive technology and convert the rooms of PLWAD at long-term healthcare centers into a smart therapeutic environment, there is a need to understand in depth the needs and problems of PLWAD, especially concerning self-orientation, as well as the architectural barriers that can become obstacles to PLWAD performing their daily activities in their room in long-term healthcare centers.

However, applying the same therapeutic environment design to different PLWAD is inadequate because each individual's health status and related problems differ. Each resident has a different identity, background, habits, and symptoms. For this reason, researchers should examine the possibility of developing an experience that is precisely tailored to each individual AD patient's requirements. User natural shadowing observation via sensors can be a useful analytical tool to create a personalized smart therapeutic environment with a positive outcome for PLWAD in their rooms in long-term healthcare centers. User shadowing observation is a qualitative research method that collects rich data about the behaviors of PLWAD in their familiar therapeutic environments [6,7]. This research method prioritizes the users' interaction with the therapeutic environment. It is a research method [8] with a fresh beginning in user experience design concepts (UX) and a design thinking framework. It can potentially gather critical evidence for researchers to create, develop, and improve the existing therapeutic environment for PLWAD in long-term healthcare centers, transforming it into a smart environment. User shadowing observation can provide information about elementary spatial characteristics related to residents' activities and their behavior in their living environment.

IoT technology-based monitoring systems provide an opportunity to support PLWAD [9]. Such systems enhance the quality of life of PLWAD and reduce caregivers' burden and healthcare costs while maintaining patient safety [4,10]. Analyzing continuously monitored data using machine learning and artificial intelligence (AI) [11,12] can deliver accurate long-term evaluations and produce valuable information about the actions and routines of PLWAD. In a smart therapeutic environment, the vast majority of recognition systems focus primarily on logical or temporal constraints and overlook the constraints of spatial aspects [13,14]. Nevertheless, these aspects can substantially impact recognition [15,16]. A spatial constraint is an object's spatial configuration in relation to its environment and other objects. For instance, as each object has a size that represents the spatial area in 2D/3D, the area of the object (chair) should not intersect the area of another object (wardrobe) during a step (open the wardrobe door) of an activity. Constraints regarding objects engaged in an activity can be specified based on that premise [15].

Furthermore, objects can feature embedded sensors, actuators, and other devices. This can include smart connections, cloud computing, context-aware processing, etc. Based on an object-oriented approach, the building information modeling (BIM) system performs all of the features of classic 3D CAD/CAM approaches. The BIM technology can create a virtual 3D building model, including data from other analysis applications, such as energy consumption simulations, cost estimation, natural lighting, etc., as shown in Figure 1. BIM can be employed in smart homes in monitoring and management systems. Related studies have focused on managing sensor data flows and the integration of BIM and actuators in the environment [17–19].

Ambient assistive technology-based smart devices reshape the therapeutic environments of PLWAD, where each device can interact with other devices and humans. This connection between smart devices and systems is defined as the Internet of Things (IoT). Connecting real-time data streams from the rapidly expanding set of IoT sensor networks to BIM models provides an essential framework for applications that increase the construction and operational efficiency of the interactive therapeutic environment. However, BIM and IoT integration research is still in its early stages [20,21]. There exists a gap in the understanding of the current situation regarding BIM and IoT device integration to create interactive therapeutic environments supporting the orientation abilities of PLWAD while performing their daily tasks in their rooms in long-term healthcare centers. In this context, this article focuses on strategizing the implementation of interactive indoor environments for PLWAD to support their orientation abilities while performing their daily tasks in their rooms in long-term healthcare centers, so as to enhance their quality of life (QoL).

Figure 1. BIM technology advantages for facility management.

1.1. Background and Related Work

The COVID-19 pandemic adds another layer to the caregivers at the long-term healthcare centers for Alzheimer's by increasing the demand for renovating old healthcare centers and adopting assistive technology-based monitoring in the rooms of PLWAD. PLWAD may be more susceptible to contracting the virus and more prone to spreading it simply because their memory of proper sterilization is not always present. Moreover, the COVID-19 pandemic highlighted the need for decision support tools in Alzheimer's care to help researchers continue collecting and analyzing their research data; the architects in built-environment decision-making processes; and neurologists to follow up the health statuses of PLWAD. The COVID-19 pandemic was the most significant difficulty encountered during the research study [22] that occurred at one of the long-term healthcare centers in Vienna, Austria. This problem has prevented the researcher from carrying out more shadow observations for PLWAD in their room at the long-term healthcare center due to COVID-19 restrictions. For this objective, this paper proposes a framework based on computational design as an alternative solution for the regular shadow observation by the researcher. Furthermore, combining IoT technology such as sensors, computational design technology such as algorithms, and BIM systems such as Revit, through UX design concepts and a design thinking framework, provides a wide range of tools that could be used for decision support in Alzheimer's care. The research questions that derive from the objective and articulate the research are: (1) How can we digitalize the as-built for a post-construction old building? (2) What is the criteria for selecting the IoT sensors-based monitoring motion within the context of PLWAD? (3) How can we determine the optimal sensors' placement? (4) What are the analyzing criteria for the movement of PLWAD in their rooms at the long-term healthcare center? (5) What is the movement anomaly definition within the context of the behavior of PLWAD? (6) How can we display the analyzed data output in the BIM system? (7) What is the ethical consideration for installing IoT technology-based monitoring in the rooms of PLWAD at long-term healthcare centers? Dual processes are utilized in solving design challenges using design thinking frameworks and computational design technologies to answer those questions and construct the proposed framework criteria.

1.1.1. Design Thinking Framework

A design thinking framework is an approach for creating design solutions for complex problems, such as designing a therapeutic environment for PLWAD. The design thinking framework focuses on the importance of privileging the built environment in user-centered design processes because the built environment is relational, capturing dynamic relationships between other factors of design problems [23]. Due to the design thinking framework serving industry and academia and its promising practices in a broad scope of social and technological innovation projects, such as the Golden Gate Regional Center (GGRC); various industry and academia institutions have developed their design thinking models. The most well-known models are as follows [24]: (1) the double diamond model; (2) IBM's model; (3) the 31 model; and (4) Stanford d. school. The double diamond model proposed by the design council (the British Council) consists of four stages: (1) discover; (2) define; (3) develop; and (4) deliver. IBM's model, known as the loop, employs the prompt and continued iteration methodology of (1) observing; (2) reflecting; and (3) making. The 3I model, developed by IDEO, consists of three stages: (1) inspiration; (2) ideation; and (3) implementation. Finally, Stanford d. school model consists of (1) empathizing; (2) definition; (3) ideation; (4) prototyping; and (5) testing stages. These stages are not always sequential, and the five steps are frequently part of an iterative procedure [25].

Based on what was formerly mentioned and due to the complex nature of Alzheimer's disease, Stanford d. school model (Figure 2) will be used to create the proposed framework.

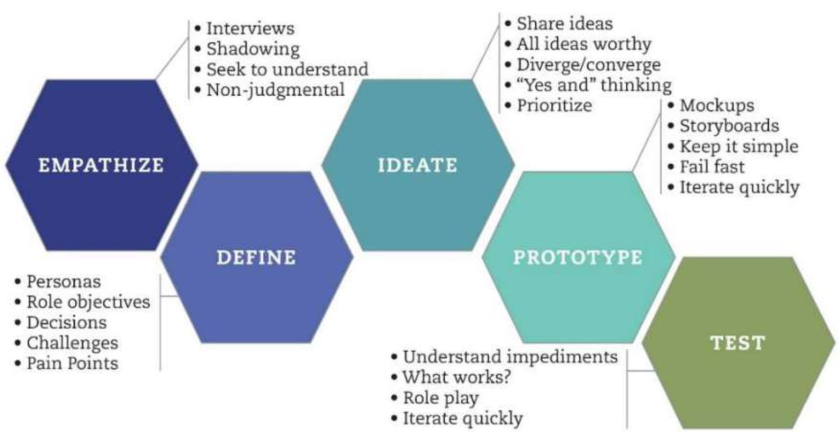

Figure 2. Stanford d. school model (https://www.stlouisfed.org/publications/bridges/winter-2018-2019/cdac-designing-for-change accessed on 25 May 2023).

1.1.2. Computational Design Technology

The computational-based design approach is known as computational design (CD). The CD is a design method that combines algorithms and parameters to address design problems through a sequence of logical processes with advanced computer processing. The CD grounds the design representation in its computational logic instead of its geometric aspects. Moreover, the CD is changing design theory and practice due to the wide range of CD toolsets, such as Grasshopper, Dynamo, Param-O, and Marionette, which provide architects with new design methods and tools, automate repetitive tasks, reduce design risks, reduce project costs, provide original aesthetical discourses, and provide never-before-used design/construction strategies [26]. Currently, the design process is enhanced with the power of computation for a more effective and optimized design solution. Documenting the design output is not the final target, but the aim of using CD is all about the steps to create the final result. Furthermore, the CD toolset, such as Dynamo, enables non-specialists an operating mode that does not usually require typing a code list, but rather the connection and processing of graphic entities.

There are three subsets of computational design [27]: (1) parametric design; (2) generative design; (3) and algorithmic design. The parameters influence parametric design in a model; it helps designers to utilize complex shapes, following the rules and programs to move more efficiently. In contrast, the generative design analyses ensure many options for architects to work more sustainably with the pieces of equipment to choose with better judgment. Finally, algorithmic design makes use of algorithms to generate design ideas. These algorithms are rules which describe information, defined in a logical sequence to generate a design [27].

Overall, the computational design technology supports architects in exploring new solutions to improve design processes and decision-making management.

2. Method

As mentioned previously in this paper, the therapeutic environments have either a negative or a positive impact on PLWAD [28], which implies the need to understand the therapeutic environment from the perspective of PLWAD, specifically in the context of spatial self-orientation, as their perspectives supplement the plans and design processes of the interactive therapeutic environments for PLWAD. Understanding the behavior of PLWAD is essential to assess the environment around oneself; therefore, design and methods, cross-disciplinary and digital architecture, and neurosciences were combined to create a model that explicitly relates neurological processes, behavior, design principles, and design. The International Classification of Functioning, Disability and Health (ICF) is the rationale behind the model [29,30]. ICF has two parts, each with two components:

Part 1. Functioning and Disability: (a) Body functions and structures; (b) activities and participation.

Part 2. Contextual Factors: (a) Environmental factors; (b) personal factors.

Each component consists of various domains and, within each domain category, the units of classification (Figure 3). Moreover, each component can be represented in both positive and negative terms [29].

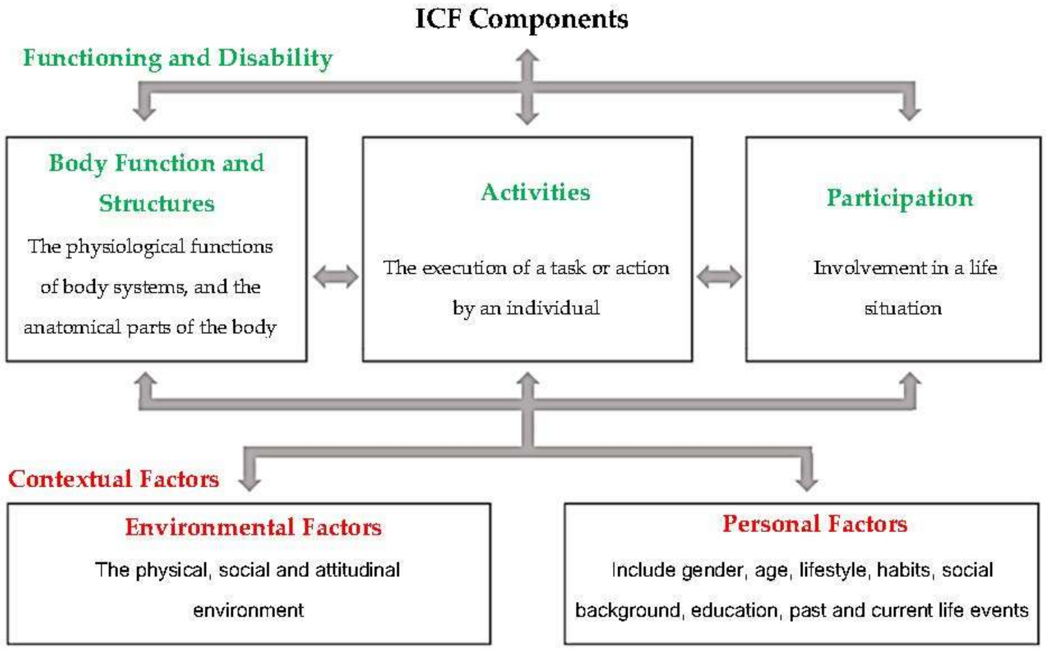

Figure 3. The interaction between components of the International Classification of Functioning, Disability, and Health.

A scoping review based on empirical studies [31], an exploratory research with a sequential design based on experience [22], and formal knowledge based on previous studies' results [15,32–36] were used to develop the assessment technique criteria of the proposed framework based on the spatial constraints' main factors. In user experience design concepts (UX), the essential trigger for effective decision-making is the in-depth knowledge of users. Within this context, the proposed framework aims to collect real-time quantitative data about the movements of PLWAD in their rooms at long-term healthcare centers via IoT sensors-based monitoring with a comprehensive analysis via computational tools. The framework then presents the output into a BIM system that aids decision-makers in investigating, analyzing, improving, and assessing the therapeutic environment through the perspective of PLWAD.

3. Results

The overarching objective of this paper is to support architects and designers in designing an interactive personalized therapeutic environment; its interior and its technologies match the needs of PLWAD and enhance their self-orientation abilities.

Based on the ICF model, the assessing model contains two critical parts, as follows:

1. It has to be based on insights into the neurological processes of PLWAD and the resulting behavioral consequences to provide an indication to translate IoT sensors' data within machine learning algorithms so as to detect the anomaly of the movements of PLWAD.
2. It has to support the computational design processes in which design specifications convert the IoT sensor data into environmental data (BIM system) and then to concrete designs, and finally defining the architectural barriers.

Figure 4 illustrates the steps of each part of the assessing model that supports the proposed framework's development.

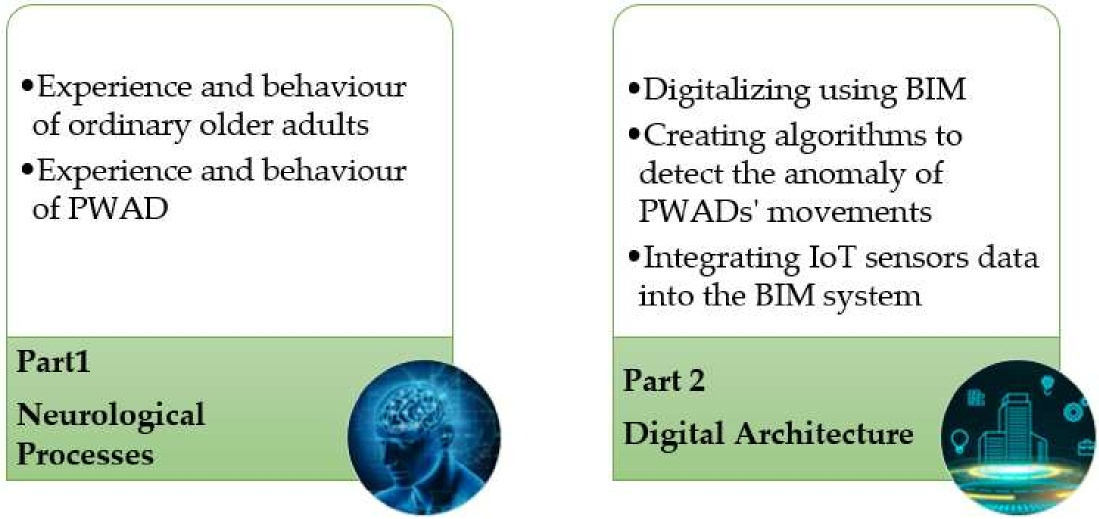

Figure 4. The steps of the each part of the assessing model that supports the proposed framework's development

Based on the formal knowledge of neurology and behavioral sciences [34,36], there is a mutual interaction between a person and the environment in normal brain functioning. According to research [36], the impaired brain becomes increasingly dependent on the surrounding environment. In other words, the person–environment relationship is damaged, and the environment becomes a key determinant of behavior [31,34,35]. Moreover, the insight gained in the study [22] led the researcher to investigate alternative sophisticated techniques based on computational design technology for collecting continuous quantitative data about the movements of PLWAD. Based on the insights gained in [15,22,31–36] studies, the proposed framework includes five main stages, which are: (1) digitalizing old building architecture plans using BIM; (2) selecting IoT sensors-based monitoring; (3) detecting the anomaly in the movement of PLWAD; (4) integrating IoT sensor data into the BIM system (environmental data); and (5) ethical consideration. This approach is intended to replace the ordinary methods for architects in decision-making processes, for researchers collecting/analyzing accurate data for shadow observations, and for neurologists following the health statuses of PLWAD.

4. Proposed Framework

Creating a therapeutic environment for PLWAD is challenging because each case is different. As they depend on their surrounding environment for self-orientation, modifying the existing therapeutic environment to meet their needs is necessary. Therefore, there is a need to assess the existing therapeutic environment to be modified according to the needs and abilities of PLWAD. The proposed framework based on a computational design approaches aim to assess and evaluate the therapeutic environment of PLWAD through their perspective, i.e., to be more precise, to partially solve the self-disorientation of PLWAD in their rooms. The goal is to provide a personalized smart therapeutic environment that serves the needs of PLWAD and their health status limitations to enhance their quality of life.

Figure 5 illustrates the methodology adopted for this study, which includes five main stages. The first stage is digitalizing old building architecture plans using BIM. Most old long-term healthcare buildings for Alzheimer's care did not use BIM systems in the pre-construction phase. Since a BIM model of an existing building is based on a real asset, collecting information about this asset is a logical first step. 'As-planned' documents like plans and sections are frequently the starting points for documenting an existing building. However, these are frequently insufficient, outdated, or simply absent. Nevertheless, the final design of a structure may change significantly from the architect's original vision. As a result, onsite surveys of the actual asset are required to acquire information on its current state.

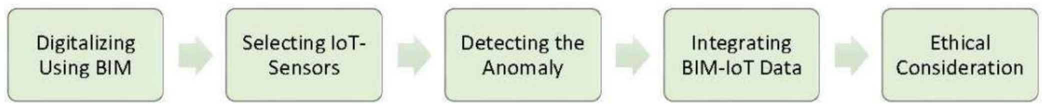

Figure 5. The five main stages of the proposed framework.

The second stage is selecting IoT sensors-based monitoring. Sensors based-monitoring have hundreds of variations and could be categorized into two main groups: (1) wearable sensors and (2) direct environment sensors. In the context of Alzheimer's care, the criteria for selecting the IoT sensors are developed based on formal knowledge [37], for example: (1) direct environment sensors should be unnoticeable because they might confuse PLWAD and (2) the wearable sensors should be comfortable and not cause anxiety for PLWAD [5,38]. Another factor to be considered when selecting the sensors is the room layout and size and the sensor's placement. Finding the optimal placement for the sensors is a significant factor to consider when implementing and adopting the ambient sensors in the room of PLWAD [39].

The third stage is detecting the anomaly in the movement of PLWAD. As previously mentioned, the assessment of the therapeutic environment is based on anomaly detection in the movement of PLWAD through the spatial constraints' main factors. Moreover, according to [14], the behavior of PLWAD is distinguished by recurring incoherencies in their actions, which arise when they perform complex tasks requiring cognitive abilities. In contrast, healthy people can detect and remedy their behavioral errors and mistakes. Furthermore, healthy people do not frequently act incoherently. PLWAD, on the other hand, will almost surely act incoherently, even while performing familiar activities, and their behavior will become increasingly incoherent as the disease evolves. Anomalies in the behavior of PLWAD will be detected utilizing this pivotal contrast based on the previous four main factors [40].

The fourth stage is integrating IoT sensor data into the BIM system (environmental data). This integration allows for collecting and analyzing real-time data, leading to better decision-making and more efficient maintenance practices. It also provides a common platform for all stakeholders involved in facility management, including architects, engineers, contractors, and facility managers. BIM and IoT integration contains three parts [17]: (1) BIM as data storage for contextual information, such as building geometry, and a list of IoT devices. Contextual information can be stored in BIM tools, for instance, Revit Suite or Archicad, as they are the most popular BIM software. (2) The time-series data record continuous sensor readings, which are stored in a well-structured database, for instance, the relational database, and can be effectively queried using, for instance, structured query language (SQL). (3) The integration method between contextual information and time-series data.

The fifth stage is the ethical consideration; concerns are also associated with using IoT technologies for PLWAD [41]. The requirement for privacy and security is one of the main challenges [42]. The data collected by these sensors are sensitive and must be protected from unauthorized access. Another challenge is the need for accuracy and reliability. For these sensors to be effective, they must accurately detect motion and location.

5. Discussion

Based on the insights gained in the exploratory research [22], and since epidemics prevented continual and extensive shadow observations, there was a need to develop a framework based on computational design to help in collecting and analyzing quantitative data and support decision-making processes. The exploratory research raised three main issues: (1) The necessity of utilizing BIM in facility management at the post-construction stage. (2) The dual use of the assistive technology; firstly, using IoT sensors-based monitoring for shadow observation encourages continuity in collecting data, mainly during the pandemic, which identify the residents' needs and problems to enhance the design thinking of the therapeutic environment and secondly, as an assistive tool to achieve a specific activity.

(3) The necessity of using computational design-based decision-support approaches. As the health status and personality of PLWAD might change [43], the data collected by the sensors can feed into machine learning and artificial intelligence-based applications that would facilitate the self-learning capacity of assistive technology setups and convert the smart therapeutic environment into a cognitive therapeutic environment, as it will be capable of learning new rules through the interactions of PLWAD with the environment [44].

Therefore, there is a need to develop a framework based on computational design to assess the therapeutic environment of PLWAD within the user experience design concept (UX) and the design thinking framework. The UX design concept and the design framework of the Stanford d. school model, with its five steps (empathizing; definition; ideation; prototyping; and testing), makes designing a therapeutic environment that matches the needs and abilities of PLWAD feasible. These four steps help validate an architectural intervention that stimulates or prevents the self-orientation of PLWAD in achieving their daily activities independently without caregivers' support inside their rooms.

Creating a framework based on computational design to assess the therapeutic environment in the context of Alzheimer's care and post-construction healthcare building with no BIM documents is challenging. On the one hand, PLWAD might interact differently with IoT ambient or wearable sensors. On the other hand, the post-construction old long-term healthcare center is not eligible to integrate new technology, such as embedded devices. Therefore, the proposed framework includes five stages with a comprehensive vision to cover all the challenges that might be considered obstacles during the implementation phase.

Since BIM has become increasingly prevalent in both digitalizing old building architecture plans and for the facility management (FM) of a smart therapeutic environment [45,46], the first stage of the proposed framework is digitalizing old building architecture plans using BIM. A complete as-built geometry is required for using BIM systems. Creating an as-built BIM model differs significantly from creating an as-planned model. The computation technology provides three methods to achieve an as-built model (geometric) efficiently: (1) Laser scanning or photogrammetry [47], which is mainly known as "scan-to-BIM" for high-detail models. Most day-to-day FM operations do not require the details supplied by these models. (2) An automated conversion of 2D to 3D plans of the BIM [48], aiming to enable more fluid and flexible workflows that do not require BIM models to be manually recreated. (3) The translation of 3D geometric models to BIM [49], translating the 3D models created in Trimble SketchUp and Mc-Neel Rhino for conceptual design to Graphisoft ArchiCAD and Autodesk Revit for BIM modeling.

An IoT technology system includes four essential parts [50]: (1) external devices (sensors, actuators), which collect monitoring data; (2) a control system (AI system), which receives the data from the external devices and makes decisions; (3) transmission system (wired/wireless network) that connects the external devices and control system; and (4) data, which could be used to control the environment to enhance the quality of life for PLWAD. The proposed framework depends on the collected quantitative data for the movements and activities of PLWAD to assess their therapeutic environment; therefore, there is a need to combine and install both the wearable and the direct environment sensors in the rooms of PLWAD to provide accurate insights. The wearable sensors have a dual use: (1) to detect the motion and movements of PLWAD and (2) to collect physiological data, including blood pressure, heart rate, body temperature, etc. The wearable biosensors/sensors-based monitoring motions include vast choices, for instance, feet- and waist-mounted inertial sensors, ankle-mounted accelerometer sensors, wrist-mounted accelerometers, and leg-mounted force sensors [10,51]. The selection of the wearable sensors depends on the resident's acceptance and which type will be comfortable and not cause anxiety to the resident.

Moreover, the direct environment sensors (ambient sensors) consist of passive infrared (PIR) sensors, preferred because of their small size, low cost, and because they consume less power and are very easy to use; pressure sensors attached to the bed; contact switch sensors (CSS) attached to doors or closets, which can capture activities such as walking, sleeping, or exiting the room; and a central energy consumption monitoring device [38,50,52]. Although most direct environment sensors are non-structural, placed on the surface of architectural elements, or installed inside furniture [53], building modification is still necessary to effectively ensure the IoT systems' performance. The sensors' placement is essential in monitoring the movement and activity of PLWAD to avoid collecting misleading information. The computational design provides methods [54] for selecting the optimal sensor placement based on the BIM system, allowing the user to have an optimal solution displayed on the BIM after a few analysis steps. These analysis characteristics are: (1) the resident's room size; (2) the sensor features; (3) the neighbor zones, which have to be covered by two different combinations of sensors to distinguish the target location according to sensor activation; and (4) a sensor number determined for each zone, which depends on the sensor field of view and zone size.

Activity recognition and anomaly detection are a complex process (Figure 6) characterized by four main phases: (1) selecting and adopting sensors-based monitoring to collect data on the behavior of PLWAD; (2) collecting, storing, and processing information through AI; (3) creating computational models to conduct reasoning and anomaly; and (4) developing reasoning algorithms to conclude activities from sensor data [15,38,55]. The anomaly detection in the behavior data of PLWAD could be determined through the spatial constraints' main factors [15,32,33].

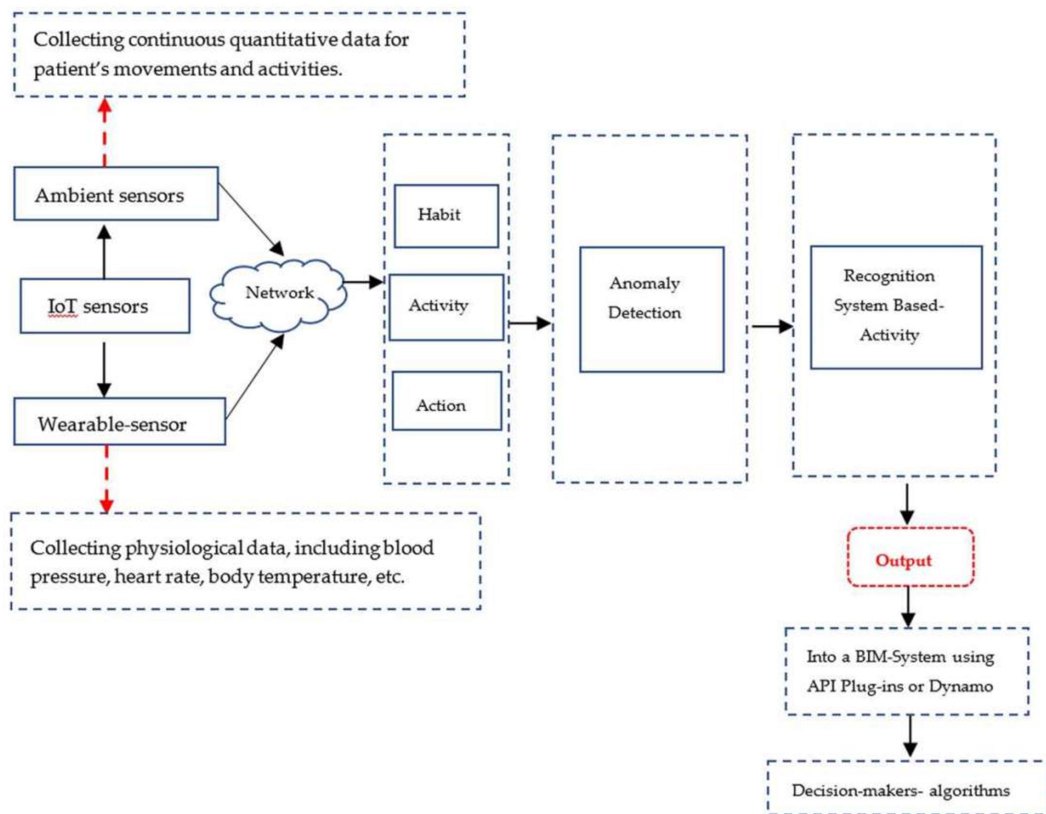

Figure 6. The anomaly detection system in the movement of PLWAD through four main factors.

For an in-depth understanding of how to detect the movement anomaly of PLWAD, it is helpful to determine human behaviors at different levels of granularity. For physical behaviors, the terms "action", "activity", and "habit" [38,41,55] are commonly used in activity recognition communities. The term "action" refers to a simple behavior performed by a person for a short duration, for instance, opening a door, while the term "activity" refers to complicated behaviors that include a series of acts and interleaving or overlapping actions for longer durations and could be performed by one person or more, for instance, two persons preparing meals. A "habit" refers to one or more activities that are repeated regularly in a consistent way [56]. Hence, to define a set of activities as a habit, there should be no or only slight variations on how such activities are performed, for instance, taking medicine with a glass of water every morning after breakfast.

Machine learning approaches are more compatible with the four main activities and anomaly recognition phases than classical mathematics and statistical techniques in extracting knowledge and discovering, learning, and inferring activity from data [12]. Machine learning provides algorithms that connect physiological and environmental data collected by IoT technologies (sensors) [11]. These algorithms include: (1) rule-based reasoning methods and adaptive learning mechanisms to make them more personalized and (2) machine-learning techniques to learn the activities/patterns of PLWAD and detect unusual behavior, as well as for the pattern detection algorithms that provide a holistic view of the activity and routines of PLWAD. Pattern detection algorithms analyze PLWAD data at different temporal granularities to develop automated procedures for macro- and micro-assessments. Moreover, the micro-assessment framework focuses on detecting underlying activity patterns that can be used to conclude the day-to-day well-being of PLWAD and categorize them according to PLWADs' behavior and movements errors [11].

Because the BIM–IoT integration has become one of the most vital current research fields, enabling non-specialists to access computational design toolsets is becoming increasingly important. Tools are frequently improving user access to algorithms [57]. For instance, Revit/Dynamo integration for sensor data management [19]. The dynamo visual programming platform is an operating mode that does not usually require typing a code list, but instead the connection and processing of graphic entities. The visual approach simplifies the development of applications by isolating the complexity of coding to the primary users of Revit (architects, designers, engineers, companies, etc.). Moreover, for professional architects, there are more advanced methods for producing the output into the BIM system, such as the application programming interface (API). API is creating plug-ins to integrate sensor technology with the BIM model using Autodesk Revit software 2023 when using BIM to analyze the collected sensor data and display the output into the BIM system [58].

Furthermore, the use of IoT technologies for PLWAD raises ethical questions such as the ability of PLWAD to provide truly informed consent, how their privacy is protected, or how the confidentiality of their information is managed. Privacy, autonomy, and data ownership are considered significant issues when implanting IoT technology-based monitoring in the rooms of PLWAD at the long-term healthcare center. The answer to these questions is presented throughout the literature [42,59,60]. The literature clarified three main aspects to be considered while using IoT technology-based monitoring: (1) the safety of PLWAD is prioritized; (2) involve PLWAD in decision-making processes; and (3) informed consent forms, the protection of privacy and confidentiality, and the acknowledgment of duty to protect, should be signed by a family member of the PLWAD. IoT technology-based monitoring is allowed, according to the literature [41,60], depending on the purpose it will be used for; additionally, it is essential to have the PLWAD and their family members' approval to use such technology.

The difference between the previous framework in the same field and the one proposed here is that the proposed framework attempts to improve the therapeutic environment at Alzheimer's long-term healthcare centers by dual processes in solving design challenges using design thinking framework and computational design technologies. Furthermore, the proposed framework evaluates each resident's room from each resident's perspective, abilities, and health status. These differences are the main novelty of this proposed framework.

The complex nature of Alzheimer's disease and designing a therapeutic environment that caters to the needs and abilities of PLWAD revealed the importance of combining and pursuing a cross-disciplinary approach with digital architecture and neuroscience to create an interactive personalized therapeutic environment with a positive impact on PLWAD, in addition to the significant contribution of computational design technology in the decision-making process. From the insight gained from this paper, a reflective question arose: How far could the contribution of cross-disciplinary methods enhance the ethical considerations concerning gerontechnology for Alzheimer's disease?

6. Conclusions

This paper proposed a framework based on a computational design as an alternative method to the ordinary shadow observations by researchers. The proposed framework aims to examine the problems experienced by PLWAD when performing their daily activities and navigating their rooms in long-term healthcare centers. Therapeutic environments have many prospects to improve the health statuses of PLWAD that could be significantly improved through specific insights into architectural and other barriers resulting from the design of the resident rooms of PLWAD. The UX design concept and design thinking framework are both underpinning the proposed framework criteria to determine these insights in architectural design. Integrating IoT sensors-based monitoring within the framework of BIM has the potential to reshape the therapeutic environment for PLWAD. IoT technology, such as sensors, actuators, and other devices, can create a personalized smart therapeutic environment that caters to the needs and abilities of PLWAD. The proposed framework highlighted several key aspects related to implementing this technology. Using BIM in the facility management of the post-construction stage allows for the efficient monitoring and management of the therapeutic environment. Additionally, the adaptive nature of the technology enables it to accommodate the changing health statuses and personalities of PLWAD through the use of machine learning and artificial intelligence-based applications. The dual use of assistive technologies was also emphasized, with sensors serving as tools for both shadow observation and specific activity assistance. By continuously collecting data on the movements of PLWAD, architectural barriers can be identified and addressed, promoting their independent performance of daily activities. Moreover, assistive technologies can provide personalized support and guidance for specific tasks, further enhancing their autonomy.

However, it is important to consider ethical implications when implementing IoT technology-based monitoring in the rooms of PLWAD. Privacy, informed consent, and data ownership are significant concerns that must be addressed. By using IoT technologies, new and extensive amounts of data are generated; to whom that data belongs to remains a subject of serious inquiry. It is essential to preserve the confidentiality of sensitive data and prevent exposing them in any personally identifiable way. Ensuring the safety of PLWAD, involving them in decision-making processes, and obtaining informed consent from them and their family members are crucial steps in addressing these ethical considerations.

Overall, the research contributes to understanding how IoT technology-based smart devices, integrated with BIM, can reshape the therapeutic environment for PLWAD. Incorporating computational design methods, collaboration, and interdisciplinary approaches can lead to holistic design solutions that address not only architectural aspects, but also healthcare requirements and the well-being of PLWAD. Moving forward, further research and exploration in this area are warranted to continue advancing the development and implementation of ambient assistive technology in the context of the therapeutic environments of PLWAD. By addressing the challenges and ethical considerations, we can harness the full potential of these technologies to improve the quality of life and care of PLWAD.

7. Patent: Inventor: Heidi Elnimr. „Verfahren und System zur Überwachung einer Person in einem Raum“ Österreichische Patentanmeldung A 50581/2023, filed on July 19th, 2023.

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56. Thompson, M. Occupations, Habits, and Routines: Perspectives from Persons with Diabetes. *Scand. J. Occup. Ther.* **2014**, *21*, 153–160.
57. Boissieu, A. De. Introduction To Computational Design: Subsets, Challenges in Practice and Emerging Roles. In *Industry 4.0 for the Built Environment: Methodologies, Technologies and Skills*, 1st Ed.; Bolpagni, M., Gavina, R., Ribeiro, D., Eds.; Springer: Cham, Switzerland, 2022; Volume 20; pp. 55–75.
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60. White, E.B.; Montgomery, P. Electronic Tracking for People with Dementia: An Exploratory Study of the Ethical Issues Experienced by Carers in Making Decisions about Usage. *Dementia* **2014**, *13*, 216–232.

DI. Heidi Elnimr, BSc.
Email: helnimr22@gmail.com

Profil

+15 Jahre internationale Erfahrung in Berufserfahrung zu den Themen Architektur, Interior Design, technischen Details und Projektmanagement sowie in Forschung und universitärer Lehre.

Computerkenntnisse

2D AutoCad 2023
3DMax 2023
Sketch up pro 2023
Revit
Adobe Premiere Pro CC 2022
Adobe Photoshop CC 2022
Adobe InDesign CC 2022
Microsoft office

Sprachkenntnisse

Arabisch: Muttersprache
Englisch: Fließend (IELTS: B2 Akademisch)
Deutsch: B2

Ausbildung

10.2019 - 2023

- **PhD Anwärterin**

Dr.-Studium der techn. Wissenschaften Architektur ,TU Wien.
Thema: “Interaktive Architektur als therapeutisches Umfeld für an Alzheimer erkrankten Personen in Langzeitbetreuungseinrichtungen“

09.2011 - 11.2014

- **MSc of Fine Arts**

Fakultät der Fine Arts,
Institut für Innenarchitektur, Universität Alexandria, Ägypten
Thema: “Smart Technologie und ihre Rolle in der Innenarchitektur in frühkindlichen Zentren”

09.2009 - 07.2010

- **Pre-Master of Fine Arts**

Architektur, Fakultät der Fine Arts, Universität Alexandria, Ägypten.
Erreichte Noten: 974, Prozentsatz: 81%, Noten: B

04.2009 - 05.2009

- **Virginia Commonwealth Universität, Schule der Künste**

Intensivkurs in Grundlagen des Designs.

09.2001 - 07.2006

- **BSc Interior Architecture**
- Institut für Innenarchitektur, Universität Alexandria, Ägypten

Abschluss: sehr gut mit Auszeichnung
Abschlussprojekt: “Nature Simulation for Children”: Ausgezeichnet.

Veröffentlichung

Interactive architecture as a therapeutic environment for people with Alzheimer's disease, a scoping review, 2021

A Study of Architectural Barriers and the Potential Role of Assistive Technologies in Long-term Healthcare Centres for People with Alzheimer's, 2022

Assessing Alzheimer's Therapeutic Environment Digitally through a People with Alzheimer's' Disease Perspective: A Computation-Based Approach Framework, 2023

Interactive Indoor Therapeutic Environment for People with Alzheimer's Disease, 2023 (Conference paper)

Using Sensors to Create Personalized Interactive Therapeutic Environments for Alzheimer's Care, 2023 (Conference paper)

The Shared Interests of EDRA and ANFA: Showcasing Research, Art, and Intersections to Encourage Member Collaboration, 2023 (Conference paper)

Forschungserfahrung

2019 - 2023

Dr.-Studium der techn. Wissenschaften Architektur ,TU Wien.
Durchführung von Primärquellenforschung in zahlreichen Archiven,
Untersuchung der Veröffentlichungsgeschichte mithilfe verschiedener Quellen.

2011 - 2014

Master Studentin
Fakultät der Fine Arts,
Institut für Innenarchitektur, Universität Alexandria, Ägypten
Faktenüberprüfung, Korrekturlesen und Bearbeiten von Forschungsarbeiten.
Recherche in print und online Medien zur Datensammlung.
Durchführung statistischer Datenauswertung.
Vorbereitung von Grafiken und Statistiken für die Präsentation.
Präsentationen und Poster für die Ausstellung herstellen.

Forschungskenntnisse

- Liebe zum Detail
- Fähigkeit Forschungsaufgaben effektiv zu planen und zu lösen
- Datensammlungskenntnisse
- Kreative Problemslösungskompetenz
- Technische Fähigkeiten: Ausgezeichnete Kenntnisse von Tabellenkalkulation- und Datenbankprogrammen
- Fähigkeit kritisch zu denken
- Projektfähigkeiten: Projektmanagement, Budgetverwaltung, Teamarbeit
- Kommunikationsfähigkeiten: Berichterstellung und Vortragstätigkeit

Akademische Erfahrung

09.2009- 07.2011

Lehrassistentin, Fakultät der Fine Arts, , Universität Alexandria, Ägypten

- Entwicklung und Anwendung geeigneter Unterrichtstechniken und Unterrichtsmaterialen, die Interesse, Verstehen und Begeisterung bei den StudentInnen erzeugen.
- Design und Entwicklung verschiedener Studienprogramme (manchmal für komplett neue Kurse) für unterschiedliche Stufen
- Design und Pflege virtuellen Lernstoffes und Umgebung.
- Akademische Anleitung für KollegInnen innerhalb des Programmbereichs; als Kursleiter oder vergleichbare Position; durch zum Beispiel Arbeitskoordination um die Kurse effektiv abzuhalten oder die Koordination der Teamrbeit durch Zielabklärung und Arbeitspläne in Referenz zum akademischen Handbuch.
- Beratender akademischer Support der Studierende.

Konferenzen und Workshops

Teilnehmerin an über 10 internationalen Konferenzen und Workshops, etnweder freiwillig im Marketing/Beratungsteam der Organsisation oder als Teilnehmerin:

- 11.2020 — AIDEM 2020 - First International Symposium on Artificial Intelligence for Dementia Prevention, Intervention and Care.
- 01.2021 — Academic Engineering Writing - Writing as an Engineer_ Workshop.
- 02.2021 — Technologies for Active and Independent Living in Old Age_ Conference.
- 03.2021 — DESIRE Workshop: Design for All In The Aging Society.
- 03.2021 — End-users Open Platforms: In the field of Active and Healthy Ageing-AHA and AAL_ Workshop.
- 09.2022 — NET4 COST Prevention and Business Models, Bucharest, Romania.
- 02.2023 — 13th Panhellenic Conference on Alzheimer’s Disease & 5th Mediterranean Conference on Neurodegenerative (one of the speakers).
- 06.2023 — EDRA 54, Mexico City (one of the speakers).
- 09.2023 — ANFA, USA (one of the speakers).

Projekte **SHAFE:** Smart Healthy Age Friendly Environments
https://www.net4age.eu/about-shafe

Berufliche Erfahrung

05.2022 – Aktuell

- **Phoenix Designs (Einzelunternehme), Wien**
- Pläne, Designs, Visualisierungen, Technische Details, Besprechung und Verhandlung mit den Kunden. (www.phoenixdesigns.at)

04.2021 – 04.2022

- **Projektmanagerin- Senior Interior Architect, Wien**
- Pläne, Designs, Visualisierungen, Technische Details, Besprechung und Verhandlung mit den Kunden (PR Architects)

2009 - 2019

- **Heidi El-Nimr Designs.**
  Projektmanagerin Ägypten
- Planung und Design 'Interior/Exterior', Detailausarbeitungs, Innen-Ausseneinrichtung, Budgetkalkulation, Arbeitsaufsicht, für verschiedenste Bereiche wie zum Beispiel:
- Öffentliche Projekte: Plätze, Stadtbilder, Tankstellen, Büos
- Gesundheitsbereich: Augenzentrum / Spitalsabteilungen
- Sportbereich: Internationales Bowling Center
- Kommerzieller Bereich: Restaurants, Beauty Centers und Kosemtikgeschäft.
- Privater Sektor: Villen und Apartments.
- Landschaftsgestaltung
- Eingangsbereiche großer Wohnkomplexe

2008 - 2009

- **Mediterranean for Marbles**
  Marbles & Interior Designer, Doha, Qatar.
- Design von Marmor Böden, Wänden, Decken
- Planung, Design, Einrichtung von Palästen
- Arbeitsaufsicht
- Kundenberatung zur Inneneinrichtung

2006 - 2007

- **El-Dar Engineering Consultant.**
  Interior Designer, Ägypten
- Planung, Design und Einrichtung von Wohnhäusern, Büros und Industriebauten.
- Entwicklung von praktischen, ästhetischen Design um die Produktivität zu erhöhen, den Verkauf anzuregen oder den life style zu verbessern
- Abstimmung mit dem Kunden zum Stil, Budget, Vorlieben und Zweck der Einrichtung
- Beratung der Kunden zum Design, zum Beispiel Raumplanung, Oberflächen, Verwendung der Einrichtung und Ausrüstung, Farbberatung
- Präsentation in Form von Skizzen und Zeichnungen

2004 - 2006

- **The Interior Design Consultation Group**
  Junior Interior Designer, Ägypten
- Design und Einbettung von Mosaiken
- Bodengestaltung
- Angebotserstellung bis zur Vertragsunterzeichnung mit den Kunden