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Wearable Devices in Dementia Monitoring: A Systematic Review of Technologies, Design, and Future Directions

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Abstract

INTRODUCTION: Dementia affects over 55 million people worldwide, impacting patient autonomy and increasing caregiver burden. Wearable technology offers new possibilities for monitoring and intervention. However, existing solutions often lack usability, adaptability, and caregiver integration. This study focuses on ear-based wearable devices, such as hearing aids and smart earphones, assessing their role in dementia care.
OBJECTIVES: This research aims to review wearable technologies for dementia monitoring, identify key user requirements, and define guidelines for future device development.
METHODS: A systematic literature review was conducted using Scopus, PubMed, IEEE Xplore, and ScienceDirect, focusing on studies from 2020-2025. Relevant articles were analysed to identify technological advancements, design considerations, and gaps in existing research.
RESULTS: Findings show that ear-based wearables effectively track physiological and behavioural data. Non-invasiveness, usability, and real-time data transmission are key factors. Despite advancements, gaps remain in device adaptability, user experience, and security. A set of physical, emotional, and cognitive requirements was established to guide future development.
CONCLUSION: Wearable technology can transform dementia care, but improvements in ergonomics, AI-driven analytics, and caregiver integration are needed. Future research should focus on secure data transmission and clinical validation to ensure real-world effectiveness.

Keywords: Dementia, Wearables, Requirements, Design, Medical Devices, Healthcare, Monitoring

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1. Introduction

Globally, over 55 million people live with dementia (1), and an even more significant number of caregivers are also affected by the disease. Wearable technology has the potential to provide support in monitoring this health condition. This research will continue a wearable device called "HowMI," designed to enhance end-user confidence by providing healthcare professionals with an innovative,

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more accurate care management tool, enabling faster responses in emergencies (2).
This study follows a systematic literature review to analyse scientific research on wearable technology in dementia care, identifying key findings, technological advancements, and gaps in existing studies. This review was conducted on four electronic databases: Scopus, PubMed, IEEE Explorer, and Science Direct, and it was limited to studies of wearable devices in dementia care. Each paper's relevance to answering the study topics was evaluated using the following inclusion (or eligibility) criteria: only papers published between 2020 and 2025, only papers written in English, and published in scientific journals or conference proceedings. Figure 1 represents a study conduct flowchart, following the steps defined in the eligibility criteria. It is observed that at first, the convergence of all the databases resulted in a total of 1388 articles, which, after all the filters, resulted in a database of fourteen articles considered relevant for the literary review.

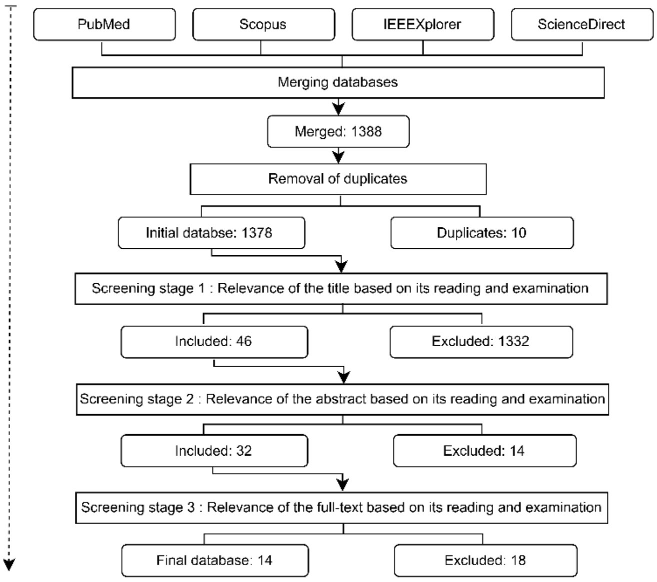

Figure 1. A framework for conducting the analysis.

In this paper, we aim to understand the state of the art and define requirements for further development. The primary objective of this paper is exploring the role of wearable technology in dementia care and the technologies currently used, and lastly this study aims to define the requirements for future research on wearable technology for dementia, with a particular focus on ear-based devices; these requirements will be established based on the significant findings from the state-of-the-art analysis.
This paper is organized into six sections. Section 2 (Theoretical Considerations) reviews existing literature on dementia care and assistive technologies, addressing current challenges and advancements in wearable devices. Section 3 (State-of-art) details the systematic literature review process with a table of a study analysis. Section 4 (Requirements Definition) outlines key design requirements for wearable dementia-monitoring devices, categorized into physical, emotional, and cognitive domains, while integrating Universal Design principles for accessibility. Section 5 (Discussion) critically evaluates these requirements, discussing implications for usability, caregiver integration, and real-world application. Section 6 (Conclusions and Future Work) summarizes the study's contributions and suggests directions for future research, focusing on usability enhancements, AI-driven analytics, and clinical validation to ensure the effectiveness of wearable solutions in dementia care.

2. Theoretical Considerations

Dementia is chronic and progressive and affects several brain functions, including memory, thinking, orientation, calculation, learning capacity, language, and judgment—often leading to significant caregiver burden (3,4). The most common cause of dementia is Alzheimer's disease, which accounts for 60–70% of cases. However, Alzheimer's is a form of dementia; other syndromes—such as dementia with Lewy bodies, vascular dementia, and frontotemporal dementia—exhibit overlapping symptoms, including depression, hallucinations, and memory loss (5). Despite extensive research into the diagnosis and treatment of neurodegenerative dementias, including Alzheimer's, these conditions remain incurable (4). Given the range of cognitive impacts associated with dementia, there is considerable focus on the potential for technology to support the independence and care of people living with dementia. Assistive technologies—including smart home devices, wearable sensors, and digital communication aids—enable individuals to complete tasks that might otherwise be challenging or unsafe, reducing risks such as wandering and medication errors while alleviating caregiver strain (6). Furthermore, emerging innovations integrating artificial intelligence and remote monitoring are increasingly being evaluated for their ability to provide personalized care and timely interventions, enhancing quality of life, and optimizing resource allocation in dementia care.

2.1. Ageing Populations

Recent studies have predicted an increased prevalence of cognitive problems, such as dementia, associated with increased life expectancy (7). People worldwide are living longer. Today, most people can expect to live into their sixties and beyond. Every country in the world is experiencing growth in both the size and the proportion of older persons. At the biological level, aging results from the impact of the accumulation of a wide variety of molecular and cellular damage over time. This leads to a gradual decrease in physical and mental capacity, a growing risk of disease, and death. These changes are neither linear nor consistent and are only loosely associated with a person's age in years. Common conditions in older age include hearing loss, cataracts, refractive errors, back and neck pain and osteoarthritis, chronic obstructive pulmonary disease, diabetes, depression,

and dementia. As people age, they are more likely to experience several conditions simultaneously (8).
Furthermore, the demographic shift toward an older population poses significant challenges for healthcare systems and social services worldwide. The increased burden of multimorbidity and age-related functional decline necessitates integrated, multidisciplinary approaches that focus not only on treatment but also on prevention, early detection, and maintenance of quality of life. Policymakers, clinicians, and researchers must collaborate to develop innovative public health strategies and care models that promote healthy aging and extend health span, ensuring that longer lives are accompanied by prolonged physical, mental, and social well-being(8).

2.2. Dementia and its Challenges

Dementia often presents significant challenges, including high rates of depression and stress, physical strain, and social isolation (9). To address these challenges, enhancing caregiver support and implementing effective dementia monitoring are crucial. Dementia monitoring offers numerous benefits, such as preventing accidents by tracking movements and reducing risks associated with wandering, as well as enabling long-term health tracking that provides valuable data for caregivers and healthcare professionals to make informed care and treatment decisions. Moreover, continuous monitoring can help detect subtle changes in cognitive and behavioural patterns, facilitating early intervention and potentially slowing disease progression. However, implementing these monitoring systems requires careful consideration of patient privacy, data security, and the usability of wearable technologies for an often-vulnerable population. Advancing dementia research further depends on cross-disciplinary collaboration—drawing on expertise from geriatric medicine, neurology, psychiatry, psychology, and related fields—to develop comprehensive models that accurately capture the complexity and heterogeneity of dementia. Unfortunately, the current dementia models are problematic (10), as they frequently fail to mirror the multifaceted nature of the human condition, limiting their predictive power and clinical utility. Therefore, there is an urgent need for more efficient, accurate, and ethically sound methods to study and manage dementia, leading to improved care outcomes and quality of life for patients and their caregivers.

2.3. Wearable Devices

Wearable technology, or wearables, typically refers to small electronic devices worn on or incorporated into the human body or clothing (11). This technology has been increasingly used in the last decade, particularly in healthcare. This equipment came to transition away from hospital-centric contexts towards more personalized home-based solutions without discharge doctor validation. The range of applications can be huge; this technology can be adapted to monitor, detect, and help in treatments for different human conditions (12). Most wearables used in healthcare have activity monitoring as their main functionality. These can encompass the measurement of an individual's data through sensors capable of measuring heart rate, daily behaviours, sleep patterns, stress level, movements, and location, among others (13). Moreover, recent advances in sensor accuracy, wireless data transmission, and the integration of machine learning algorithms for data analytics have further expanded their utility by enabling early detection of anomalies and continuous remote monitoring. As these systems become more interoperable with cloud-based platforms, they facilitate real-time health tracking and timely clinical interventions, supporting the shift toward preventive and personalized medicine. Ongoing collaboration between researchers, healthcare professionals, technology experts, and design developers can facilitate the creation of affordable wearable devices, helping to ease the financial strain of dementia care (14).

2.4. Influence on Monitoring Elderly People with Dementia

Activity Recognition is essential for enhancing the care of individuals with dementia (15). Advancements in monitoring technologies have significantly enhanced the care and management of elderly individuals with dementia. Recent studies have explored various methods to monitor physiological and behavioural parameters, aiming to improve patient outcomes and support caregivers.
One notable approach involves using Internet of Things (IoT) technology to record physiological measurements at home. A study published in Journal of Medical Internet Research Aging demonstrated that IoT-enabled devices could effectively monitor heart rate, blood pressure, oxygen saturation, and body weight in individuals with dementia. The findings suggest that such remote monitoring can aid in managing acute and chronic comorbidities in this vulnerable population (16). Furthermore, passive digital monitoring has emerged as a promising method for capturing daily behaviours and detecting changes that may be inaccessible through traditional methodologies. Research published in the Journal of the American Heart Association discussed how passive monitoring could offer solutions for observing daily behaviour patterns, thereby facilitating early detection of cognitive decline (17). These technological innovations enhance the monitoring and care of elderly individuals with dementia and provide valuable support to caregivers. By enabling continuous and non-invasive monitoring, these tools contribute to improved safety, early detection of health issues, and a better understanding of patients' needs.

3. State-of-Art

A systematic literature review was conducted through four databases, resulting in 1388 articles; after the screening, only fourteen papers were considered relevant for this study. The papers were published between 2020 and 2024 and written in

English. Table 1 includes the article title, year of publication, and a summary; Table 2 compares the wearable device type, device placement, task, validation method when applicable, and results.

Table 1. Included articles.

Article Nº	Included articles			
	Source	Year	Article title	Summary
1	(18)	2023	Design and Evaluation of Wearable Multimodal RF Sensing System for Vascular Dementia Detection	The article presents a wearable multimodal RF sensing system designed for early detection of vascular dementia by monitoring physiological signals. It includes system design, signal processing, and evaluation to enhance non-invasive diagnosis.
2	(19)	2022	Indoor-Outdoor Tracking and Activity Monitoring System for Dementia Patients.	The article proposes an indoor-outdoor tracking and activity monitoring system for dementia patients, using sensor-based technologies to ensure safety and autonomy. It focuses on real-time location tracking and activity recognition to support caregivers.
3	(20)	2020	Wearable sensors and a multisensory music and reminiscence therapies application: To help reduce behavioural and psychological symptoms in person with dementia.	The article explores wearable sensors combined with multisensory music and reminiscence therapies to alleviate behavioural and psychological symptoms in dementia patients. It highlights technology-assisted interventions to enhance well-being and care.
4	(21)	2024	User Requirements and Perceptions of a Sensor System for Early Stress Detection in People with Dementia and People with Intellectual Disability: Qualitative Study.	The article investigates user requirements and perceptions of a sensor-based system for early stress detection in individuals with dementia and intellectual disabilities. It emphasizes qualitative insights to ensure usability, acceptance, and effectiveness in care settings.
5	(22)	2021	Sleep Detection for Younger Adults, Healthy Older Adults, and Older Adults Living with Dementia Using Wrist Temperature and Actigraphy: Prototype Testing and Case Study Analysis.	The article examines sleep detection in younger adults, healthy older adults, and dementia patients using wrist temperature and actigraphy. It presents prototype testing and case studies to assess the system's accuracy and feasibility.
6	(23)	2024	Smartwatch-Based Interventions for People with Dementia: User Cantered Design Approach.	The article explores smartwatch-based interventions for dementia patients using a user-centred design approach. It focuses on usability, personalization, and effectiveness to support daily activities and well-being.
7	(24)	2023	Wearable bead-based triboelectric nanogenerator with dual-mode operation for monitoring abnormal behaviour in dementia patients.	The article presents a wearable bead-based triboelectric nanogenerator with dual-mode operation for monitoring abnormal behaviour in dementia patients. It highlights its potential for real-time, non-invasive detection to support patient care.
8	(25)	2022	Medical Assistance for Alzheimer's Disease Using Smart Specs.	The study presents a wearable technology solution designed to aid individuals with Alzheimer's disease. It explores the development of smart glasses equipped with assistive features such as facial recognition, voice guidance, and memory recall support to help patients recognize familiar faces and navigate daily tasks.
9	(26)	2022	Evaluating the Empatica E4 Derived Heart Rate and Heart Rate Variability Measures in Older Men and Women.	The study evaluates the accuracy of heart rate (HR) and heart rate variability (HRV) measurements derived from the Empatica E4 wristband in older adults. By comparing data from the wearable device with standard electrocardiogram (ECG) measurements, the research assesses the reliability of the E4 for monitoring cardiovascular and autonomic function in aging populations.
10	(27)	2023	Factors Influencing Continued Wearable Device Use in Older Adult Populations: Quantitative Study.	The study explores factors influencing the continued use of wearable devices among older adults, focusing on usability, comfort, perceived benefits, and technical support. The findings provide insights into improving design and

				engagement strategies to enhance long-term adoption in this population.
11	(28)	2024	Assessment of Wearable Device Adherence for Monitoring Physical Activity in Older Adults: Pilot Cohort Study.	The study evaluates adherence to Fitbit devices for monitoring physical activity in older adults. It identifies factors affecting sustained use, such as comfort, ease of use, and perceived health benefits. Findings offer insights into improving engagement and compliance in this population.
12	(29)	2021	D-SORM: A digital solution for remote monitoring based on the attitude of wearable devices.	The study presents D-SORM, a digital solution for remote health monitoring using wrist-worn wearable devices. It analyses device positioning and user behaviour to enhance data accuracy and reliability, highlighting its potential for improving remote patient monitoring and healthcare outcomes.
13	(30)	2023	Wearable Activity Trackers That Motivate Women to Increase Physical Activity: Mixed Methods Study.	The study explores how wearables activity trackers motivate women to increase physical activity. Using a mixed-methods approach, it identifies key factors such as goal setting, feedback, and social support that drive engagement. The findings suggest that these trackers can effectively encourage women to adopt and maintain active lifestyles.
14	(31)	2025	Acoustic Stimulation to Improve Slow-Wave Sleep in Alzheimer's Disease: A Multiple Night At-Home Intervention.	The study investigates the effects of acoustic stimulation on improving slow-wave sleep in individuals with Alzheimer's disease. Through a multiple-night, at-home intervention, the research finds that sound-based therapies can enhance sleep quality, potentially benefiting cognitive function and overall well-being in Alzheimer's patients.

The literature review identified 14 relevant studies on wearable devices for dementia monitoring. These studies explore a variety of technologies, including sensor-based systems for early stress detection, indoor-outdoor tracking, sleep monitoring, and smartwatch-based interventions tailored to individuals with dementia. The findings indicate that wearable technology can improve patient safety, facilitate early intervention, and reduce caregiver burden by providing real-time data on physiological and behavioural patterns. However, significant challenges remain, particularly in terms of device usability, user acceptance, and integration into daily life. Many existing solutions lack adaptability to different stages of dementia, require improvements in user experience, and need better caregiver integration to ensure effective and ethical implementation.

Table 2. Technical specifications of commercial wearable devices.

Product	Technical specifications of commercial wearable devices.			
	Article	Measurement Method	Device placement	Company
E4 Empatica wristband	(20,26)	Electrodermal Activity (EDA) Heart Rate (HR) Skin Temperature Movement and Accelerometery	Wrist	Empatica
Xiaomi Mi Band 2	(22)	3D Accelerometer 3-axis accelerometer Activity Tracking Sleep Monitoring optical heart rate sensor	Wrist	Xiaomi
Huawei Watch 2 (4G)	(23)	6-axis motion sensor Accelerometer optical heart rate sensor Sleep Monitoring GPS and Location Tracking stress tracking using the heart rate variability (HRV)	Wrist	Huawei
Xiaomi Mi Band 3	(27)	Steps, distance, and calories burned Heart Rate Monitoring Step Counting & Activity Tracking Sleep Tracking Calorie Burn Estimation	Wrist	Xiaomi

Verisense watch	(28)	3-Axis Accelerometer (Motion & Activity) PPG Sensor (Heart Rate & Oxygen Levels) EDA Sensor (Electrodermal Activity)	Wrist	Shimmer Research
Wrist-worn device RF-Track	(29)	Skin Temperature Sensor Accelerometers Gyroscopes Temperature Sensors Electrodermal Activity (EDA) Sensors	Wrist	RF Track Sociaty
Apple Watch	(30)	Heart Rate Monitoring ECG (Electrocardiogram) Blood Oxygen Monitoring Activity Tracking Sleep Tracking Fall Detection Oxygen Saturation (SpO2) GPS	Wrist	Apple
Oura Ring	(30)	Heart Rate and Heart Rate Variability (HRV) Sleep Tracking Activity Tracking Temperature Monitoring Readiness Score Oxygen Saturation (SpO2)	Finger	Oura Health
Bellabeat Leaf Urban	(30)	Activity Tracking Sleep Monitoring Stress Management Menstrual and Health Tracking Wellness and Insights	Can be worn as a bracelet, necklace, or clip	Bellabeat
DREEM2 headband	(31)	EEG (Electroencephalogram) Accelerometers Neurostimulation Personalized Insights Real-time Monitoring	Head	Dreem

The wearable devices analysed in this study employ diverse measurement methods to monitor physiological and activity-related parameters, highlighting advancements in wearable technology for health. Electrodermal activity (EDA) sensors, such as those in the Empatica E4 and Verisense Watch, assess autonomic nervous system responses.
At the same time, photoplethysmography (PPG)-based heart rate monitoring is widely used across devices, including the Xiaomi Mi Band series and Apple Watch. More advanced cardiac monitoring, such as electrocardiography (ECG), is featured in the Apple Watch, providing enhanced cardiovascular assessments. Motion tracking, through 3-axis and 6-axis accelerometers, supports activity recognition, step counting, and sleep monitoring, with devices like the Huawei Watch 2 incorporating heart rate variability (HRV) for stress detection. Additionally, temperature sensors and SpO2 monitoring, found in the RF-Track and Apple Watch, contribute to broader health insights, including oxygen saturation levels and thermoregulation. These multimodal sensing capabilities underscore the growing role of wearable technology in real-time health monitoring, stress management, and preventive healthcare, emphasizing the potential for continuous, AI-enhanced health assessments in future applications.

4. Requirements Definition

The primary goal of defining requirements is to ensure the product facilitates seamless and intuitive user interaction. Dementia patients face cognitive, physical, and emotional challenges that impact their daily lives. To ensure effective interaction with the product, requirements were categorized into seven key dimensions: physical, emotional, cognitive, functional, usability, aesthetics, and security—with some requirements overlapping multiple categories. Wearable technology involves interaction between the user and the device, and in cases involving dementia, also with caregivers. Therefore, these requirements must comprehensively address the needs of all stakeholders involved. Before defining the requirements, it is important to understand the user's needs and respect the principles of Universal Design.

4.1. User Needs

Users with dementia and their caregivers have distinct needs in their daily routines. Because of deteriorating social and cognitive abilities, the person with dementia experiences numerous failures in everyday life (32). The device we aim to develop must be non-invasive and seamlessly integrated into the patient's daily life; this wearable will monitor temperature and oximetry through the ear, ensuring continuous health tracking. Additionally, it must adhere to ergonomic, security, and usability principles, prioritizing simplicity, and ease of use to accommodate patients and caregivers effectively; minimizing the resistance to use is another goal, and the device must be strong enough to avoid potential accidental impacts.

4.2. Universal Design

At the Center for Universal Design (CUD) at North Carolina State University, a group of architects, product designers, engineers, and environmental design researchers established seven principles of UD to guide the design of products and environments. These principles help ensure that designs are inclusive and accessible to all. The Universal Design (UD) process involves both a macro and micro approach to creating products or environments that are accessible to all, considering the diversity of user characteristics. The main steps are: identify the application and target audience, define the diverse characteristics of the population, involve consumers with different characteristics in all phases, adopt and apply UD guidelines or standards, plan accommodations for specific needs, train and support stakeholders, and evaluate the design periodically, adjusting based on user feedback (33) . Below, we present the seven principles of Universal Design, along with a brief definition adapted from (34).

Principle 1
Equitable Use - The design is useful and marketable to people with diverse abilities.
Principle 2
Flexibility in Use- The design accommodates a wide range of individual preferences and abilities.
Principle 3
Simple and Intuitive Use - Use of the design is easy to understand, regardless of the user's experience, knowledge, language skills, or current concentration level.
Principle 4
Perceptible Information – The design communicates necessary information effectively to the user, regardless of ambient conditions or the user's sensory abilities.
Principle 5
Tolerance for Error - The design minimizes hazards and the adverse consequences of accidental or unintended actions.
Principle 6
Low Physical Effort - The design can be used efficiently and comfortably and with a minimum of fatigue.
Principle 7
Size and Space for Approach and Use - Appropriate size and space is provided for approach, reach, manipulation, and use regardless of user's body size, posture, or mobility.

UD can be applied to any product or environment, such as curriculum, instruction, career services offices, multimedia, tutoring and learning centres, conference exhibits, museums, microwave ovens, computer labs, worksites, and web pages (33).

4.3. Requirements Domains

In this section are presented the key design requirements for wearable dementia-monitoring devices, namely physical, emotional, and cognitive.

4.3.1 Physical Requirements

Physical domain requirements specify the tangible, real-world constraints and conditions under which a system or component must operate. These requirements are critical in ensuring that the designed product not only functions correctly but also withstand the environmental, mechanical, and operational challenges of its intended setting. Table 3 presents the physical requirements and their description.

Table 3. Physical domain requirements and their description.

Requirement	Physical Domain Description
Non-invasive	The device must not cause discomfort, skin irritation, or require medical procedures for installation.
Ergonomic design	It should fit naturally around the ear, ensuring comfort and security for prolonged use.
Lightweight	The device should be lightweight to minimize the sensation of heaviness and avoid discomfort.
Durability	It must withstand daily use, accidental drops, and minor impacts.
Material safety	The device should be made of hypoallergenic, non-toxic materials.
Water and dust resistance	The device should have an adequate protection rating (IP54 or higher) to ensure resistance to dust and sweat.
Rechargeable battery	It should have a long-lasting and easy-to-recharge battery to minimize frequent maintenance.
Universal fit	The design should allow adaptability to different ear sizes and user profiles.

4.3.2. Emotional Requirements

Emotional Domain Requirements refer to the specifications that define the desired emotional experience a product, service, or environment should evoke in its users. Unlike functional or physical domain requirements—which focus on performance, durability, and safety—emotional domain requirements are centred on how a user feels during and after interaction. They are essential for fostering positive user engagement, satisfaction, and long-term loyalty. Table 4 presents the emotional requirements and their description.

Table 4. Emotional domain requirements and their description.

Requirement	Emotional Domain
	Description
Discreet design	The device should be small and neutral in appearance to prevent embarrassment or resistance to use.
Comfortable materials	Soft, adaptive materials should be used to prevent irritation or a sense of discomfort.
Minimal user interaction	The device should require minimal actions from the user to operate effectively.
Stress-free usability	It should not emit excessive noise or intrusive alerts that could cause confusion or anxiety.
Seamless integration with routine	The device should function smoothly without disrupting the patient's daily activities.

4.3.3. Cognitive Requirements

Cognitive Domain Requirements define the specifications that ensure a product, service, or environment supports and enhances users' mental processes. These requirements focus on how users perceive, process, remember, and apply information—ensuring that interactions are efficient, comprehensible, and supportive of complex thinking. Table 5 presents the cognitive requirements and their description.

Table 5. Cognitive domain requirements and their description.

Requirement	Cognitive Domain
	Description
Easy placement and removal	The patient or caregiver should be able to put on and remove the device effortlessly.
Automatic health monitoring	The device should track temperature, oxygen levels, and other parameters without manual activation.
Real-time alerts and notifications	Alerts should be issued only, when necessary, in a clear and intuitive manner.
Minimized risk of user errors	The device should avoid complex settings or functions that could be accidentally activated.
Caregiver connectivity	It should be compatible with caregivers' mobile devices, allowing remote monitoring.
Adaptive feedback system	The device should provide clear and understandable warnings when detecting changes in the user's health patterns.

4.3.4. HowMi Requirements

HowMi stands out in the wearable health technology market with its innovative ear-based design , which is subject to less movement compared to wrist devices such as watches or bracelets, which are susceptible to movement during daily activities, contributing to a more accurate acquisition of vital signs, while at the same time becoming a discreet device, avoiding possible psychological discomfort associated with its psychological condition,, making it particularly effective for monitoring individuals with dementia. The ear-worn device provides a stable and discreet way to continuously track vital signs such as oxygen saturation, heart rate and temperature, which helps reduce resistance from patients—a common issue with more intrusive devices. This design enables individuals with cognitive impairments to benefit from seamless health monitoring integrated easily into their daily routines. Additionally, HowMi facilitates early interventions that enhance patient safety and reduce the burden on caregivers.

Beyond considerations of usability and security, HowMi incorporates oximetry and temperature sensors to deliver continuous, real-time monitoring with minimal user interaction. The HowMi project (2) establishes specific requirements for developing an in-ear wearable device for dementia monitoring., table 6 represents requirements.

Table 6. HowMi requirements.

HowMi product requirements pre-stablished
Wearable device
Temperature Measurement
Oximetry measurement
Durability and impact resistance
Discreet and compact
Universal design (adaptability to different users)
Intuitive interface (minimizing errors)
In-ear device

The key specifications include the ability to measure body temperature and blood oxygen levels, ensuring real-time health tracking. The device must be impact-resistant, compact, and discreet to promote user comfort and continuous use. Additionally, it should follow Universal Design principles to accommodate diverse users, including those with different levels of cognitive decline. A user-friendly and intuitive interface is essential to minimize operational errors, making the device accessible to both patients and caregivers. The intra-auricular design is a strategic choice to enhance wearability and ensure non-invasive, unobtrusive monitoring.

5. Discussion

In this section, comparisons between wrist-worn devices and ear-based devices (HowMI) are presented. The requirements were also analysed in depth.

5.1. Wrist-Worn Devices vs. Ear-Based Devices (HowMi)

A comparative analysis of key specifications for wrist-worn devices used in monitoring dementia was conducted, incorporating insights from the literature review and HowMi's established features. Table 7 represents the comparison conducted.

Table 7. Wrist-Worn Devices vs. Ear-Based Device – HowMi

Specifications	Wrist-Worn Devices vs. Ear-Based Device - HowMi	
	Wrist-Worn Devices	Ear-Based Device - HowMi
Sensor Accuracy	Wrist placement can be susceptible to motion artifacts, which may reduce accuracy in certain conditions.	The ear canal provides a more stable measurement site, reducing motion interference.
Wearability	Generally lightweight and familiar to users, these devices are widely accepted.	Ear-based devices are often more discreet, and comfort varies with design. It is crucial to establish clear design requirements.
Usability and Patient Adherence	Their familiarity, ease of use, and established market presence enhance adherence. Many users already wear wristwatches or fitness bands, which facilitates integration into daily routines.	These devices need more adjustment, especially for older adults who may not be used to wearing in-ear devices. However, they can be advantageous for individuals who already utilize hearing aids.

Interoperability with Other Systems	These are often compatible with smartphones, fitness platforms, and healthcare applications.	Advancements are enhancing their integration with platforms and real-time monitoring systems; it is also possible to connect with smartphones.

Both wrist-worn and ear-based wearable devices offer unique advantages for dementia monitoring. Wrist-worn devices benefit from familiarity, ease of use, and longer battery life, making them a preferred choice for continuous tracking. In contrast, ear-based wearables provide potentially higher sensor accuracy and reduced motion artifacts but may face challenges related to comfort and power efficiency. A hybrid approach or personalized selection based on patient needs may optimize monitoring outcomes for individuals with dementia.

5.2. Requirements Analysis

Figure 2 shows the requirements defined categorized in three domains: physical, emotional and cognitive, and those dedicated to the HowMi project pre-stablished requirements. This structured approach not only clarifies the multifaceted nature of the project's goals but also enables targeted design interventions that address each aspect of the user experience effectively.

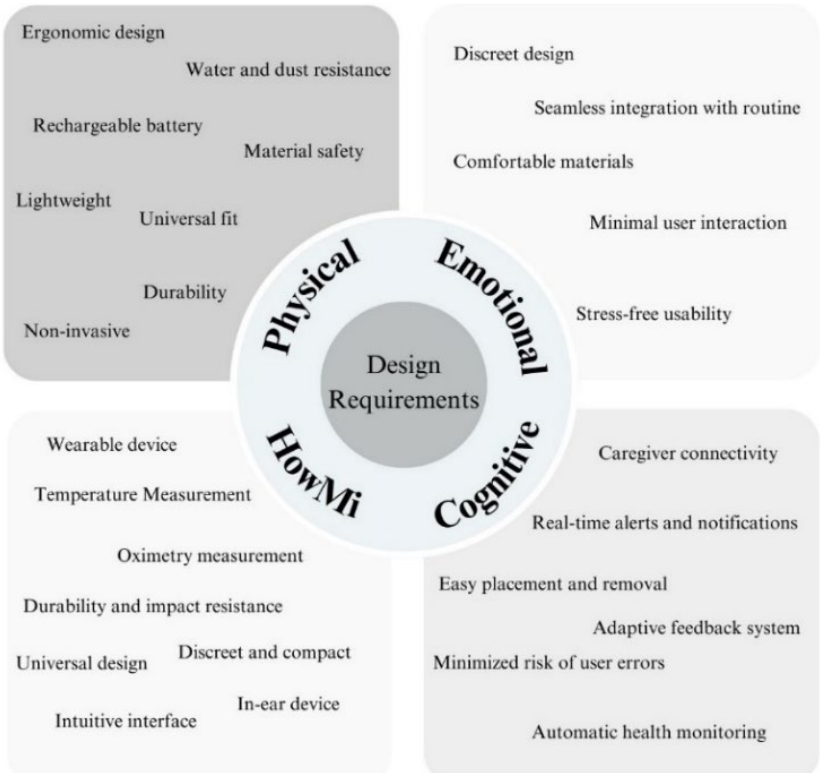

Figure 2. Design requirements diagram.

For a deeper understanding, the requirements have been further subdivided and classified into categories—namely, functional, usability, aesthetic, and security—and additionally organized by domain. It is important to note that some requirements may belong to more than one category. Table 8 presents a detailed classification, illustrating the interrelationships between domain requirements. Table 9 provides an overview of the classification for HowMi requirements.

Table 8. Requirements classification.

Requirement	Classification				
	Functional	Usability	Aesthetic	Security	Domain
Non-invasive		x			Physical
Ergonomic design		x	x		Physical
Lightweight		x			Physical
Durability	x	x		x	Physical
Material safety				x	Physical
Water and dust resistance	x			x	Physical
Rechargeable battery	x				Physical
Universal fit	x	x			Physical
Discreet design		x	x		Emotional
Comfortable materials		x			Emotional
Minimal user interaction	x	x			Emotional
Stress-free usability		x			Emotional
Seamless integration with routine	x	x			Emotional
Easy placement and removal	x	x			Cognitive
Automatic health monitoring	x				Cognitive
Real-time alerts and notifications	x				Cognitive
Minimized risk of user errors	x	x			Cognitive
Caregiver connectivity	x				Cognitive
Adaptive feedback system	x				Cognitive

Table 9. HowMi Requirements classification.

Requirement	HowMi Classification			
	Functional	Usability	Aesthetic	Security
Wearable device	x			
Temperature Measurement	x			
Oximetry measurement	x			
Durability and impact resistance	x	x		x
Discreet and compact	x	x	x	
Universal design (adaptability to different users)	x	x		
Intuitive interface (minimizing errors)	x	x		
In-ear device	x			

The physical requirements focus on ensuring durability, lightweight design, comfort, and resistance to environmental factors such as water and dust. The emotional requirements prioritize discreet design, seamless integration into daily routines, and minimal user interaction to reduce stress and resistance to use. The cognitive requirements emphasize ease of use, automatic health monitoring, and connectivity with caregivers for remote supervision and alerts. Furthermore, the HowMi-specific requirements reinforce the need for an intuitive interface, universal adaptability, and real-time health data collection to support early intervention strategies. This structured classification ensures that the device meets both technical and human-centred needs, promoting long-term user adherence and effectiveness in dementia care.

6. Conclusions and Future work

Wearable technology presents a promising opportunity to enhance dementia care by providing continuous health monitoring, real-time alerts, and improved patient autonomy. Ear-based devices, such as hearing aids and smart earphones, have shown potential for tracking physiological and behavioural data, supporting early intervention, and reducing caregiver burden. However, existing solutions often lack adaptability, intuitive design, and seamless integration with caregiver support systems.

This study highlights the need for non-invasive, ergonomic, and user-friendly wearable devices tailored to dementia patients. The physical, emotional, and cognitive requirements outlined serve as a foundation for future development, ensuring usability, comfort, and data reliability.

Enhancing usability and accessibility is crucial, with a particular emphasis on improving user interfaces to accommodate cognitive impairments and ensuring seamless connectivity with caregiver platforms.

AI integration is a key focus for future work, in which we plan to develop the device's communication with a cloud that incorporates AI and machine learning, enabling the transmission and analysis of the data acquired by the device's sensors.

Lastly, this study presents a systematic literature review aimed at identifying gaps in existing research and guiding future advancements. Recognizing the need for empirical validation, we will take the next steps to develop a prototype that evaluates usability, sensor accuracy, and overall effectiveness. Additionally, we will explore innovative design solutions, such as using alternative materials to enhance comfort and durability, as well as implementing wireless charging to improve long-term usability. Addressing these challenges can significantly enhance patient adherence and overall experience. By overcoming these barriers, wearable devices have the potential to transform dementia monitoring, improving patient care, autonomy, and quality of life, while also providing essential support to caregivers and healthcare professionals.

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