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SALUTOGENIC ARCHITECTURE, AGING, AND HEALTHCARE FACILITIES: interfaces between accessibility, ergonomics, and neuroscience

ARQUITETURA SALUTOGÊNICA, ENVELHECIMENTO E AMBIENTES DE SAÚDE: interfaces entre Acessibilidade, Ergonomia e Neurociência

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ABSTRACT: The demographic shift towards an aging population in Brazil necessitates the adaptation of healthcare environments to address the biopsychosocial needs of older adults. According to the Instituto Brasileiro de Geografia e Estatística, by 2029, the population aged 60 and over will surpass the population aged 0 to 14, thereby intensifying the need to adapt these spaces. This study proposes practical applications of salutogenic architecture in healthcare environments by integrating gerontology, neuroscience, and architecture. An integrative literature review was conducted, selecting peer-reviewed scientific articles in English and Portuguese published between 2019 and 2025. Using the Capes Journals repository, nine databases were consulted, including PubMed, ScienceDirect, Springer Nature, and Taylor & Francis, among others considered relevant to the topics addressed in this article. Of the 1,492 studies initially identified, 12 met the eligibility criteria. the 1,492 studies initially identified, 12 met the eligibility criteria. The findings were systematized into three categories: (i) physical and ergonomic quality, involving usability, functionality, safety, and protection; (ii) sensory and cognitive quality, related to spatial orientation and comprehension as well as environmental factors such as lighting, acoustics, thermal comfort, and air quality; and (iii) social quality, emphasizing well-being and inclusion. The findings suggest that healthcare environments have the potential to play an active role in maintaining and restoring health. However, this potential can only be realized if these environments are guided by scientific evidence, symbolic relevance, and designed in accordance with the specificities of the regional context.

KEYWORDS: Ergonomics; Architectural accessibility; Healthy aging; Gerontology; Neurosciences.

RESUMO: O envelhecimento populacional no Brasil exige a readequação dos ambientes assistenciais às demandas biopsicossociais da pessoa idosa. Segundo o Instituto Brasileiro de Geografia e Estatística, até 2029, a população com 60 anos ou mais superará a de 0 a 14 anos, intensificando a necessidade de adaptação desses espaços. Objetiva-se propor aplicações práticas da arquitetura salutogênica em ambientes de saúde a partir da articulação entre gerontologia, neurociência e arquitetura. A metodologia adotada foi uma revisão integrativa da literatura, com seleção de artigos científicos em inglês, revisados por pares, publicados entre 2019 e 2025. Dos 1.492 estudos inicialmente identificados, 12 atenderam aos critérios de elegibilidade. Os achados foram sistematizados em três eixos: (i) qualidade física e ergonômica, envolvendo aspectos de usabilidade, funcionalidade, segurança e proteção; (ii) qualidade sensorial e cognitiva, relacionada à orientação espacial, compreensão e fatores ambientais como iluminação, acústica, conforto térmico e qualidade do ar; e (iii) qualidade social, com ênfase em bem-estar e inclusão. Os resultados indicam que os ambientes de saúde podem atuar de forma ativa na manutenção e recuperação da saúde, desde que orientados por evidências científicas e concebidos em consonância com as especificidades do contexto regional, aprimorando tanto sua funcionalidade quanto sua relevância simbólica.

PALAVRAS-CHAVE: Ergonomia; Acessibilidade arquitetônica; Envelhecimento saudável; Gerontologia; Neurociências.

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1. INTRODUCTION

According to the "Decade of Healthy Aging 2021–2023" proposed by the Pan American Health Organization (PAHO) in December 2020, global indicators of the growth of the elderly population, increased life expectancy, and low fertility rates have necessitated the reconfiguration of healthcare settings based on principles that address the biological, psychological, and social needs of human aging (PAHO, 2020). Among the countries of the Global South, Brazil is distinguished by its accelerated population aging process (Bull; Banik, 2025). According to data from the Instituto Brasileiro de Geografia e Estatística (IBGE), 15.8% of the Brazilian population is already elderly, and projections from the United Nations (UN) suggest that by 2029, the number of individuals aged 60 or older will exceed the number of children and adolescents aged 0 to 14 in Brazil (IBGE, 2023; UN, 2024).

From the perspective of architectural design for healthcare environments, the integration of neuroscience[1] and gerontology[2] provides theoretical and empirical insights for planning environments that are more inclusive of the needs of older adults. This integration takes into account the measurable effects of the physical space on these users' cognition, behavior, and affective and perceptual states (Albuquerque; Kopper, 2024; Kok et al., 2025). In this context, the utilization of Evidence-Based Design (EBD) facilitates the systematic incorporation of scientific data into design decision-making processes, ensuring greater alignment between the characteristics of the environment and the functional profiles of the occupants (Assem; Khodeir; Fathy, 2023).

Furthermore, ergonomics, defined as a field of knowledge focused on the study of human abilities, limitations, and other characteristics relevant to the development of products, systems, activities, and environments that are safe, comfortable, intuitive, efficient, and functionally suited to users' needs, is indispensable for planning

[1] A field of study dedicated to the nervous system, encompassing its structure, function, development, biochemistry, physiology, pharmacology, and pathology. Its goal is to understand how the brain and other neural structures influence behavior, emotions, cognitive functions, and sensory and motor processes (Lent, 2010).

[2] An interdisciplinary field that studies the aging process in its many dimensions—biological, psychological, social, cultural, and environmental—with the aim of understanding the changes that occur throughout life and promoting quality of life in old age (Freitas; Py, 2022).

healthcare environments that are accessible and dignified for older adults (Rosciano, 1999). Therefore, in addition to aspects related to accessibility, ergonomics, gerontology, and neuroscience, the objective is to present a set of design strategies for healthcare environments that are responsive to human aging. These strategies are guided by the "Theory of the Salutogenic Environment," proposed by Aaron Antonovsky (1979). The integration of this knowledge will be necessary for the development and implementation of "Salutogenic Architecture" strategies in healthcare settings.

These factors highlight the importance of integrating salutogenic architecture principles with neuroscience and gerontology insights to improve accessibility and ergonomics. This integration informs the design of environments that promote well-being and ensure dignified conditions of use, responding more adequately to the demands of the growing elderly population, particularly in developing countries.

1.1 HEALTHCARE ARCHITECTURE, ERGONOMICS, ACCESSIBILITY, AND INCLUSION

Healthcare environments are classified in Brazil as “Estabelecimentos Assistenciais de Saúde (EAS)” — translated into English as “Healthcare Facilities” — in accordance with Administrative Council Resolution (RDC) No. 51, dated October 6, 2011. These facilities are defined as "any building intended for the provision of healthcare to the population, requiring patient access, whether inpatient or outpatient, regardless of the level of complexity" (Art. 4, VII). These environments must be designed to promote, restore, and maintain the physical, mental, and social well-being of users. To that end, they should integrate functional, technological, sensory, and accessibility principles. These initiatives must extend beyond the scope of rudimentary technical capabilities, encompassing a more comprehensive conception of health that aligns with the Sustainable Development Goals (SDGs) outlined by the United Nations. "Goal 3: Ensure healthy lives and promote well-being for all at all ages" and "Goal 11. The objective is to foster inclusive, secure, resilient, and sustainable urban and human settlement environments" (Silva, 2020).

However, although Brazil has made legislative progress, including: (i) Law No. 10,741, of October 1, 2003: Statute of the Elderly, which sets forth the rights and duties of persons aged 60 or older and establishes the priority of their protection by society; (ii) Law No. 12,587, of January 3, 2012: National Urban Mobility Policy, which aims to integrate different modes of transportation and improve accessibility and mobility for people and goods within the municipality; (iii) Law No. 13,146, of July 6, 2015: Brazilian Law on the Inclusion of Persons with Disabilities (Statute of Persons with Disabilities), intended to ensure and promote, under conditions of equality, the exercise of fundamental rights and freedoms by persons with disabilities, with a view to their social inclusion and citizenship; (iv) Law No. 14,878, of June 4, 2024: National Policy on Comprehensive Care for People with Alzheimer’s Disease and Other Dementias, which aims to address Alzheimer’s disease and other dementias through participatory implementation and monitoring. In addition to technical standards, such as NBR 9050/2020 and NBR 16537/2024, regarding accessibility and inclusion, the full implementation of legal measures is still progressing slowly. Architectural, communicational, methodological, instrumental, programmatic, and attitudinal challenges remain to be addressed in a systemic manner (Santos et al., 2020).

A study by Santos et al. (2020) examined the architectural and communication accessibility of 38,812 Basic Health Units (UBS). This analysis was based on data from the National Census of UBS, which was conducted by the Secretariat of Health Care in 2012. With respect to external access, it was determined that 31.8% of the UBSs have entrance sidewalks in good condition for wheelchair users and people with special needs, with 49.3% having standard flooring, 28.4% with non-slip flooring, and 36.0% with smooth flooring. With respect to the presence of rugs, the rate is 16.4%, and 43.5% of the units have access ramps. However, a recent study by Santos et al. (2020) revealed that only 7.6% of the UBSs were equipped with handrails, and 34.7% had entrance doors and hallways adapted for wheelchairs.

With regard to internal accessibility, 11.8% of the UBS have restrooms fully adapted for people with disabilities and the elderly, while 14.2% have grab bars, 5.7% have handrails, and 23.6% have corridors and interior doors adapted for wheelchair users. With regard to adapted interior doors, the percentage is 23.4%, and 29.3% of them offer adequate space for wheelchairs in waiting rooms. A mere 8.9% of these establishments have drinking fountains that are accessible to all, and 34.2% provide wheelchairs for users to move around. A comprehensive analysis of the data revealed that all five regions of the country exhibited rates that fell below the 50% threshold, indicating a general dissatisfaction with the services provided (Santos et al., 2020).

As Silva and Ribeiro (2020) demonstrate, noncompliance with accessibility and inclusion laws and regulations is an ongoing issue. Architectural barriers, including stairs, steep public roads, and narrow corridors, persist as significant obstacles to full accessibility in health services (Silva; Ribeiro, 2020). These physical barriers were identified in 80% of studies focused on people with physical disabilities, in 66.67% of those related to visual impairment, and in 16.67% of those addressing hearing impairment (Silva; Ribeiro, 2020).

While the challenges faced by people with disabilities are increasingly being addressed, groups that are vulnerable to the built environment — such as older adults, children, pregnant women, and people with limited mobility — may also experience negative emotional effects when accessing these spaces, even for brief periods. This underscores the necessity for the interdisciplinary dissemination of the principles of inclusion and accessibility among architects and healthcare professionals.

1.2 SALUTOGENIC ARCHITECTURE: APPLICATIONS OF AARON ANTONOVSKY’S THEORY

In 1979, the sociologist and physician Aaron Antonovsky introduced the

"Salutogenic Environment Theory," which seeks to understand the factors responsible for maintaining health by considering environmental factors, rather than focusing solely on disease prevention or risk factors, according to Figure 1. Contrary to dichotomous approaches that pit health against illness, the theory is based on a continuum between these two poles (Antonovsky, 1979). The salutogenic perspective emphasizes the strengthening of individual resources and capacities that promote health (Farrow, 2024). Despite its extensive implementation in health promotion initiatives, this approach extends beyond the initial application outlined in the salutogenic model by aiming to elucidate the factors that perpetuate an individual's well-being and resilience in the face of adversity.

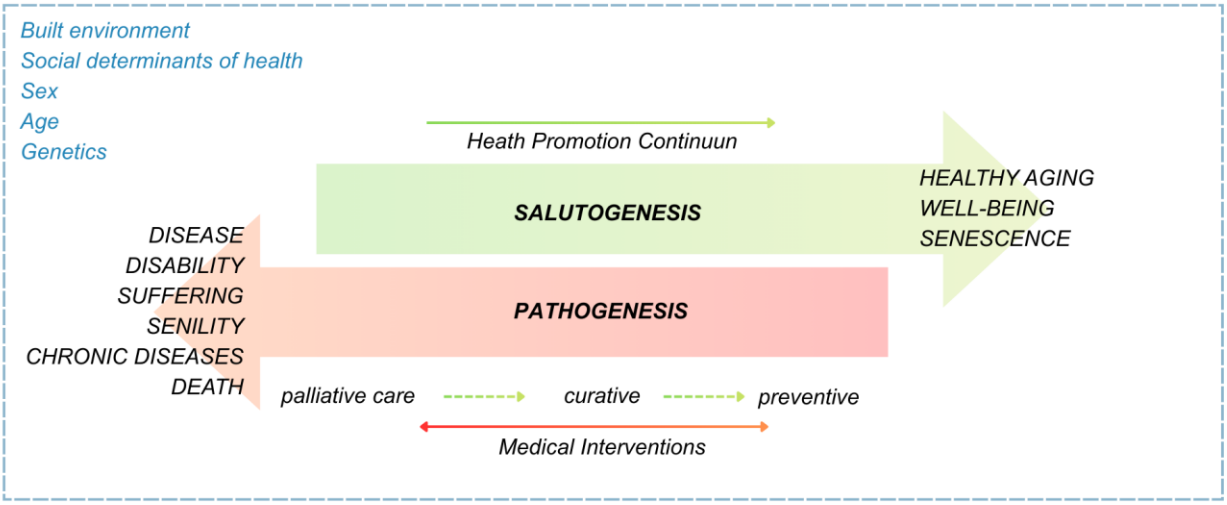

Figure 1. Modern medicine primarily focuses on pathology and the pathogenesis of disease conditions. However, there is a whole different concept called "Salutogenesis," which focuses precisely on the opposite of modern medicine, not pathogenesis, but health factors that promote good health. Consequently, the built environment, the social determinants of health, and other variables present in the person-environment dynamics are taken into consideration. Source: Adapted from Antonovsky (1979). Elaborated by the authors (2025).

Environments designed according to salutogenic principles have been shown to stimulate and engage individuals on mental and social levels, thereby contributing to the strengthening of the “sense of coherence" (SOC). The SOC is a central concept in Antonovsky's theory. The fundamental objective of salutogenic design is to initiate cognitive processes by capturing human attention, thereby reducing anxiety and fostering positive psychological emotions. The principles guiding this design approach can be outlined as follows. The first component, “environmental comprehensibility”, involves creating an orderly setting, one that is predictable and easily legible. Clear visual organization within the built environment is essential to this process. This can be achieved through intuitive wayfinding systems that support efficient navigation while minimizing visual clutter and disorientation.

The second component is “environmental manageability”, which refers to the individual's familiarity with the environment and the existence of social support that fosters a sense of efficacy in the individual's actions within the designated space. The third component is “environmental meaningfulness”, which pertains to the provision of visual and aesthetic meaning, interest, positive stimuli, satisfaction, and the presence of spaces that promote contemplation and mental restoration in the built environment.

According to Dilani (2001), the concept of SOC is strengthened when individuals are able to understand their environment (comprehensibility), feel effective in their actions (manageability), and derive meaning from the experiences provided by the environment (meaningful). A high degree of SOC has been demonstrated to contribute to enhanced stress management, thereby promoting health (Antonovsky, 1979; Dilani, 2001; Farrow, 2024). Salutogenic design applied to the built environment seeks to identify the physical elements that contribute to strengthening the sense of coherence, which is associated with improved health and well-being, according to Figure 2.

THEORY OF "SALUTOGENESIS" *Sense Of Coerence (SOC)*		
COMPREHENSIBILITY *Ability to understand the settings and comprehend scenario*	***MANAGEABILITY*** *Ability to use internal and external resources to cope and be effective in behavior*	***MEANINGFULNESS*** *Ability to tolerate different situations and promote environmental subsidies to facilitate mental restoration.*
Environmental structure and legibility *Order, predictability, and spatial clarity* *Ease of orientation and understanding of the environment* *Organization that reduces uncertainty and cognitive overload*	***Intrapersonal processes*** *Encouragement of reflection and self-awareness* *Environments that foster contemplation and mindfulness* *Promotion of states of relaxation and emotional self-regulation*	***Social and symbolic dimension*** *Social cohesion and strengthening of attachment to the place* *Valuing culture, a festive atmosphere, and a sense of belonging* *Encouraging sociability and meaningful interactions*
Adaptive principles *Use of perceptual cues to facilitate navigation and understanding* *Environmental diversity associated with legibility* *Integration of nature as a structuring element of the experience*	***Restorative Principles*** *Environments geared toward inner contemplation and stress reduction* *Encouragement of self-awareness and mental rest* *Incorporation of meditative elements, formal simplicity, and privacy*	***Social and symbolic dimension*** *Social cohesion and strengthening of attachment to the place* *Valuing culture, a festive atmosphere, and a sense of belonging* *Encouraging sociability and meaningful interactions*

Figure 2. Salutogenic design focuses on creating environments that promote health by fostering coherence, meaning, and manageability through sensory, cognitive, and social stimuli integrated into the context. Source: Adapted from Dilani (2001) and Farrow (2024). Elaborated by the authors (2025).

In the same way that the physical components of a design can create spatial exclusion and deny older adults the right to accessibility in architectural spaces, these same components also have the potential to foster a sense of belonging, promote comfort, preserve dignity, and contribute to maintaining users' mental and cognitive well-being in health-oriented built environments (Dilani, 2001; Farrow, 2024).

1.3 CONTRIBUTIONS OF NEUROSCIENCE AND GERONTOLOGY TO THE AGING BODY IN THE BUILT ENVIRONMENT

In 2019, the World Health Organization published the report World Health

Statistics 2019: Monitoring Health for the SDGs, a document that establishes global targets in alignment with the Sustainable Development Goals and underscores strategic challenges related to population aging (WHO, 2019). Key priorities include the prevention and control of chronic noncommunicable diseases, the expansion of equitable access to health services, the strengthening of primary care, and the improvement of the capacity to respond to public health emergencies, including pandemics (WHO, 2019).

Within this paradigm, chronic noncommunicable diseases (NCDs) emerge as a pivotal challenge for contemporary health systems. According to the World Health Organization (WHO), cardiovascular diseases, cancer, and diabetes account for more than 70% of deaths recorded worldwide, equivalent to approximately 41 million deaths annually (2019). In the Brazilian context, data from the Longitudinal Study on the Health of Brazilian Older Adults (ELSI-Brasil) indicate that approximately 39.5% of the older adult population has at least one chronic condition, while 29.8% live with multimorbidity, characterized by the simultaneous occurrence of two or more such diseases (Lima-Costa et al., 2022).

This complex issue is further compounded by the prevalence of dementia, a group of progressive neurodegenerative conditions that affect more than 55 million people worldwide (ADI, 2025). The report, entitled Dementia Prevention, Intervention, and Care: 2024 Report of the Lancet Standing Commission, revealed that approximately 45% of cases could be prevented or delayed through interventions targeting fourteen modifiable factors across various domains, including environmental conditions, cardiovascular and metabolic health, education, cognitive reserve, sensory aspects, mental health, and daily habits (Livingston et al., 2024).

This evidence underscores the notion that health during the aging process is influenced not only by individual biological characteristics but also by the social and environmental conditions that shape life trajectories (Albuquerque; Kopper, 2024; Bonicenha, 2024). The built environment, encompassing both indoor and urban spaces, has the capacity to either facilitate or impede opportunities for autonomy, functionality, and well-being. This issue assumes particular pertinence in countries characterized by pronounced socioeconomic inequalities and a rapid demographic transition, a phenomenon exemplified by Brazil (Bonicenha, 2024).

The observable disparities in territory across major metropolitan areas serve to underscore this reality. In the city of São Paulo, disparities in life expectancy between relatively proximate neighborhoods can reach 24 years. In the city of Rio de Janeiro, this variation can reach 29 years, while in Fortaleza the discrepancies reach 21 years (IBGE, 2023). Such disparities underscore the pivotal role that one's place of residence plays in determining opportunities for optimal health during the aging process and the distribution of risks associated with illness and premature mortality.

In this context, the Social Determinants of Health (SDHs) have been shown to contribute to the understanding of the inequalities observed throughout the aging process (Fedecostantem; Sabbatinelli; Cherubini, 2025). Poor housing conditions, defined by architectural barriers, unsanitary conditions, excessive humidity, or overcrowding, have been demonstrated to increase the incidence of household accidents and compromise functional independence (Fedecostantem; Sabbatinelli; Cherubini, 2025). In a similar vein, urban environments characterized by violence and insecurity have been shown to impede movement in public spaces, restrict community participation, and diminish levels of physical activity. Accessibility issues, such as deteriorated sidewalks, unsafe crossings, a lack of street furniture, and limitations in public transportation, constitute additional obstacles to daily mobility (Albuquerque, 2025; Fedecostantem; Sabbatinelli; Cherubini, 2025).

Concurrently, the fragility of social support networks and the experience of loneliness have been demonstrated to be associated with elevated rates of depression, anxiety, cognitive decline, physical frailty, and mortality. Inequalities in access to health services have been demonstrated to impede the process of early diagnosis, curtail the implementation of preventive measures, and compromise the effective management of chronic conditions. The combination of these factors exerts a direct influence on both longevity and the quality of life (Albuquerque, 2025; Fedecostantem; Sabbatinelli; Cherubini, 2025).

The integration of insights from cognitive and behavioral neuroscience with those of environmental gerontology has led to significant advancements in our understanding of these processes. This synthesis has elucidated the intricate relationship between the environment and human functioning throughout the aging process. The Ecological Theory of Aging, developed by Lawton and Nahemow (1973), is a foundational principle of Environmental Gerontology. This theory posits that functionality, autonomy, and well-being in old age are the result of a continuous interaction between individual competencies and environmental characteristics (Lawton; Nahemow, 1973). The Competence–Environmental Pressure Model posits that human behavior is a consequence of the equilibrium between an individual's physical, cognitive, and social capabilities and the demands imposed by physical and social contexts (Albuquerque; Santiago; Pereira, 2025). As age-related changes occur, the influence of environmental conditions becomes progressively more relevant to the maintenance of functional independence and quality of life.

In recent decades, the convergence of cognitive neuroscience, behavioral neuroscience, and environmental gerontology has led to a substantial expansion in our understanding of these processes. This expansion is evidenced by the demonstration that the brain, behavior, and environment constitute interdependent systems. For many years, the prevailing view was that the adult nervous system had limited capacity for change. However, studies conducted by researchers such as Donald Hebb (1949), Marian Diamond (1964), Eric Kandel (2006), and Fred Gage (2002) have shown that the brain retains remarkable adaptive potential throughout life. These contributions have solidified the concept of neuroplasticity, understood as the capacity for structural and functional reorganization of neural circuits in response to experiences, environmental stimuli, and behavioral demands (Albuquerque, 2025).

From the perspective of human aging, this evidence demonstrates that the trajectory of cognitive decline is not determined exclusively by biological or genetic factors. Mechanisms such as synaptic remodeling, long-term potentiation, cortical reorganization, and, in certain brain regions, adult neurogenesis remain active during old age, allowing for continuous adaptations in the face of the changes inherent in the aging process (Fratiglioni; Marseglia; Dekhtyar, 2020). In line with this, Environmental Gerontology maintains that functionality depends not only on individual capabilities but also on the opportunities, stimuli, and constraints present in the physical and social context (Albuquerque, 2025). Enriched environments tend to promote the preservation of cognitive and emotional abilities, while conditions characterized by a lack of stimuli, isolation, or environmental barriers can increase vulnerabilities and accelerate functional decline (Albuquerque, 2025), according to Figure 3.

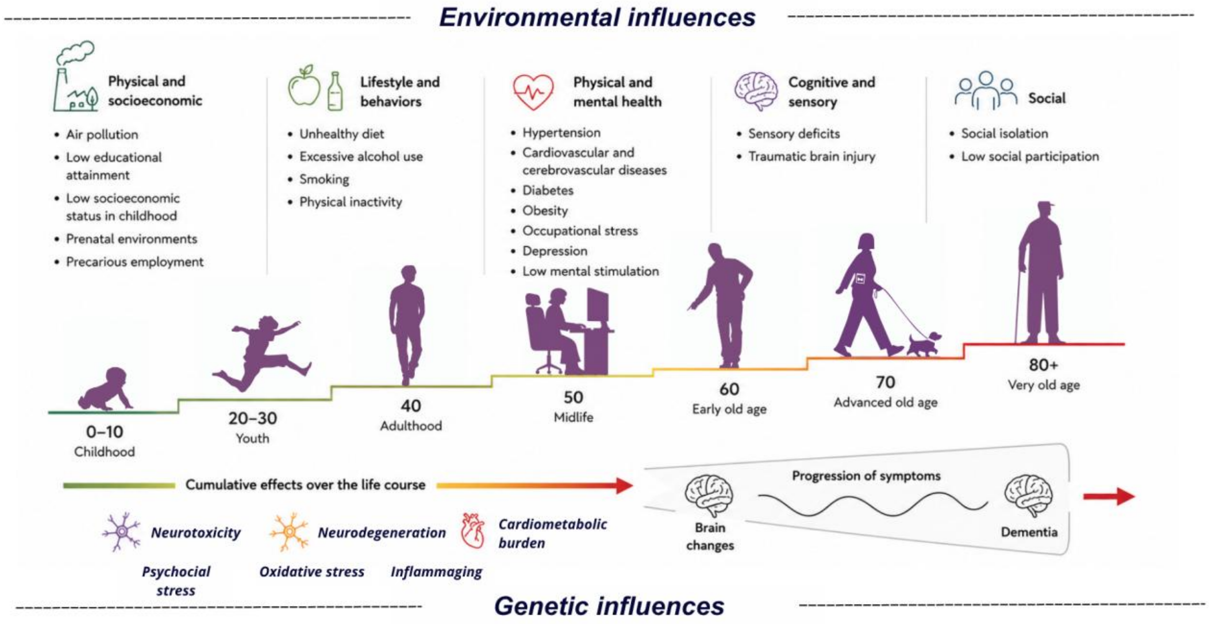

Figure 3. Temporal interface between the influence of the built environment, especially regarding the social determinants of health, with genetic factors during aging. Source: Adapted from Fratiglioni, Marseglia and Dekhtyar (2020). Elaborated by the authors (2025).

This theoretical convergence is supported by the concept of cognitive reserve, extensively developed by Yaakov Stern (2002). According to this perspective, experiences accumulated over the course of a lifetime contribute to increasing the brain's capacity to compensate for neuropathological changes without these immediately translating into clinical manifestations. Education, intellectually challenging activities, sociocultural participation, community engagement, complex occupations, and ongoing learning opportunities are among the main factors associated with building this reserve (Albuquerque, 2025; Stern, 2002). Thus, cognitive health in old age depends not only on the absence of disease but also on the set of experiences that strengthen the brain's adaptive capacity over time.

In this context, mobility constitutes a pivotal element in the promotion of healthy aging. A body of research in the field of neuroscience has demonstrated a correlation between regular physical activity and an enhancement in cerebral perfusion, augmented hippocampal neurogenesis, modulation of inflammatory processes, and an improvement in executive functions (Albuquerque, 2025; Fratiglioni; Marseglia; Dekhtyar, 2020). However, the feasibility of daily mobility is contingent upon the characteristics of the built environment. The quality of sidewalks, spatial connectivity, safety, urban legibility, universal accessibility, and the availability of diverse destinations all shape opportunities for mobility and social participation. From this perspective, walking transcends its utilitarian function and becomes an activity capable of stimulating neurobiological processes related to cognitive preservation, functionality, and psychological well-being (Albuquerque, 2025).

Concurrently, the extant neuroscientific literature demonstrates that chronic social isolation is associated with increased allostatic load, elevated inflammatory markers, the presence of depressive symptoms, and a higher risk of cognitive impairment (Fratiglioni; Marseglia; Dekhtyar, 2020). Gerontology acknowledges social participation as a fundamental element of healthy aging, as interpersonal relationships provide emotional support, a sense of belonging, and opportunities for community engagement. In this regard, public squares, parks, green spaces, cultural facilities, and communal spaces fulfill functions that extend beyond their initial urban planning role, thereby constituting significant resources for promoting mental health and quality of life (Albuquerque; Santiago; Pereira, 2025).

This understanding suggests that accessibility and ergonomics play a strategic role at the intersection of the built environment, neuroplasticity, and aging. Architectural barriers, inadequate signage, complex routes, furniture incompatible with users' anthropometric characteristics, and poor spatial orientation conditions increase the environmental pressure described by Lawton and Nahemow (1973), requiring greater physical, cognitive, and sensory effort to perform daily activities. Conversely, solutions grounded in the principles of universal design, environmental ergonomics, and architectural accessibility have been shown to reduce unnecessary demands, enhance autonomy, and foster more efficient interactions between the individual and their environment (Albuquerque, 2025).

From the perspective of salutogenic architecture, these interventions not only eliminate physical barriers but also create conditions capable of stimulating adaptive processes related to neuroplasticity and the preservation of cognitive reserve. Environments that facilitate spatial exploration, safe mobility, social interaction, contact with nature, intuitive orientation, and participation in meaningful activities offer ongoing opportunities for cognitive, emotional, and behavioral stimulation. Consequently, the built environment is no longer regarded as a mere physical support, but rather as an active agent that promotes brain health, functionality, and quality of life throughout the aging process.

2. METHODOLOGY

In this regard, the objective is to propose practical applications of salutogenic architecture in EAS, taking into account the physical, cognitive, and social aspects of the elderly population, in conjunction with accessibility and ergonomics standards established by technical regulations such as NBR 9050/2020[3] and NR-17/2021[4]. The integrative literature review (ILR) method was employed, as outlined by Botelho, Cunha, and Macedo (2011). According to the authors, this protocol consists of six steps: (1) identification of the topic and formulation of the research question; (2) definition of inclusion and exclusion criteria; (3) identification of preselected and selected studies based on titles, abstracts, and keywords; (4) categorization and critical analysis of the studies; (5) interpretation of the results; and (6) synthesis and presentation of the findings, with identification of gaps and suggestions for future research (Botelho; Cunha; Macedo, 2011).

The objective of this method was to identify relevant articles in neuroscience and gerontology with a focus on their application in EAS projects. These projects include clinics, hospitals, long-term care facilities for the elderly (LTCFs), and rehabilitation clinics, among others. The review is guided by the following question. The central question guiding this inquiry is: “How can integrating knowledge from neuroscience, gerontology, and salutogenic architecture contribute to planning accessible, ergonomic, and inclusive healthcare environments for older people?”. The keywords were defined, and the Boolean operator "AND" was selected. Five groups were identified: neuroscience "AND" environmental ergonomics "AND" aging; health care services "AND" built environment "AND" aging; salutogenesis "AND" ergonomics "AND" health care; aging "AND" built environment "AND" neuroscience; aging 'AND' built environment "AND" accessibility. The searches were conducted between February and April of 2025 in the CAPES periodicals database.

The search strategy encompassed nine databases indexed on the platform. A comprehensive list of journals is available, including PubMed, ScienceDirect, Springer Nature, Taylor & Francis, Oxford Journals, BMJ Open Access, Sage Premier, Social Sciences, and Emerald Complete Journals. It is important to note that sources from the gray literature, such as clinical research, corporate information, conference presentations, and government reports, were not included in this study. This methodological decision was made with the objective of enhancing the scientific rigor of the study, with a particular emphasis on leveraging evidence from studies that have undergone the peer-review process. This approach aligns with the fundamental principles of evidence-based design, particularly as they pertain to interventions within the built environment.

Another salient methodological aspect pertains to the time frame adopted (2019–

[3] Brazilian Standard NBR 9050/2020 establishes technical criteria and parameters to be followed regarding the design, construction, installation, and adaptation of urban and rural environments, as well as buildings, with respect to accessibility requirements.

[4] Brazilian Regulatory Standard No. 17 (NR-17) aims to establish guidelines and requirements that enable working conditions to be adapted to the psychophysiological characteristics of workers, in order to ensure safety, health, comfort, and efficient performance on the job.

2025). While this constraint may have curtailed the identification of studies published in earlier periods, it was predicated on recent scientific advances in neuroscience and gerontology, particularly regarding the understanding of cognitive, social, and motor factors associated with aging. Therefore, the objective was to prioritize evidence that is aligned with the current state of scientific knowledge regarding the relationship between the built environment and the health of older adults.

As part of the ongoing review process, 12 articles were fully analyzed and classified into three groups: 6 were considered highly relevant (blue), 4 were considered partially relevant (yellow), and 2 were considered minimally relevant (red), according to Figure 4. Additionally, Table 1 shows the categorization and titles of the articles, along with their respective authors and the total number of articles read in their entirety.

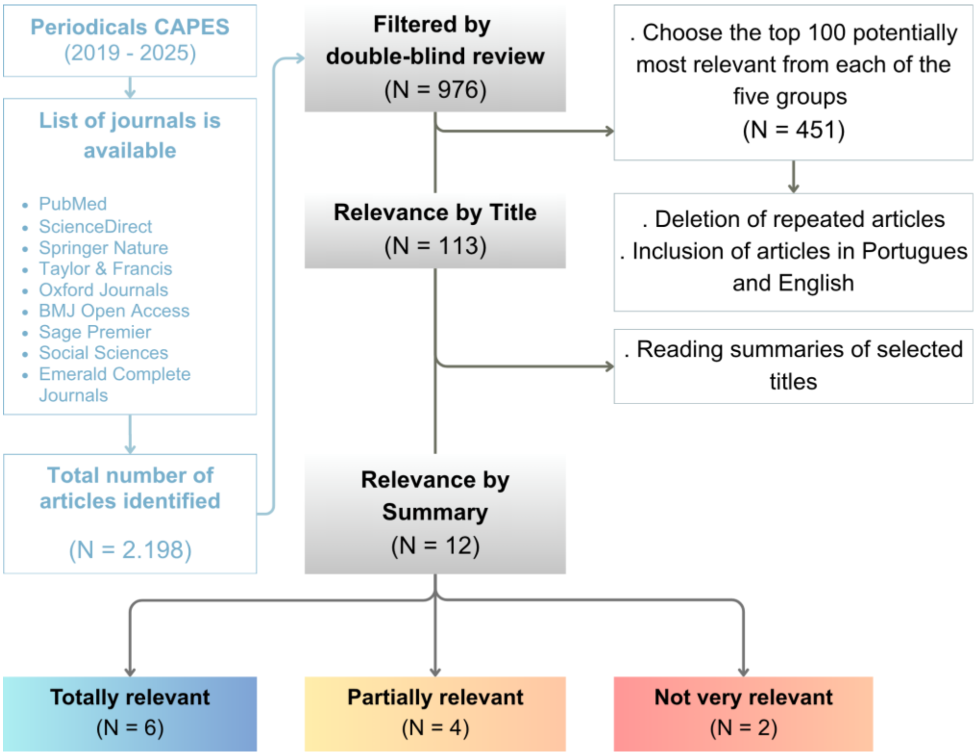

Figure 4. Article screening process based on the integrative review protocol by Botelho, Cunha, and Macedo (2011). Source: Elaborated by the authors (2025).

Categorization	Títles/ Article/ Year	Quantity

Categorization	Títles/ Article/ Year	Quantity
Totally relevant	*Biophilia and Salutogenesis as restorative design approaches in healthcare architecture*, by Abdelaal and Soebarto (2019) *Human Factors and Ergonomics Considerations for Aging-in-Place Part 1*, by Beer and Owens (2022) *Effects of a Tailored Lighting Intervention on Sleep Quality, Rest–Activity, Mood, and Behavior in Older Adults With Alzheimer Disease and Related Dementias*, by Figueiró et al. (2019) *Neuroinclusive workplaces and biophilic design: Strategies for promoting occupational health and sustainability in smart cities*, by Hutson and Hutson (2023) *Human Factors and Ergonomics Considerations for Aging-in-Place Part 2*, by Owens and Beer (2022) *Salutogenic Architecture, Non-Therapeutic Environments and the Health of the Elderly*, by and Khakzand (2025)	6
Categorization	**Títles/ Article/ Year**	**Quantity**
Partially relevant	*Towards human-centred general hospitals: the potential of dementia-friendly design*, by Kirch and Marquardt (2021) *Ageing- and dementia-friendly design: theory and evidence from cognitive psychology, neuropsychology and environmental psychology can contribute to design guidelines that minimise spatial disorientation*, by Wiener and Pazzaglia (2021) *Environmental design for dementia care - towards more meaningful experiences through design*, by Ludden (2019) *Salutogenic-based interventions among community-dwelling older adults*, by Chow (2022)	4

Not very relevante	*Socio-spatial relationships in design of residential care homes for people living with dementia diagnoses*, by Burke and Veliz-Reyes (2021) *Using ecological theory to manage behaviour and symptoms in people living with dementia*, by Golembiewski (2023)	2

Table 1. Classification of articles based on relevance detected in the adopted review protocol. Source: Developed by the authors (2025).

Following a thorough review process, it was determined that a total of six articles met the criteria for full relevance to the fifth and sixth steps of the aforementioned protocol. The primary applications and implications of evidence-based planning and management in health services for older adults were analyzed based on this sample.

3. RESULTS AND DISCUSSION

After an integrative review based on an interdisciplinary approach that incorporated ergonomics, accessibility, neuroscience and gerontology, proposals for spatial interventions were outlined and organised into three categories: (i) physical-ergonomic quality, (ii) sensory-cognitive quality, and (iii) social quality. Within the scope of EAS, these guidelines inform design strategies that aim to improve the functional efficiency and performance of built environments in line with the biopsychosocial needs of the elderly population.

The six publications were written in English and had an international focus, although they were also grounded in the specific contextual realities of different regions, including the United States, Canada, and the United Kingdom. During the review, a paucity of studies in Latin American countries was observed that considered the interplay between the aging body, accessibility to ergonomic healthcare environments, and the promotion of long-term health and quality of life.

The study by Abdelaal and Soebarto (2019) emphasises the relationship between environmental performance and the quality of the built environment, focusing on passive design strategies, thermal comfort, and energy efficiency (Abdelaal; Soebarto, 2019). While not exclusively focused on aging, this work contributes to our understanding of how environmental variables influence users' physiological and perceptual responses.

In a subsequent study, Beer and Owens (2022) outlined guidelines for adapting environments throughout the life course, emphasising the functional changes associated with aging. Owens and Beer (2022) further develop this discussion by emphasising interventions that promote safety, spatial legibility and comfort, particularly in residential contexts. This reinforces the integration of the physical and symbolic dimensions of living. The relevance of ergonomic solutions and spatial adaptation for maintaining autonomy is of particular note, in conjunction with the concept of aging in place — the possibility of remaining in one's own home or within familiar surroundings while preserving comfort, safety and social connections (Owens; Beer, 2022).

Additionally, Figueiró et al. (2019) analyse the effects of lighting on circadian rhythms and neurophysiological regulation, particularly in vulnerable populations such as the elderly (Figueiró et al., 2019). There is evidence that characteristics such as light intensity, spectrum and timing influence sleep, cognition and mood, thus reaffirming the role of lighting ambience in promoting health.

In their 2023 study, Hutson and Hutson shift the focus of their analysis to the social dimensions of care, addressing spatial organisation and institutional practices in care settings. The authors emphasise the significance of social interactions, ambience, and institutional dynamics in fostering more humanised experiences.

Finally, Rakhshani and Khakzand (2025) take a broader perspective, discussing the role of the built environment in promoting health and well-being and integrating urban, environmental, and behavioural dimensions. This study engages with salutogenic principles by recognising the influence of spatial contexts on human experience and quality of life (Rakhshain; Khakzand, 2025).

Despite the paucity of studies establishing direct causal relationships between ergonomics, accessibility, neuroscience, and gerontology associated with healthcare environments, a review of the extant literature reveals a growing convergence around the need for interdisciplinary approaches to promote healthy aging.

From this perspective, salutogenic architecture understands health and well-being as phenomena resulting from the interaction between biological, behavioral, social, cultural, and environmental factors throughout the life course.

The contributions of cognitive and behavioral neuroscience, particularly those associated with neuroplasticity, cognitive reserve, and enriched environments, provide substantial support for this approach. As demonstrated in the preceding studies, including those by Hebb (1949), Diamond, Krech, and Rosenzweig (1964), Kandel (2001), Gage (2002) and Stern (2002), experiences and environmental stimuli have been shown to exert a continuous influence on brain organization and functioning. Environments conducive to physical activity, social interaction, cognitive challenges, and a diversity of sensory stimuli have been shown to facilitate mechanisms associated with learning, memory, emotional regulation, and the maintenance of functionality (Diamond; Krech; Rosenzweig, 1964; Gage, 2002; Hebb, 1949; Kandel, 2001; Stern, 2002).

The analyzed studies also align with Lawton and Nahemow's (1973) Ecological Theory of Aging. According to this theory, adaptation in old age depends on the relationship between an individual's abilities and the pressure exerted by the environment (Lawton; Nahemow, 1973). When physical, cognitive, or sensory demands exceed a person's capabilities, the risk of functional difficulties, social isolation, a sedentary lifestyle, and cognitive decline increases (Albuquerque, 2025). Conversely, environments that are accessible, legible, and ergonomically adequate reduce environmental pressure and expand opportunities for mobility, social participation, and engagement in meaningful activities.

In this context, salutogenic architecture can be understood as a strategy to support brain health and functionality. Examples of its applications include layouts that favor spatial orientation and safe movement, the elimination of architectural barriers, the ergonomic adaptation of furniture, lighting systems aligned with circadian rhythms, and the use of materials that reduce the risk of accidents (Abdelaal; Soebarto, 2019; Figueiró et al., 2019).

Within the sensory-cognitive dimension, interventions focused on environmental legibility, spatial orientation, and providing stimuli compatible with users' abilities are notable. Incorporating natural elements has been associated with reducing stress, improving attention, and enhancing psychological well-being (Beer; Owens, 2022). Similarly, spaces designed for community interaction and participation promote cognitive reserve by providing opportunities for social interaction, continuous learning, and occupational engagement (Rakhshani; Khakzand, 2025; Hutson; Hutson, 2023).

With regard to the integration of the principles of salutogenic architecture — (i) physical-ergonomic quality, (ii) sensory-cognitive quality, and (iii) social quality — into technical standards for accessibility and ergonomics, the NBR 9050/2020 and NR-17/2021 standards were considered. They cover the principles of Universal Design (UD) and worker ergonomics in EAS, respectively. According to NBR 9050:2020 (sections 4.2, 4.3 and 5.4), usability and comfort require minimum dimensions, manoeuvring areas and an absence of barriers. NR-17 (item 17.3) complements these requirements by stipulating a layout that minimises effort and forced postures. NBR 9050 (item 6.7) defines appropriate heights and depths for furniture, while NR-17 (item 17.3.3) establishes ergonomic parameters to prevent strain.

Functionality is associated with Universal Design (NBR 9050: items 3.4 and 4.1) and the adaptability of furniture and equipment (NR-17: item 17.3.4). The layout must ensure accessible routes (NBR 9050, item 5.2) and minimise unnecessary movement (NR-17, item 17.2). Safety and security measures include non-slip flooring, adequate lighting and signage (NBR 9050, items 5.4.3 and 5.4.4) and the prevention of physical hazards (NR-17, item 17.6). Perceived safety involves clear spatial organisation (NBR 9050, items 5.5 and 6.1) and psychophysiological well-being (NR-17, item 17.1), as illustrated in Figure 5.

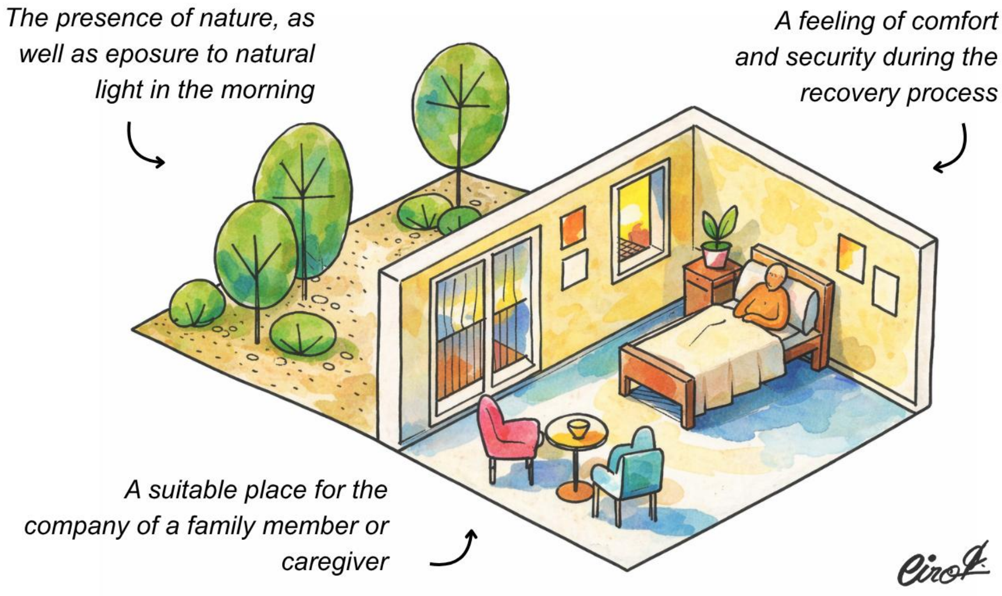

Figure 5. Example of the application of salutogenic architecture in healthcare settings from the perspective of human aging. Source: Elaborated by the authors (2025).

In terms of sensory and cognitive accessibility, NBR 9050 (sections 7.3 and 7.4) stipulates the use of tactile, visual and audible signage, while NR-17 (section 17.5) suggests a layout that facilitates wayfinding. Information must have the correct contrast and positioning (NBR 9050: items 7.5 and 7.6) and be legible (NR-17: item 17.5.3). Comprehension is ensured through the use of multiple formats and plain language (NBR 9050, item 7.7; NR-17, item 17.1.2).

Warning systems must be accessible (NBR 9050, item 7.8) and perceptible without causing sensory overload (NR-17, item 17.6.2). In terms of environmental factors, NBR 9050 (item 9.3) and NR-17 (item 17.5.2) address adequate lighting, while NBR 9050 (item 9.4) and NR-17 (item 17.5.4) address noise. Regarding thermal comfort, NR-17 (item 17.5.1) establishes parameters, while NBR 9050 recommends adjustments. Both also provide for effective ventilation in relation to air quality (NBR 9050: item 9.2; NR-17: item 17.5.1).

Social quality encompasses well-being through access to outdoor areas (NBR 9050, items 5.6 and 5.7), breaks (NR 17, item 17.2.4), hygienic conditions (NBR 9050, item 10.1; NR 17, item 17.1) and promoting physical activity (NBR 9050, item 5.6; NR 17, active breaks), as illustrated in Figure 6.

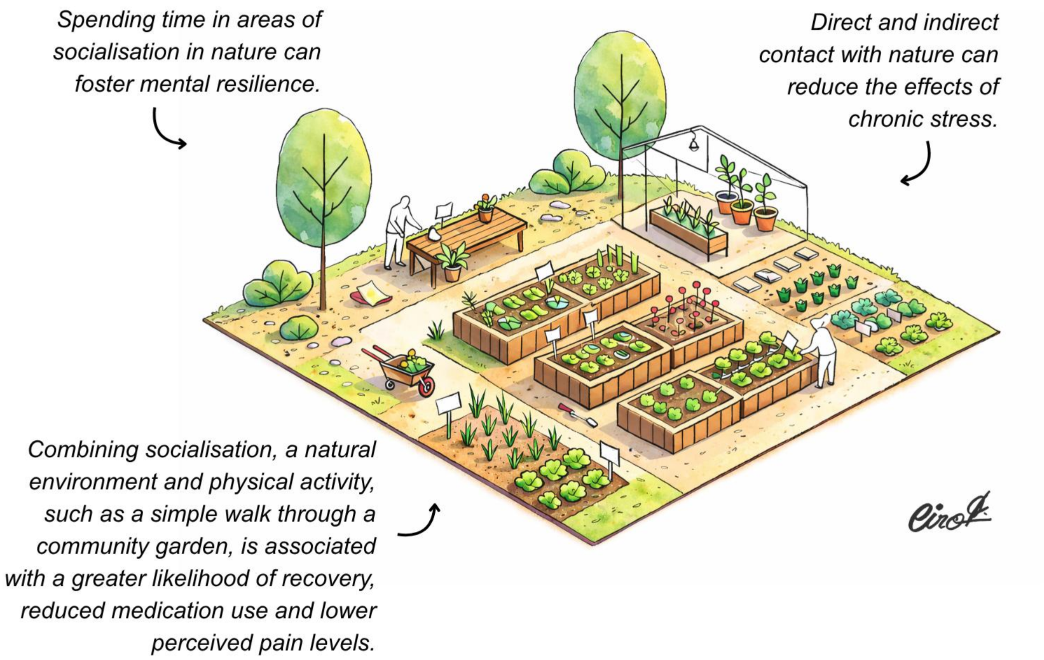

Figure 6. Example of the application of salutogenic architecture in outdoor areas in healthcare settings from the perspective of human aging. Source: Elaborated by the authors (2025).

Social inclusion encompasses respect for diversity (NBR 9050, item 3.4) and ergonomic customisation (NR-17, item 17.1.1). Social relationships are fostered through accessible communal spaces (NBR 9050, item 5.7) and environments that encourage interaction (NR-17, item 17.1.2). NBR 9050 (item 3.2) and NR-17 (item 17.1.1) provide for a participatory process to align projects with actual needs.

As previously mentioned, salutogenic architecture primarily involves designing layouts that promote spatial orientation, accessibility, and safe mobility. It also includes physically and ergonomically qualifying environments by adapting furniture, removing architectural barriers, adopting lighting systems that align with circadian rhythms, and specifying materials that minimize the risk of accidents. Additionally, it involves sensory and cognitive qualification, which focuses on environmental legibility, perceptual comfort, and incorporating natural elements that reduce stress and promote well-being. Finally, salutogenic architecture can stimulate social interactions, strengthen community ties, and expand opportunities for participating in meaningful activities (Abdelaal; Soebarto, 2019; Beer; Owens, 2022; Figueiró et al., 2019; Hutson; Hutson, 2023; Owens; Beer, 2022; Rakhshani; Khakzand, 2025). Table 2 summarizes the practical applications of these principles in healthcare settings.

Principle	Indicator	Justification	Bibliographic reference
(I) Physical and Ergonomic Quality	**1.1 Usability –** Comfort in the use of spaces	Aging affects mobility, balance, and muscular strength, making accessible, barrier-free layouts essential. Spatial proportions and environmental predictability reduce cognitive load.	(Abdelaal; Soebarto, 2019; Beer; Owens, 2022).
	Comfort in the use of furniture	Furniture dimensions (height, depth, firmness) must accommodate joint and proprioceptive limitations. Inadequate design increases discomfort and fall risk.	
	1.2 Functionality – Flexibility	Flexible environments adapt to different users (e.g., wheelchair users, frail older adults, caregivers), supporting Universal Design principles and gradual cognitive adaptation.	(Abdelaal; Soebarto, 2019; Beer; Owens, 2022; Rakhshani; Khakzand, 2025).
	Layout distribution	Efficient spatial organization promotes intuitive circulation, reduces unnecessary movement, and optimizes physical effort.	
	1.3 Safety and protection – Minimization of risk situations	Environments should prevent slipping, uneven levels, poor lighting, and obstacles. Fear of falling may trigger stress responses (amygdala activation), reducing mobility.	(Abdelaal; Soebarto, 2019; Beer; Owens, 2022).
	Perception of safety	Clear organization, visibility, and absence of isolated areas reduce anxiety and encourage continued use of space.	
Principle	Indicator	Justification	Bibliographic reference

(II) Sensory and Cognitive Quality	**2.1 Wayfinding –** Orientation through layout	Spatial orientation depends on executive function and memory. Legible layouts and landmarks enhance autonomy.	(Abdelaal; Soebarto, 2019; Beer; Owens, 2022; Figueiró et al., 2019; Owens; Beer, 2022; Rakhshani; Khakzand, 2025).
	Clear and perceptible information	Accessible signage, tactile maps, and pictograms improve comprehension for users with visual, cognitive, or literacy limitations.	
	2.2 Comprehension – Easily understandable information	Clear language and multimodal communication (visual, tactile, auditory) support users with sensory or cognitive impairments.	(Abdelaal; Soebarto, 2019; Beer; Owens, 2022; Figueiró et al., 2019; Hutson; Hutson, 2023; Owens; Beer, 2022; Rakhshani; Khakzand, 2025).
	Communication and informational awareness	Accessible communication systems (visual and auditory alerts) improve safety and decision-making, especially in emergencies.	
	2.3 Environmental factors – Lighting	Light regulates circadian rhythms, mood, and cognition. Poor lighting increases accident risk; excessive blue light at night disrupts sleep.	(Beer; Owens, 2022; Figueiró et al., 2019; Hutson; Hutson, 2023; Owens; Beer, 2022; Rakhshani; Khakzand, 2025).
	Acoustics	Noise overload impairs cognition and communication. Presbycusis requires controlled acoustic environments.	
	Thermal comfort	Reduced thermoregulation in older adults makes them vulnerable to extreme temperatures, affecting well-being and physiological stability.	
	Air quality	Proper ventilation and air control reduce respiratory risks. Exposure to VOCs may impair cognition.	
Principle	**Indicator**	**Justification**	**Bibliographic reference**

(III) Social Quality	**3.1 Well-being –** Restorative environment	Natural elements and contemplative spaces reduce cortisol, improve mood, and support mental health.	(Hutson; Hutson, 2023; Owens; Beer, 2022; Rakhshani; Khakzand, 2025).
	Hygienic conditions and maintenance	Clean, well-maintained environments enhance safety and reduce infection risks.	
	Health promotion and physical activity	Physical activity supports neurogenesis and brain plasticity. Environments that encourage movement promote active aging.	
	3.2 Social inclusion – User-centered care and cultural appropriateness	Respect for users' habits and diversity fosters belonging and supports culturally sensitive care.	(Hutson; Hutson, 2023; Owens; Beer, 2022; Rakhshani; Khakzand, 2025).
	Social interaction	Spaces that promote informal encounters (e.g., verandas, shared areas) support social engagement and cognitive health.	
	Design process	Participatory design ensures user involvement, improves solution effectiveness, and strengthens inclusion.	

Table 2. Proposal for the Practical Application of Salutogenic Architecture in Healthcare Environments. Source: Based on Abdelaal and Soebarto (2019), Beer and Owens (2022), Figueiró et al. (2019), Hutson and Hutson (2023), Owens and Beer (2022), and Rakhshani and Khakzand (2025). Developed by the authors (2025).

Thus, applying the principles of salutogenic architecture to the intersection of accessibility, ergonomics, and neuroscience transcends merely adapting spaces physically. This approach acts as a resource that can reduce environmental pressure, stimulate neuroplasticity mechanisms, and strengthen cognitive reserve. This approach favors creating environments that are more responsive to the needs of the elderly population. These environments have the potential to encourage autonomy, mental health, functionality, and quality of life. This is especially important in contexts marked by accelerated population aging and socio-spatial inequalities. In this sense, we propose an adaptable model based on integrating socio-spatial relationships among the elderly, their family members, caregivers, and health professionals.

This model can respond to contemporary care demands. This model presupposes the shared responsibility of the various stakeholders, encouraging user participation in all stages of care and fostering more inclusive, collaborative, and health-promoting environments.

4. CONCLUSIONS

This research contributed to the development of a theoretical framework articulating ergonomics, accessibility, salutogenic architecture, neuroscience, and environmental gerontology in care environments for elderly populations. A literature review revealed that the quality of the built environment influences not only user safety and functionality, but also mental health, autonomy, social participation, and quality of life. The findings demonstrate that incorporating ergonomic, accessible, and inclusive principles promotes the development of spaces that better address the needs associated with aging. This helps reduce physical, cognitive, and sensory barriers that can hinder the user experience.

In addition to benefiting the elderly, the results indicate that environments designed from this perspective positively impact family members, visitors, and healthcare professionals. Features such as spatial organization, acoustic comfort, privacy, environmental orientation, and communal spaces enhance social interactions, encourage humanized care practices, and promote the presence of a support network. These features also help reduce the physical and emotional burden on caregivers. Additionally, spatial legibility and proper environmental structuring can optimize workflows, minimize operational errors, and increase service efficiency, particularly in institutions with high staff turnover.

This study's main contribution is the systematization and integration of evidence from various fields, reinforcing the understanding of the built environment as an active element in promoting health, functionality, and well-being during the aging process. Considering the biological, cognitive, functional, and sociocultural characteristics of old age broadens our understanding of how space mediates care relationships, autonomy, and quality of life. This approach offers theoretical support for planning and managing more inclusive, safe, and health-promoting environments.

Although the literature identifies limitations, particularly in Latin American research, regarding studies that integrate functional, cognitive, and environmental aspects of aging, these issues are presented as opportunities for future research. Empirical and experimental research should be conducted to evaluate the application of these principles in various care, cultural, and territorial contexts. This will contribute to the deepening and validation of the existing evidence.

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