The Influence of Healthcare Environment Architecture on the Psycho-Neuro-Endocrine-Immunological System

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Abstract: *This article is a re-elaboration based on the book* Archi-Therapeia. The Influence of Architecture on the PNEI Mind-Body System *authored by Silvia Moneti, Architect and Teacher with a Master's degree in PNEI and Integrated Care Science.*

In particular, reference is made to the chapter concerning design guidelines for healthcare facilities, with the aim of presenting a set of strategies that can be implemented within care environments to promote patients' psychophysical well-being.

The initial sections address issues related to orientation, accessibility, social interaction, spatial organization and personalization of the patient room.

The discussion then proceeds with the presentation of guidelines concerning lighting, acoustics and clinical aromatherapy.

The final sections focus on the design of labor and breastfeeding rooms, intensive care units and spaces for home-based care.

The article concludes with the hope that the collected evidence may be translated into future architectural projects for healthcare facilities and care environments, while continuing to promote Architecture as a discipline within the PNEI framework and as a form of integrated therapy in its own right.

Keywords: *Architecture, PNEI, Healthcare Facilities, Labor Room, Intensive Care Unit, Home Care.*

Introduction

This article is derived from the book *Archi-Therapeia. The Influence of Architecture on the PNEI Mind-Body System*, and in particular from the chapter addressing design guidelines for healthcare facilities.

Its aim is to present a range of architectural strategies that can be implemented to promote the psychophysical well-being of patients undergoing treatment for specific pathologies, whether in acute or chronic phases.

The article is therefore intended for both Healthcare Professionals and Technical Professionals, who are called upon to engage in dialogue and collaboration in order to promote the health of a "shared patient".

Orientation and Accessibility

Spatial perception can be defined as the individual's ability to interpret the surrounding environment and to understand the relationship between physical space and the position of one's own body within it. The concept of accessibility, by contrast, refers to the extent to which an environment can be used by individuals with diverse functional characteristics, including those with sensory, motor or cognitive impairments, whether temporary or permanent.

The study *Patient-Friendly Hospital Environments: Exploring the Patients' Perspective* (Calbert and Mary, 2004) investigated how fifty patients admitted to departments of Internal Medicine, Surgery, Geriatrics and Maternity perceived hospital spaces. The findings highlighted that a significant number of participants experienced difficulties in orienting themselves within the healthcare facility, resulting in increased anxiety, reduced perceived control and a loss of personal autonomy.

Evidence from research on so-called place cells suggests that a clear and recognizable characterization of environments may enhance spatial orientation processes, as the presence of distinctive elements facilitates the stabilization of cognitive spatial representations generated within neural circuits involving the hippocampus and entorhinal cortex. Conversely, environments lacking spatial cues may promote persistent activation of the physiological stress response, which is associated with immunosuppression, delayed wound healing and an increased severity and frequency of viral infections (Vedhara *et al.*, 1999; Glaser and Kiecolt-Glaser, 2005; Sternberg, 2006).

In the field of healthcare architecture, the concept of "hospital wayfinding" has been developed, encompassing a set of design and communication strategies aimed at facilitating user orientation within hospital settings. Commonly adopted measures include the use of differentiated color-coding systems, the installation of interactive digital information devices and the integration of Braille signage.

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Social Interaction

Some patients exhibit a more marked reduction in stress levels when hospitalization occurs in single rooms, environments characterized by lower exposure to acoustic and visual stimuli and a higher degree of privacy. For other individuals, however, staying in shared environments (such as double or four-bed rooms) may be psychologically more beneficial, as the presence of other patients reduces the perception of isolation. Preferences for a specific type of accommodation are not determined solely by individual personality traits but are also influenced by the type of ward and the expected length of stay (Calbert and Mary, 2004).

For patients who retain an adequate level of psychophysical autonomy, the availability of common spaces dedicated to recreational activities is particularly relevant. Such environments promote social interaction and contribute to the stimulation of cognitive and motor functions. In several healthcare settings, dedicated indoor spaces have been designed, including libraries, tea rooms and small screening areas. In parallel, some healthcare institutions, particularly in the United States and Northern Europe, have established collaborations with local museums to organize guided cultural visits for patients who are able to temporarily leave the hospital.

These initiatives fall within the therapeutic paradigm known as "Art on Prescription", an approach that involves the use of artistic experiences as complementary interventions aimed at improving psychophysical well-being. Numerous studies have shown that this practice can enhance patient's awareness of their clinical condition and encourage a more active role in managing their own health.

A significant contribution in this field derives from a study conducted in Australia, which evaluated the psychophysiological responses of patients with dementia participating in a cultural visitation program at the National Gallery of Australia (D'Cunha *et al.*, 2019). After six weeks of participation in the museum-based therapy program, several beneficial effects were observed, including increased dynamism of the circadian cortisol rhythm (indicative of improved functioning of the hypothalamic-pituitary-adrenal axis), more effective blood pressure regulation, reduction in depressive symptoms, improvements in memory performance and verbal fluency, enhanced self-esteem, higher levels of empowerment and a greater propensity for social interaction.

The "Art on Prescription" approach has recently also been applied in the prevention and treatment of depression associated with prolonged hospitalization (Monsuez *et al.*, 2019). In Paris, the Louvre Museum established a collaboration with several city hospitals to develop a cultural program for long-term patients admitted to Geriatrics, Psychiatry and Palliative Care wards. Over the course of

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one year, sculptures were installed in patient gardens, reproductions of renowned paintings were displayed in common areas and educational art history sessions were organized for patients, caregivers and healthcare staff. The results observed at the end of the study indicated that approximately 80% of patients reported a significant reduction in perceived stress, while more than 90% reported benefiting from the artistic experience in terms of improved quality of life during hospitalization. Furthermore, the joint participation of patients, caregivers, and healthcare professionals contributed to the creation of a relational climate characterized by greater trust, familiarity and collaboration.

Spatial Arrangement

In 2019, MacAllister and colleagues conducted a study on patient satisfaction in relation to the spatial arrangement of hospital rooms, titled *Exploring the Relationships Between Patient Room Layout and Patient Satisfaction*. Rooms located at an intermediate distance (10-20 meters) from the nursing station, with the entrance positioned on the patient's right side and the head of the bed not visible from the doorway, were found to be the most appreciated. These configurations were valued because they were close enough to healthcare staff to allow prompt assistance if needed, while simultaneously providing privacy and a restful environment.

Personalization

It has been observed that, as the length of hospital stay increases, patients exhibit a growing need to intervene in their surrounding environment through forms of personalization that help reinforce their sense of identity and belonging (Andersson, 2017).

From this perspective, Andersson and colleagues (2019) propose various design and organizational strategies, including the possibility of displaying family photographs in frames provided by the facility, installing a magnetic board for posting drawings, posters or personal notes, providing a small writing desk, allowing the introduction of personal objects from home, offering potted flowers or plants that patients can care for themselves, enabling individual control of room lighting, distributing books and newspapers on a daily basis and granting access to personal devices for listening to music or viewing visual content.

The implementation of these interventions aims to create a more humanized care environment, capable of supporting the patient's psychological well-being during hospitalization and fostering a greater sense of control over their temporary living space.

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Lighting and Circadian Rhythm

Visible light represents one of the primary environmental cues through which humans synchronize their biological clock. Circadian rhythms are physiological oscillations with an approximately 24-hour periodicity that regulate numerous biological functions, including body temperature, hormone secretion, the sleep-wake cycle and cognitive performance.

In 1998, specific photoreceptors were identified in the human eye, known as intrinsically photosensitive retinal ganglion cells (ipRGCs), which express the photopigment melanopsin. This pigment allows the transmission of information to the suprachiasmatic nucleus (SCN), which serves as the body's central clock, aligning internal biological rhythms with external environmental cycles (Wahl *et al.*, 2019).

Blue light (wavelength between 380 and 435 nm; correlated color temperature between 5000 and 7000 K) is one of the most potent synchronizers of the circadian system. Exposure to this spectral component during daytime contributes to melatonin suppression, increased body temperature, heart rate and blood pressure. Additionally, it is associated with heightened alertness, improved concentration, and enhanced cognitive performance, while reducing perceived effort during mental tasks (Zauner, 2020).

Conversely, prolonged exposure to low-intensity blue light during nighttime hours (LAN – Light At Night) can disrupt normal circadian function, impair sleep quality, and potentially contribute to adverse psychophysical health outcomes, including increased risk of oncological (Haus and Smolensky, 2006) and diabetic pathologies (Kreier *et al.*, 2007), cognitive decline (Stevens *et al.*, 2007), reproductive dysfunction (Mahoney, 2010), obesity (Bass and Takahashi, 2010), as well as gastrointestinal issues and alterations in gut microbiota composition (Codoñer-Franch and Gombert, 2018).

Based on this evidence, Giménez and collaborators (2017) proposed a model for optimized circadian lighting in hospital patient rooms, integrating guidelines for color temperature and illuminance levels throughout the day. According to this model, during daytime hours, light sources with a high blue-light component (approximately 4000-6500 K) are recommended to enhance mood, cognitive performance and physiological activation. Under these conditions, average illuminance should be around 300 lux, with possible peaks up to approximately 1500 lux between roughly 10 a.m. and 1 p.m. In the evening, the color temperature should be progressively reduced and maintained below 3000 K to promote melatonin secretion and facilitate sleep onset. Simultaneously, illuminance should decrease to a maximum of around 100 lux in the early evening, and further reduced to between 5 and 10 lux during nighttime rest periods.

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Acoustics and Soundscape

The topic of acoustics in hospital settings is addressed in a particularly comprehensive and insightful manner in the article *Exploring the Effect of Sound and Music on Health in Hospital Settings: A Narrative Review*, published in 2016 by the research group led by Timothy Onosahwo Iyendo. The authors first emphasize the importance of distinguishing between the notions of sound and noise, introducing the concept of the soundscape, defined as the ensemble of acoustic components perceived within a specific environment.

Noise is generally defined as any auditory stimulus perceived as unwanted and is considered a significant stressor, capable of producing negative psychological and physiological effects (Plack, 2013). Exposure to intrusive sound sources represents one of the most frequently reported environmental problems by both patients and staff in healthcare facilities. Since the 1960s, there has been a progressive increase in sound pressure levels within hospitals: during daytime hours, average levels range between 57 and 72 dB (comparable to a busy restaurant or an urban street), while nighttime levels typically range from 42 to 60 dB (similar to the noise produced by an operating household appliance) (Busch-Vishniac *et al.*, 2005). These levels exceed by approximately 20-30 dB the recommended limits for background environmental noise in healthcare facilities set by the World Health Organization (Berglund *et al.*, 1999).

Numerous studies have shown that prolonged exposure to unwanted noise can produce adverse effects in hospitalized patients, including increased urinary cortisol levels, headaches, and heightened pain sensitivity (Melamed and Bruhis, 1996), elevated blood pressure, increased risk of cardiovascular disease, potential alterations in neonatal development and modifications of immune responses (Segerstrom and Miller, 2004). Additionally, high noise levels have been associated with longer hospital stays (Bailey and Timmons, 2005), deficits in memory functions and psychomotor agitation (Short *et al.*, 2011).

In contrast, a growing number of studies have highlighted the beneficial effects of music on patient's psychophysical health, preferably listened to through personal devices at sound levels below approximately 60 dB. Reported benefits include reductions in preoperative pain and anxiety (Chaput-McGovern and Silverman, 2012), improved management of behavioral and psychological symptoms in patients with dementia (Ueda *et al.*, 2013) and enhanced motor and communication skills in individuals with Parkinson's disease (Pohl *et al.*, 2013).

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Clinical Aromatherapy

Aromatherapy is a discipline within the field of phytotherapy that utilizes natural essential oils with the goal of promoting an individual's psychophysical well-being.

According to the article *Clinical Aromatherapy* (Farrar A.J. and Farrar F.C., 2020), the historical origins of aromatherapy cannot be attributed to a single cultural context, as practices involving the use of aromatic plant substances were widespread across numerous ancient civilizations. Among the most significant records is the *Ebers Papyrus*, dated around 2800 BC, considered one of the principal documents of Ancient Egyptian medicine, containing instructions on the therapeutic use of resins, balms, and scented oils. Around the same period, the *Shennong Manuscript*, attributed to the Chinese deity associated with agriculture, describes over 350 plant species along with their medicinal properties. In Europe, the Greek philosopher and botanist Theophrastus (a student of Aristotle) is traditionally regarded as the founder of scientific botany; in the 4th century BC, he authored *Historia Plantarum*, documenting the characteristics and medicinal uses of more than four hundred plant species. With the spread of Christianity in Europe, some practices involving aromatic plants were associated with pagan rituals, leading Pope Gregorio Magno in the 6th century AC to prohibit their use.

The modern scientific rediscovery of essential oils occurred in the 1920s, when French chemist René Maurice Gattefossé coined the term "aromatherapy" after studying the wound-healing properties of lavender essential oil during experiments conducted in military hospitals. Later, during World War II, French surgeon Jean Valnet significantly contributed to the diffusion of aromatherapy in medical practice, using essential oils to treat soldiers' wounds and manage trauma-related psychological disorders. In 1961, the nurse and naturopath Marguerite Maury published *Le Capital de Jeunesse*, analyzing the effects of essential oils on the central nervous system and cellular regeneration processes.

Currently, clinical aromatherapy is administered through three main modalities: topical application, oral ingestion, and inhalation. Depending on the patient's clinical needs, aromatherapy may serve as a complementary therapeutic intervention with multiple purposes, including antibacterial, antifungal, antiviral, analgesic, antiseptic, anti-inflammatory, antioxidant, anticoagulant, antipyretic, antidepressant, detoxifying, decongestant and muscle-relaxing effects (Kaufmann, 2018).

The influence of aromatherapy on the PNEI system is evident when considering the path of essential oil molecules: once inhaled, the molecules reach the olfactory bulb and then the amygdala and hippocampus, facilitating the retrieval of positive memories and emotions associated with specific scents. Simultaneously, the molecules travel from the respiratory system into the bloodstream, reaching organs and

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tissues that can benefit from their therapeutic properties (Farrar A.J. and Farrar F.C., 2020; Vora *et al.*, 2024).

Despite the potential benefits of clinical aromatherapy, its use requires specialized expertise and adherence to strict safety protocols. Essential oils are highly concentrated and flammable substances that must be stored in cool environments, preferably in amber glass bottles to minimize exposure to ultraviolet light. Additionally, prior to topical application, preliminary allergy testing is recommended to prevent potential skin reactions, dermatitis or photosensitization.

Labor and Breastfeeding Rooms

Between 2005 and 2007, Osborne Park Hospital in Western Australia hosted a research program focused on the implementation of controlled multisensory environments, used as spaces for labor and breastfeeding.

The first published study, titled *Women's Experiences of Using a Snoezelen Room During Labour in Western Australia* (Hauck *et al.*, 2008a), examined the experiences of sixteen women who used a labor room designed to provide multisensory stimuli under the direct control of the birthing women. The room featured floors and walls painted in warm, muted tones, natural fabrics, comfortable furnishings, and adjustable lighting with individualized control over intensity and color temperature. Obstetric care could be continuous or intermittent, depending on the woman's preferences. Pain management and relaxation strategies included immersion in warm-water tubs, acupuncture, aromatherapy, music therapy, massage, and transcutaneous electrical nerve stimulation (TENS). Post-experience interviews revealed that participants perceived the environment as an active factor enhancing their sense of control and self-efficacy while significantly reducing pain perception.

Subsequently, the same space at Osborne Park Hospital was used as a breastfeeding room. The results of this second research phase were published in *A Qualitative Study of Western Australian Women's Perceptions of Using a Snoezelen Room for Breastfeeding During Their Postpartum Hospital Stay* (Hauck *et al.*, 2008b). The study aimed to evaluate the influence of the architectural environment on the breastfeeding experiences of eleven new mothers who exhibited high levels of anxiety or difficulties in establishing intimate bonding with their newborns. At the conclusion of the experience, all participants expressed a positive assessment, highlighting the benefits of being able to step away from the traditional hospital environment and access a space with an intimate and welcoming atmosphere. Privacy reduced external distractions and direct control over environmental conditions promoted maternal relaxation, reinforced self-esteem and facilitated a more enjoyable breastfeeding experience.

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In recent years, numerous studies have examined the impact of ICU architectural design on clinical outcomes and patient well-being. These investigations have compared traditional intensive care units with innovative design models featuring single-patient rooms, neutral color schemes, eco-friendly materials, noise-reducing technologies, circadian rhythm-aligned lighting systems, and the possibility of including personalized elements such as photographs and personal objects (Andersson *et al.*, 2019).

Patients admitted to traditional ICUs, even when sedated or in a state of reduced consciousness, often report fragmented memories of their hospitalization, frequently characterized by unpleasant auditory perceptions, disturbing visual images, and feelings of disorientation and vulnerability (Johansson *et al.*, 2012; Olausson *et al.*, 2013; Baumgarten and Poulsen, 2015). From a pathophysiological perspective, these conditions may be associated with spatial-temporal disorientation, increased risk of persistent cognitive deficits, elevated heart rate and blood pressure, sleep disturbances and delayed wound healing. More favorable outcomes have been observed in studies conducted in ICUs designed according to innovative principles, where patients reported lower distress levels, improved pain management and reduced risk of infectious complications (Andersson *et al.*, 2019; Tronstad *et al.*, 2023).

Designing Neonatal Intensive Care Units (NICUs) requires even greater consideration, as the physical environment can significantly influence the neuro-sensory development of preterm infants. Dr. Stanley Graven was the first to introduce the concept of a "critical period": a temporal window during which the physical environment exerts a particularly significant effect on the visual and auditory systems of premature infants (Graven, 2000; Robinson and Pallasmaa, 2017).

The critical auditory period begins approximately 10-12 weeks before birth and extends until the second year of life. Follow-up studies of preterm infants exposed to inadequate acoustic conditions during NICU hospitalization have shown potential long-term negative outcomes, including delays in language development, difficulties in auditory discrimination, and reduced ability to recognize complex acoustic patterns (Wright *et al.*, 1983). These findings highlight the necessity of designing an appropriate soundscape within NICUs, one that simulates the acoustic conditions of the uterine environment. Operationally, this involves maintaining average sound pressure levels below 50 dB and emphasizing frequencies below 250 Hz (Graven and Browne, 2008), thereby promoting physiological stability, weight gain, sleep quality and reducing long-term language development disorders (Graven, 2000).

The critical visual period begins immediately after birth, when the combination of light and visual stimuli activates the primary visual cortex and related neural net-

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works. Assessment of visual development in neonates relies on multiple interdependent functional parameters, each maturing at different rates: visual acuity, horizontal visual field, color perception and binocular vision (Niessen, 2006). NICUs are not always optimized to support proper visual system maturation in preterm infants. For example, prolonged exposure to high-intensity artificial light can cause retinal damage proportional to wavelength, intensity and duration of exposure. Even natural light entering through large windows may exceed neonatal tolerance, as eyelids do not yet provide full protection. Another frequently overlooked aspect is the alternation of light and dark periods: appropriate modulation of environmental lighting is essential to promote circadian rhythm synchronization in neonates.

Prosthetic Architecture

Prosthetic architecture is designed to compensate, much like a prosthesis, for certain physical or cognitive disabilities. Creating a prosthetic environment requires a thorough understanding of the patient who will benefit from it, including personal characteristics and medical history, as well as an assessment of deficits and the development of compensatory strategies to ensure a good quality of life.

Most studies conducted to date on prosthetic architecture have focused on patients with Alzheimer's disease. This condition, even in its early stages, involves reduced environmental control due to diminished visual fields and eye movements, impaired depth and distance perception, decreased contrast sensitivity and reduced ability to detect moving objects and cool-colored stimuli.

A well-designed prosthetic environment can enhance residual autonomy and preserve patient dignity while minimizing risks and caregiver burden-effectively functioning as a "Non-Human Caregiver". Key principles for designing such environments include:

- furniture and furnishings: these should be easy to use and create an intimate, homelike atmosphere. Since certain behavioral disturbances may result from misinterpreted reflections, mirrors should be easily removable or obscurable;
- spatial readability: to facilitate perception of the surrounding environment, corners and edges should be highlighted in contrasting colors. Horizontal and vertical surfaces should be distinguished using different colors for floors, baseboards, walls and ceilings. Flooring should be uniform throughout and black-and-white checkerboards should be avoided, as dark tiles may be perceived as gaps or holes in the floor;
- orientation aids: the use of photographs, labels, and stylized signage on doors and walls can enhance wayfinding and clarify the functional purpose of each space. To support temporal orientation, large clocks and calendars should be

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installed at a height no greater than 170 cm, as individuals with dementia often have visual field deficits in the upper-middle range.

These design strategies aim to create environments that support autonomy, reduce disorientation, and provide a safe, comprehensible space tailored to the cognitive and sensory capacities of the patient.

Impact of Architecture on Home-Based Care

As reported in *L'infermiere. Manuale teorico-pratico di infermieristica* (Fabbri and Montalti, 2011), home-based care encompasses all healthcare and support interventions delivered directly at the patient's residence, aiming to reduce hospitalization while ensuring continuity of care. From an integrated medicine perspective, home care services must provide adequate support not only to the patient but also to their family unit.

Within the framework of the Individualized Care Plan (Piano Assistenziale Individualizzato, PAI), it is therefore necessary to include not only diagnostic and therapeutic interventions but also actions aimed at:

- preserving functional autonomy: enhancing the patient's residual abilities to maintain independence in daily activities;
- improving quality of daily life: creating conditions that promote comfort, well-being and meaningful engagement in routine tasks;
- supporting and training caregivers: guiding family members in the administrative management of care, as well as in the proper use of medical devices and equipment present in the home;
- organizing the domestic space: adapting the home environment to meet specific clinical needs without compromising its emotional and symbolic value.

These principles underscore the importance of considering architecture and environmental design as integral components of home-based care, where the physical space itself becomes a therapeutic and supportive element for both patients and caregivers.

Conclusions

The article concludes with the hope that the scientific evidence presented will be translated into future architectural projects for healthcare facilities and care environments. Architecture, conceived as an integrated therapeutic tool, has the potential to significantly and effectively promote patient health, both in preventive and curative contexts. By embedding evidence-based design principles into healthcare settings, future projects can transform the built environment into an ac-

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tive agent of well-being, supporting recovery, enhancing quality of life and fostering a truly holistic approach to patient care.

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