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Healing Architecture and Evidence-based Design

“Is there an architecture that helps you live?” For almost three decades Charles Jencks – co-founder of Maggie’s Centres in the UK – has insisted "architecture does matter for health, as placebo or to evoke hope for those in need". Despite placebos known to lack of clinical value, many assure they do work for illnesses deriving from emotional or mental stressors[1]. The same principle applies to these Centres created for people affected by cancer. Its users forgive functional issues in exchange for quality experience[2].

What Charles Jencks refers to as good architecture for health, other authors call Healing Architecture. Defined by Michael Mullins (Aalborg University) as, "the supporting factor in the human healing process" or more extensively, the planning approach that recognizes architecture as a variable to support the physical and mental wellbeing of staff, patients, and relatives.

This chapter develops on the premise that Healing Architecture works but cannot explain its curing capacities without support of an Evidence-based Design (E-bD) approach. A field redefined in this essay as the process that ensures architecture develops to enhance human health. As this relation is described, questions arise on the significance of architecture in well-known E-bD recommendations which for decades have guided designers. Clarification is sought with a background review on how Architecture has aimed the care process, followed by three sections which elaborate on: the need to distinguish technical devices from architectural features; medical planning preference over architectural design; and the failure in précising environmental factors for healing as natural, technical, or architectural.

To close the chapter, reflections are shared on how E-bD as an evolving field can not only assist architecture, but also Public Health! an area in need of studying how environment interventions affect and influence health behavior.

Has architecture been healing us?

Yes, as mentioned, the premise is that architecture heals. The question remains, how.

We've intuitively known that the physical environment (natural and built) affects our health,maybe since times way before ancient Greece. In recent history what has seemed to matter most are facts and proof, to the point that science in architecture has overruled its artistic best half.

Healing Architecture during its modern conception, leaned on the side of science in three distinctive occasions: sanitation, environmental risk, and perception.

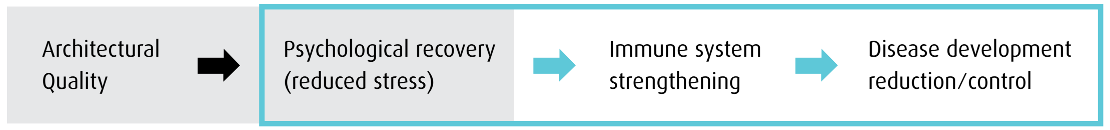
A pioneering document for buildings, was the patient ward design guidelines from Florence Nightingale’s 1859, Notes on Hospitals. Through statistical records, it alerted architects about the effects healthcare settings were having on human health. Her notes structured a number of measures which significantly improved the deplorable sanitary conditions of the Barracks Hospital (in the Crimean War of 1854). What is commonly referred to as the "Nightingale Ward", became a reference for hospital buildings; a space with limited amount of beds, three windowed sides, elements designed to trap dust, admit light, fresh air, plus other features which in general enhanced cleanliness and the comfort of patients[3].

Nearly a century later (mid-1940’s), the World Health Organization (WHO) redefined the concept of health, eventually including the environment (social, natural, and built) as one of its determinants. The concept took distance from a merely medical perspective towards a more

1 Erle C H Lim and Raymond C S Seet, “What Is the Place for Placebo in the Management of Psychogenic Disease?,” *Journal of the Royal Society of Medicine 100*, no. 2 February 2007): 60–61.

2 Dr Fionn Stevenson and Professor Mike Humphris, “A Post Occupancy Evaluation of the Dundee Maggie Centre” (Scottland: Ecological Design Group, School of Architecture, University of Dundee, March 2007), https://www.ads.org.uk/wp-content/uploads/4560_new-maggiecentre1.pdf.

3 Marie T. O’Toole, Mosby’s Medical Dictionary, 9th Edition (St. Louis, Mo.: Elsevier/Mosby, 2013).



Healing Architecture Rationale.
The blue box shows what is scientifically proven: reducing stress also reduces disease. What needs substantial evidence is how architectural quality reduces stress.

holistic approach, which included the effects of environmental factors on the health of individuals and societies. Thereon, health research combined multidisciplinary efforts within the scientific community to better understand the environment and develop tools for its assessment.
In the early 1960's, facing the vast and fast-growing scientific knowledge, architecture started considering environmental risk theory and its survey methods[4]. At the time, scientific communities were already concluding that socio-physical environments are medium for disease transmission, a stressor, and a source of danger.
Along the evermore duality of disease and health, environments were starting to also be considered a possible enabler for heath behavior[5], here the importance of Salutogenesis. Introduced by the medical sociologist Aaron Antonowsky in 1979, the theory offered a deeper knowledge and understanding of health and disease. It aimed at identifying factors originating health, contrary to the still ruling pathogenic approach which focuses on those causing disease. This definitely marked a milestone in conceptualizing what Healing Architecture would be years later.
In the 1980s, environmental psychology was moving forward in investigating the psychological effects of buildings. Two scientifically proven findings redefined architecture for health with renewed knowledge: that surrounding environments induce a psycho-physiological arousal, and the fact humans have a limited capacity for processing stimuli and information.
These theoretical grounds encouraged environmental designers to set course on pursuing behavior adaptation and stress coping through design; a path a.k.a. architectural determinism. The opportunity was given for architects to tackle the underlying causes of stress linked to the environment such as, the lack – or excess – of social contact, access to privacy, and control over environment[6].
As here depicted until now, Healing Architecture's early roots - relating environment and health – stem from a solid scientific background. It leaves the question open whether architecture alone has been able to heal us or not. A casual conversation a few years ago, gave away that this question might remain unanswered for some time.
When attending an international conference on urban health (ICUH, Manchester 2014), I had the great opportunity to sit next to Trevor Hancock (WHO, Healthy Cities) for the official get-together dinner. I shared highlights of my presentation held earlier titled, Walkability for Health; a work on possible links between urban streetscapes (street visual structure) and health status in Berlin. Back then for an ICUH, some kind of architecture intertwined with public health was a rare combination. Anyhow, after much discussion with other colleagues at the table, Hancock graciously came back to the work saying, "if we know for certain that ugly makes us ill, then we should explore more how aesthetics makes us healthy."

Architecture aiming the care process
Science laid the initial basis, and continued so with two important events in the 80's which shaped our early understanding of healing architecture as part of the care process.
The first event was a clinical-based research conducted by environmental psychologist Roger Ulrich in 1984 considered a landmark study in built environment and health outcome. Ulrich, a Professor of Texas A&M University, led a clinical research project that empirically proved a room with a view to nature does improve a patient's post-operative recovery. His quasi-experimental study showed a reduction in length of stay and pain medication in patients whose room had a nature view compared to those with a brick wall view. The study provided data on the direct impact of an environmental variable on the patient's outcome[7]. Roger Ulrich's research boosted the curiosity of architects about the interface between clinical/medical research and design. For healthcare managers, the cost reduction of such recovery processes was eye opening and motivating to keep exploring.
The second event was the development of a patient-centered care and healing hospital concept by the Planetree Organization (USA). Despite this organization being founded in 1978, it was not until the mid-80's that their research was materialized into a full testable model depicting the relationship between healthcare science and environmental science. They opened a 13-bed medical-surgical unit in San Francisco which included and evaluated the environment as a variable in patient recovery. It was the first time a healthcare design was built to structure a case study.
The design principles of the model were developed by Roslyn Lindheim, a professor of architecture at UC Berkeley who worked in collaboration with epidemiologists. The research and findings brought architectural solutions which evoked feelings of home, welcomed the patient's family and friends, valued human beings over technology, enabled patients to fully participate as partners in their own care, provided flexibility to personalize the care of each patient, and encouraged caregivers to be responsive to patients and foster a connection to nature and beauty[8].
The Planetree hospital became an exemplary model across the globe, settling healing architecture as a concept and to be considered for further exploration. In 2007 the Planetree Designation Program was launched to award organizations with the highest level of achievement in patient-centered care and healing environments based on best practice and standards.
The patient-centered approach was early adopted by other organizations such as the Picker Institute founded in 1986, which focused in assessing the patients' actual experience in hospital settings. As well did the Joint Commission International (JCI) in the early 90's, developing an accreditation and certification system with emphasis on patient, staff, and visitor safety.

The need of evidence in design
The continuous work of Planetree, the Picker Institute, and similar organizations have caught the eye of building professionals accountable for design solutions which mainly seek hospital cost-effectiveness and return on investment. For them, the economic benefits of designing environments which control patient anxiety and stress is palpable but not as evident as engineering for energy efficiency, for medical error prevention, or to reduce hospital-acquired conditions such as infections, falls, and injuries to staff, patients, and visitors. Strong evidence of the healing capacities of architecture was needed to structure compelling business cases.
Since the seminal study of Roger Ulrich in 1984, the most relevant effort in relating hospital environment design with health-related outcomes belongs to the Center for Health Design (CHD). Founded in 1993, its main purpose has been to launch several research and practice programs for the healthcare industry gradually defining Evidence-based Design (E-bD) as a discipline. CHD in clear reference to the concept of evidence-based medicine[9] defined E-bD as "the process of basing decisions about the built environment on credible research to achieve the best possible outcomes". In 1995 this Center with medical researchers from their database, began conducting systematic reviews of clinical literature on facility design and its effects[10].
The first grand review was commissioned to the Johns Hopkins University in 1998. It consisted in revising all published research showing a connection between design interventions and medical outcomes, such as where to place sinks to encourage hand washing, and how to position rooms and windows to reduce length of stay. 78,761 articles were reviewed and only 84 were acceptable from a scientific standpoint[11].
A second systematic review was commissioned in 2004 titled, "The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity". More than 600 studies were found in reputable journals from which 240 were included for analysis linking "a range of hospital environment aspects to: staff stress, patient safety, patient and family stress and healing, and overall healthcare quality and cost"[12].

4 John. Zeisel, *Inquiry by Design: Tools for Environment-Behavior Research* (Cambridge: Cambridge Univ. Press, 1984); Wolfgang F. E. Preiser, Harvey Z. Rabinowitz, and Edward T. White, *Post-Occupancy Evaluation* (New York: Van Nostrand Reinhold, 1988).
5 Daniel Stokols, "Establishing and Maintaining Healthy Environments: Toward a Social Ecology of Health Promotion," *American Psychologist* 47, no. 1 (1992): 6–22.
6 Paul A. Bell et al., *Environmental Psychology* (New York: Psychology Press, 2011).
7 R. Ulrich, "View through a Window May Influence Recovery from Surgery," Science 224, no. 4647 (April 27, 1984): 420–21, https://doi.org/10.1126/science.6143402.

8 Laura Gilpin and M. Schweitzer, "Twenty-five Years of Plantree Design," HCD Magazine (blog), August 31, 2003, https://www.healthcaredesignmagazine.com/architecture/twenty-five-years-planetree-design/; B. Arneill and F. Frasca-Beaulieu, "Healing Environments: Architecture and Design Conducive to Health," in *Putting Patients First: Designing and Practicing Patient-Centered Care*, by Susan B. Frampton, Laura Gilpin, and Patrick A. Charmel (San Francisco: Jossey-Bass, 2003).
9 A. L. Cochrane, *Effectiveness and Efficiency: Random Reflection on Health Services* (London: The Nuffield Provincial Hospitals Trust, 1972).
10 Haya R. Rubin et al., *Status Report (1998): An Investigation to Determine Whether the Built Environment Affects Patients' Medical Outcomes* (Martinez, Calif.: Center for Health Design, 1998).
11 Stefan. Lundin, "Healing Architecture: Evidence, Intuition, Dialogue" (Chalmers University of Technology, 2015).
12 Roger Ulrich et al., "The Role of the Physical Environment in the Hospital of the 21st Century: A Once-in-a-Lifetime Opportunity," September 2004.

Study	Inclusion/exclusion criteria	No. of studies for inclusion
1998 An Investigation to Determine Whether the Built Environment Affects Patient Medical Outcomes.	Articles in English published from 1966 on.	78,761 articles reviewed only 84 were accepted from a scientific standpoint
2004 The Role of the Physical Environment in the Hospital of the 21st Century	No information provided.	600 relevant articles, 240 articles were analyzed
2008 A review of the research literature on evidence-based healthcare design.	Studies in English. 32 keywords referred to healthcare-related issues and physical environmental factors.	Approx. 1,200 studies reviewed

(Table 1) CHD – Literature growth: The number of studies included for review increased significantly from 84 in 1998 to more than 1,200 in 2008.

E-bD then was defined by Ulrich as, a process of creating healthcare buildings, informed by the best evidence available, with the goal of improving health outcomes and continuing to monitor the success of designs for subsequent decision-making.
The third and last CHD review to date was realized in 2008: A Review of the Research Literature on Evidence-based Healthcare Design. Thirty-two search keywords, referred to health-related issues and physical environment factors, were employed to yield over 1,200 studies. After the review, CHD defined E-bD as "the process of basing decisions about the built environment on credible research to achieve the best possible outcomes".
Nearly a decade later since Roger Ulrich first defined E-bD, director emeritus of the CHD Kirk Hamilton and colleague David Watkins[13], extended the definition to multiple building types, by stating, "evidence-based design is a process for the contentious, explicit, and judicious use of current best evidence from research and practice in making critical decisions, together with an informed client, about the design of each individual and unique project." Expert practitioner Rosalyn Cama elaborated further précising the four basic components of this process as: gathering qualitative and quantitative knowledge; map strategic, cultural and research goals; hypothesize design outcomes and implement translational design; and measure and share outcomes[14].
The three prominent reviews led to other important milestones for the CHD, being the most relevant the launch of the Pebble Project in 2000; an initiative aiming to produce E-bD documents on patient, staff, and economic outcome improvement. Also important, was the creation of EDAC (Evidence-based Design Accreditation and Certification) in 2008, which still today offers architects, hospital executives, healthcare providers and researchers, a certification for introducing an evidence-based process in the design and development of healthcare settings.

Technical devices over architectural features
The three reviews redefined E-bD as a concept, positioned it as a research field, and it rapidly gained the interest of practitioners as the amount of research exponentially increased. From the first review realized in 1998 finding 84 studies to its last in 2008 with over 1,200 studies included, meant nearly a 1,300 percent increase of research in just one decade. A growth that Debra Levin president and CEO of the CHD predicted as sustainable in 2014, "If we were to do the search again today, I have no doubt the number would surpass 2,000."
The amount of research in the field without doubt increased, what today is still questioned, is if the amount of findings has also increased and most important, if there is strong evidence for an architecture that heals.
The following comparison of the three CHD reviews (see table 1), finds inspiration in an exercise Arch. Stefan Lundin included in his 2015 dissertation on healing architecture. Perhaps in this occasion, under the cap of a public health researcher, my search for evidence turns suspiciously more rigorous.
Two tables here presented contrast two trends, one showing literature growth (table 1) against another pointing evidence growth – or of significant findings – to be applied in practice (table 2). A third table summarizes all E-bD recommendations and discriminates hard factors attributable to technical devices from soft factors proper of architecture.
For this analysis the definition of hard and soft factors will be borrowed from business management (due to the common economic purposes with E-bD) and conceptualized for architecture as follows. Hard factors, are those features which visibly affect functions and processes with objective (measurable) outcomes such as injuries, errors, infection rates, among many others.
Soft factors, are qualities that support human behavior

13 Kirk Hamilton and David H Watkins, *Evidence-Based Design for Multiple Building Types* (Hoboken (N.J.): Wiley, 2009).
14 Rosalyn Cama, *Evidence-Based Healthcare Design* (Hoboken, N.J.: J. Wiley, 2009).

Study	Strategies to apply in practice	Significant new findings
1998 An Investigation to Determine Whether the Built Environment Affects Patient Medical Outcomes.	1. Quiet Coronary Care Unit (unclear if architectural development) 2. Music during Minor Surgery (technical devices, non-architectural) 3. Air Quality (technical devices, non-architectural) 4. Exposure to Daylight and Sunlight	1. Quiet hospital environment 4. Daylight and sunlight exposure is the only strategy Architecture directly relates to. In general, no new insight was provided.
2004 The Role of the Physical Environment in the Hospital of the 21st Century	1. Single-bed rooms 2. Acuity-adaptable rooms 3. Quiet hospital environments (strategy suggested in 1998) 4. Views of nature 5. Other positive distractions 6. Develop way-finding systems 7. Appropriate lighting (technical devices, most cases non-architectural) 8. Design wards and nurses' stations to reduce staff walking and fatigue	1. Single-bed rooms 2. Acuity-adaptable rooms 4. Views of nature 5. Other positive distractions 6. Develop way-finding systems 7. Appropriate lighting 8. Design wards and nurses' stations to reduce staff walking and fatigue
2008 A review of the research literature on evidence-based healthcare design.	1. Single-bed rooms (strategy suggested in 2004) 2. Access to daylight (strategy suggested in 1998) 3. Appropriate lightning (strategy suggested in 2004) 4. Views of nature (strategy suggested in 2004) 5. Noise-reducing finishes (technical devices, non-architectural) 6. Ceiling lifts (technical devices, non-architectural)	None

(Table 2) CDH – Evidence growth: Despite the increase of studies for inclusion throughout 10 years, the latest review did not show new findings.

CHD Systematic Reviews	11 E-bD Strategies in total suggested	Review analysis, feature classification
1998 **2004** **2008**	1. Exposure to daylight/sunlight 2. Single-bed rooms 3. Acuity-adaptable rooms 4, 5. Quiet hospital environments/ Noise-reducing finishes (technical feature, non-architectural) 6. Views of nature 7. Positive distractions (amenities) 8. Develop way-finding systems 9. Appropriate lighting (technical feature, most cases non-architectural) 10. Design wards and nurses' stations to reduce staff walking and fatigue 11. Ceiling lifts (technical feature, non-architectural)	3 Pertaining to Architecture (soft factors) • Exposure to daylight/sunlight • Acuity-adaptable rooms • Views of nature 7 Non-architectural (technical/hard factors) • Provide single-bed rooms • Positive distractions (amenities) • Develop way-finding systems (signage) • Appropriate lighting (technical devices, most cases non-architectural) • Quiet hospital environments/Noise-reducing finishes (technical devices, non-architectural) • Design wards and nurses' stations to reduce staff walking and fatigue • Ceiling lifts (technical devices, non-architectural)

(Table 3) E-bD Strategies into architectural and technical features: From the 3 CHD systematic reviews, 11 E-bD strategies were recommended in total; quietness and noise reduction overlap leaving the count in 10 strategies.

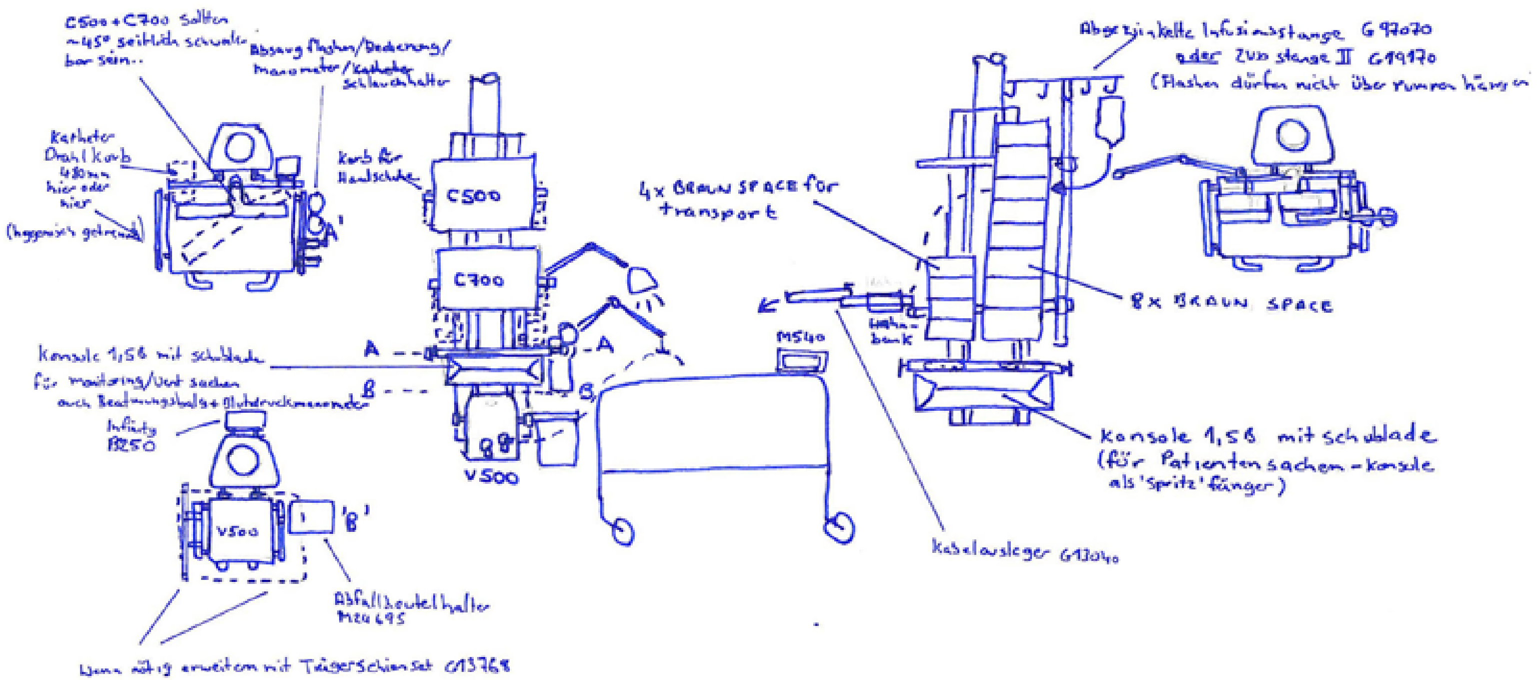
(individual or collective) influencing subjective outcomes (less easy to measure) such as satisfaction, stress, social cohesion, and others.
From comparing and analyzing results from these reviews one can conclude: (1) the volume of evidence finding architectural strategies supportive in care processes has improved but is not abundant, (2) growth of new findings has decreased, and (3) the relevance of architectural recommendations raise serious doubts. Doubts as the one architect Stefan Lundin phrases in his dissertation: "Is the research referred to merely confirming what has long been sensed, understood and applied already?" In a recent trip to Barcelona, similar doubts mirrored everywhere in the Hospital de la Santa Creu i Pau, today

(1) Nature seen from pavilions

(2) Art integrated in architecture

(3) Natural light supporting underground hallways

(1–3) Hospital de la Santa Creu i Sant Pau, Barcelona. Architect: Lluís Domènech i Montaner (1901–1930) (photos: Wilfried Humann)



(4) Sketch by Prof. Dr. Schaffartzik (UKB) and David Biddel (Dräger)

(5) Staff-focused environment by Dräger (photo: © Drägerwerk AG & Co. KGaA)

(6) Patient-focused environment by Graft Architects, Virchow Klinikum, Berlin (photo: Tobias Hein)

(7) Nurse station by Graft Architects, Virchow Klinikum, Berlin (photo: Tobias Hein)

mostly a museum. As walking along its corridors and landscape, the purpose of designing exclusively for healing was called into question. Looking at its rooms mostly stripped from medical equipment, I wondered if Healing Architecture was not more than simply good architecture.

Architecture or technical-medical plans?

If Healing Architecture is not more that good architecture, then why insist in developing this concept. After analyzing the CHD systematic reviews, it seems to be more sensible for E-bD practitioners to implement technical features rather than a rightful development of an architectural design. As experienced in our formation and practice, we also tend to succumb what hospital functionality and efficiency dictates over creativity and exploration. Medical input in synergy with technological requirements, often trigger a process of re-drawing in two dimensions spatial demands over and over in detriment of spatial quality and other architectural factors.

As seen in the CHD reviews, most studies miss distinguishing technical features from architectural quality and its factors. The problem might lie in the evaluation frameworks used to assist surveyors in differing evidence-based designs with an architectural character from those showing extruded medical-technical plans (from 2d to 3d).

Aside from conceptualizing terms properly, research activities in general face other common limitations, such as attaining useful results within limited budget. Analyzing small but representative samples of a problem, cuts research times and resources making studies feasible. This is the case of studying the intensive care unit (ICU) in regards to the hospital. The ICU is arguably the department with highest impacts on care delivery within hospitals and of greatest concern for healthcare professionals[15]. Its economic, technical, spatial, and staff demands can topple a hospital's budget with services estimated to suffer a higher demand and growth in upcoming years[16]. Studying the ICU environment and its complexities could very well clarify how to tackle larger scale issues concerning architecture and care processes.

In 2013, two architects from the Academy for Design & Health realized an environment evaluation study on ICUs called, Critical Care Design – Trends in Award Winning Designs. It was based on an annual competition organized by the Society of Critical Care medicine between 1992 and 2013. The competition jury used two scoring sheets to assess relevant characteristics of the projects.

Scoring sheet 1, studied environmental qualities and sheet 2, its particular features. Using both sheets, the researchers made a comparative data analysis to 12 winning projects, resulting in the definition of ten design trends[17].

The more I read through this evaluation study, the more arguments I found to establish differences between architectural projects and medical-technical plans. In trail for a future study, both scoring sheets were distinguished into architectural and non-architectural features using the classification from previous CHD reviews (see table 4). All ten design trends were then classified into: technical recommendations, technical-medical planning, and architectural design (see table 5).

This rough start of a merely indicative study, showed the need of developing or improving conceptual frameworks for architecture evaluation in healthcare settings.

More differences between medical planning and architecture, are emphasized with the following image comparison of two intensive care environments. As architects for health would say, one with a staff-focused design, the other with a more patient-centered one.

Simply explained, a staff-focused design helps medical teams easily navigate the environment with comfort and safety. A patient-centered design ensures patients and relatives an environment stress-free from care delivery mechanisms. Ideally these two strategies are not mutually exclusive, on the contrary they should be reciprocal and interdependent. Many are the cases where patient-centered designs trade-off staff satisfaction to ensure patient wellbeing, disregarding the fact that staff is a leading

15 Charles D Cadenhead, "Critical Care Design Twenty Years of Winners and Future Trends: An Investigative Study" (Healthcare Design Conference, Orlando, Florida, November 18, 2013).

16 Jason N. Katz, Aslan T. Turer, and Richard C. Becker, "Cardiology and the Critical Care Crisis: A Perspective," *Journal of the American College of Cardiology* 49, no. 12 (March 27, 2007): 1279–82, https://doi.org/10.1016/j.jacc.2006.11.036.

17 Charles D Cadenhead and Diana C Anderson, "Critical Care Design: Trends in Award Winning Designs," Critical Care Design: Trends in Award Winning Designs, 2013, http://www.worldhealthdesign.com/critical-care-design-trends-in-award-winning-designs.aspx.

SSCM Scoring Sheet 1 Environmental Qualities:	CHD Reviews – feature classification	SSCM Scoring Sheet 2 Features	CHD Reviews – feature classification
1. Visual (color, light) 2. Simplicity (neatness) 3. Organization (layout) 4. Auditory (noise, avoidance, therapeutic sound) 5. Psychological Amenities (TV, VCR, plants)	Architectural • Visual • Simplicity (neatness) • Organization (layout) Non-architectural (technical factors) • Auditory • Psychological Amenities	1. Size 2. Functionality 3. Safety/Security 4. Decor 5. Amenities (refreshment, toiletry, sleep, seating) 6. Technology	• Architectural • Size • Functionality Non-architectural (technical factors) • Safety/Security • Decor • Amenities • Technology

(Table 4) Scoring sheets distinguished by architectural and non-architectural features

2 Technical recommendations (non-architectural)
- Stabilized patient room size. The standard size will be approximately 23m2. Important design considerations derive from patient bed placement and delivery of medical support substitution of headwalls (medical devices placed vertically at the head of the patient) for ceiling-mounted articulating arms called booms (monitoring, outlets, and gasses)
- Remote technology & support systems. In ICU patient rooms, ceiling-mounted booms are preferred over traditional headwall devices.

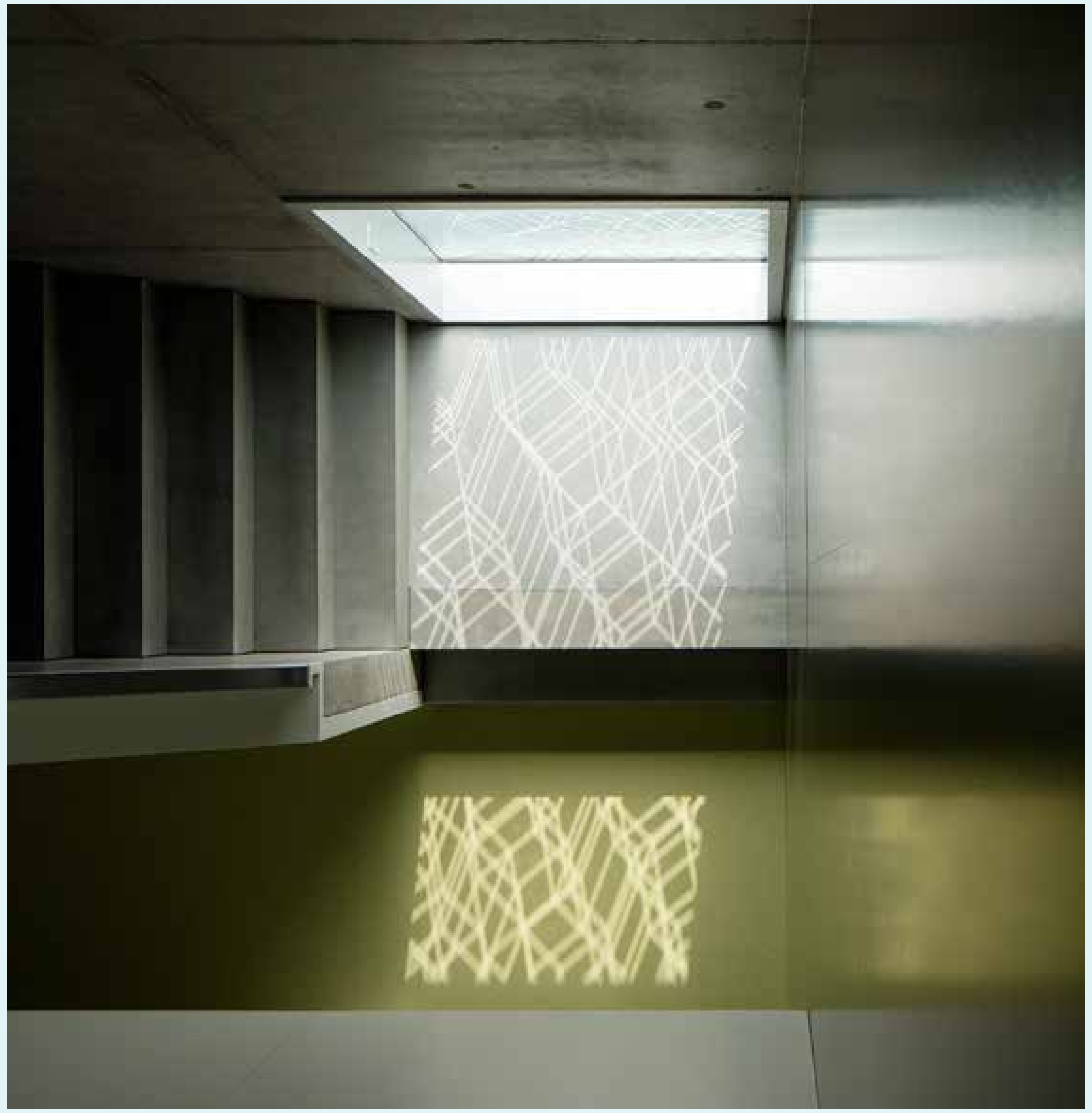
5 Technical-medical planning solutions
- Larger, consolidated units. As demand for service grows, an increase in number of units, larger units, and space for support areas, will be seen.
- Continued design for interdisciplinary teams. Staff work stations tend to have a combination of centralized & decentralized layouts.
- Integration of diagnosis & treatment facilities. These services are eventually shared with the entire hospital.
- Integration of administration & support spaces within the unit.
- Segregated circulation. Distinction of circulation regarding on-stage (patients with staff) and off-stage (only staff) separations.

2 Architectural design directives
- Defined in-room family space. Most recent units incorporate designated family and visitor space in the unit, or within the patient room itself.
- Visual & Physical Access to Nature. Nature incorporated in the unit for patients, families and staff.

1 No-trend
- Variable unit geometric form. There are no clear trends pointing at a specific ICU geometry

(Table 5) 10 ICU design trends – classified

factor for quality of care frequently carrying out long working shifts under harsh environmental conditions.
The first images (Images 4, 5), depict a technical sketch developed by Prof. Dr. Schaffartzik (UKB) with David Biddel (Dräger) and an ICU room as result of a tight research collaboration. This teamwork has led Dräger – a well-known healthcare manufacturing company – to constantly improve its ICU products in the workplace. The other two images (Images 6, 7) were taken at the Charité Medical University Berlin, where Prof. Dr. Claudia Spies and Graft Architects also teamed to research, delivering a new treatment concept within a new kind of intensive care unit. This ICU design comprehensively combined factors for stress-reduction such as: room acoustics (reducing noise of alarms and signals), temperature control, and visual structure (from material, light, color, and media surfaces). It maximized privacy for patients and family members, disguising the technical equipment in the background and buffering alarm sounds.



Staff-focused design integrating light and art, central sterilization in Martigny Valais Hospital, architects: bauzeit architekten GmbH (2017) (photo: © yves-andre.ch)

Environmental factors and its healing effects
The CHD reviews and ICU evaluations have helped discern technical devices from architectural features and differ medical-technical planning from architecture. In an effort to keep defining the elements and capacities of Healing Architecture, it is important to look at environmental factors and variables proven to influence human health and well-being.
In late 2012 an extensive review was realized at the Technical University of Berlin about the physiological and psychological influences of environmental features which impact patient recovery and staff performance[18]. The following section of this chapter updates the text and descry which factors are natural, technical, or architectural. The information is written as a glossary of empirical findings, standing alone from the rest of the chapter. Here the reader is encouraged to move on to the last section, "E-bD research an evolving field" and always come back for facts and references.

Natural factors
1. Light
There is a significant amount of clinical and non-clinical evidence showing the effect of light on human health recovery and well-being. Light can impact: pain, sleep, circadian rhythm, hospitalization period, medical errors, mortality, stress, depression, user satisfaction, mood and orientation, as well as staff effectiveness[19]. Daylight is preferred over electric light as a primary source of illumination in working and living settings[20]. It is not superior to artificial light when it comes to carrying out activities, but does have clear advantages for all kinds of physiological processes and overall health[21]. Daylight tends to be brighter and have a more balanced spectrum of

colors than most artificial light sources. It affects health through the visual system, the biological system, or the psychological system[22].

1.1 Length of patient hospitalization and mortality
Beauchemin and Hays[23] show in their research that patients with severe depression and placed in sunny rooms, stay on average 2.6 days less than patients in dull rooms. According to Benedetti et al.[24], patients with bipolar disorder having access to direct sunlight in the morning stay on average 3.67 days less than patients in rooms with sunlight access in the evening[25]. Female patients with myocardial infarction in a cardiac intensive-care unit treated in sunny rooms stayed a shorter time in than those in dull rooms (2.3 days in sunny rooms, 3.3 days in dull rooms). Mortality in both sexes was also higher in dull rooms[26].

1.2 Human biological processes and circadium rythm
According to Aarts and Westerlaken[27], daylight (among other factors) controls the biological clock responsible for body temperature and the sleep-wake rhythm through production of hormones, such as melatonin (sleeping, activity, and energy hormone) and cortisol (stress hormone).

1.3 Pain
According to Walch et al.[28], patients recovering from spinal surgery place in a brighter part of the hospital experienced less perceived stress, marginally less pain, and took 22% less analgesic medication per hour than patients on the dim side of the hospital.

1.4 Depression
Wirz-Justice et al.[29] affirm that patients with seasonal affective disorder reduce depressive symptoms and improve daily secretion of melatonin and cortisol after regular morning walks outdoors.

1.5 Mood and perception
Daylight impacts satisfaction, mood, and performance of work through sensory stimulation, changes in daylight (color, shadow, brightness contrast, position of the sun)[30], and thermal sensations (perceived effect of sunlight, wind, and humidity)[31]. It also offers people a sense of place and time and prevents feelings of disorientation[32]. Nurses who are provided with three hours of exposure to daylight during work shifts reported greater work satisfaction[33].

1.6 Physiological processes
According to McColl and Veitch[34], most of the vitamin D in the blood can only be derived from exposure to light.

2. Nature
The "Biophilia Hypothesis" suggests that there is an instinctive bond between human beings and other living system[35]. Research on the effect of nature on human health is based on this hypothesis. In healthcare environments, nature is connected to the three main subjects: views of nature, therapeutic gardens, and indoor plants.

2.1 View of nature
Views of nature in buildings are obviously connected to the subject of windows. According to Devlin and Arneill[36], access to windows and views helps patients develop a perceptual and cognitive link with the external environment. Patient satisfaction is achieved when windows occupy 20 to 30% of the room.

2.2 Pain and human physiological responses
Views of nature or images of nature may provide relief from pain, raise pain tolerance, and reduce post-surgical recovery time. It also provides additional support to reduce pain as "distraction therapy"[37]. Patients with rooms with a view of nature after bladder surgery required fewer strong painkillers and shorter length of stay, comparing to those who were assigned to a room with the view of a brick wall[38]. According to Wilson[39], views of nature in intensive care units lower levels of organic delirium. Natural scene murals at the bed was found to reduced pain during bronchoscopy procedures[40].
The blood pressure and pulse of blood donors were lower while watching videos of natural settings (a park and a stream) in waiting rooms[41]. Views of real aquariums and/or ocean scenic images improved the food intake of people with Alzheimer's disease[42].

2.3 Stress alleviation - restoration theory
"Restoration theory" describes the relationship between the view of green areas and improvement in health. It is a stress recovery mechanism categorized in three types[43]:
– Affective recovery refers to positive emotions and mood improvement.
– Physiological recovery refers to sympathetic-specific mechanisms related to positive change in blood pressure, heart rate, skin[44].
– Cognitive recovery assumes that nature stimulation and fascination invoke involuntary attention, modestly allowing directed-attention mechanisms a chance to regenerate[45].
According to Van den Berg and Winsum-Westra[46], natural views were associated with better performance in attention measures, it would hence be plausible to assume that a view of greenery will also have significant positive effects to reduce the chances of medical errors.
Adults and children (in particular females) who live in houses with views of urban nature have a greater ability to concentrate, are less aggressive, and more self-disciplined than individuals who live in houses with views of built environments. The former also reported greater well-being than the latter[47].

2.4 Therapeutic gardens
Stress restoration is the key motivation for patients, family members, and staff to use gardens in healthcare facilities[48]. This idea is supported by two important studies: In their studies, Cooper-Marcus and Barnes[49] and Whitehouse et al[50] found that hospital gardens improved moods of all hospital users and that many healthcare employees used gardens as an effective means for escape from work stress and aversive conditions. As more evidence is showing that hospital gardens increase staff satisfaction, it may help hire and retain qualified personnel[51]. Also, according to Sadler[52] gardens and nature in hospitals can significantly increase patient satisfaction and perception of the overall quality of care. This increased patient satisfaction can create a positive market identity and thereby improve economic or financial outcomes[53]. Exercising and social support are other mechanisms through which gardens and natural settings may improve people's health and well-being[54]. A study in 1991, Hartig, Mang, and Evans exemplify this association between nature and health. After performing mentally fatiguing tasks, the students who walked through nature as a means to recover showed higher performance in attention tests afterwards in comparison to those who recovered through passive relaxation[55].

2.5 Indoor plants
Research on indoor plants in clinical settings mainly focused on health risks rather than benefits. Transmission of diseases through the soil and water of plants has not been scientifically confirmed. On the contrary, Fjeld[56] (Study 2 in the research) found out that foliage plants and full spectrum lamps reduced sick building syndromes such as fatigue, headaches, dry throat and itching, and/or dry hands in a radiology department at a Norwegian hospital. Additionally, an inverse linear relationship was found between performance in productivity tasks and number of plants in the office; lower concentration levels but higher self-reported perceptions of performance improvement[57].

3. Smell
Aromatherapy is applying compounds for improving psychological or physical well-being through inhalation. In a study regarding 40 post-open-heart surgery patients in Iran, lavender essential oil 2% was placed with a cotton swab in patients' oxygen masks and the patients breathed for 10 minutes. The results show that aromatherapy significantly alleviated stress and improved sleep quality in intensive care unit patients after two days of the experimental treatment[58]. It implies the possibility of applying this method as an independent nursing intervention to stabilize vital signs such as blood pressure, heart rate, and central venous pressure, etc.[59].

Staff-focused design integrating views to nature, central sterilization in Martigny Valais Hospital, architects: bauzeit architekten GmbH (2017) (photo: © yves-andre.ch)

Technical Factors

1. Lighting

1.1 Staff performance and medical error

The level of light needed for task performance increases with age due to reduced transmittance of aging eye lenses. Performance on visual tasks increases as light levels increase[60]. Bright light (1,500 lux) improves the performance of duties, which is especially important in reducing errors in medication[61]. High level daylight without glare, shadows, and reflection is superior for tasks involving fine color discrimination[62]. There is some indication that certain properties of indoor lighting, such as luminance level, lamp color, and flicker can affect people's mood and performance[63]. Dim lighting in counseling rooms could enhance communication between patients and doctors[64].

1.2 Sleep

Providing cycled lighting (reduced light levels in the night) in neonatal intensive-care units results in improved sleep and weight gain among preterm infants[65]. Exposure to higher levels of light (1,000 lux) for longer periods during the day increases sleeping efficiency for people with dementia[66].

1.3 Depression

Exposure to artificial high-intensity light (usually ranging between 2,500 lux and 10,000 lux) in the morning has been successfully used in the treatment of patients with seasonal affective disorder[67] and reducing agitation of patients with Alzheimer's disease[68].

1.4 Mood and perception

Nurses exposed to intermittent bright light during nightshifts is effective in adapting circadian rhythms of nightshift workers, improving subjective well-being, and reducing distress level[69].

1.5 Physiological processes

Exposure to light is an effective treatment for neonatal hyperbilirubinaemia (neonatal jaundice)[70].

2. Acoustics

There are many manifestations of sound in the healthcare setting: noise, music, speech privacy, and speech intelligibility[71]. Peace and quiet are also important for good communication, both with patients and among the staff[72]. There are different sources of noise in hospital environments, such as alarms, equipment, computers, printing, people, staff communication, etc. Besides, hospital

Staff-focused design integrating access to nature, central sterilization in Martigny Valais Hospital, architects: bauzeit architekten GmbH (2017) (photo: © yves-andre.ch)

materials are sound-reflecting rather than sound-absorbing[73]. As a result, noise in the hospital setting usually exceeds the values recommended in the guidelines of The World Health Organization (WHO). These guidelines recommend continuous background noise limits in hospital patient rooms at 35 dB(A) during the day and 30 dB(A) during the night, with peaks in wards not to exceed 40 dB(A) at night. However, many studies indicate that peak hospital noise levels often exceed 85 dB(A) to 90 dB(A)[74]. A poor acoustic environment may well lead to many errors in automatic transcription of doctors' spoken notes, and automatic dispensing of pharmaceuticals, etc.[75]. Moreover, speech recognition systems, which are critical for the functioning of a digital hospital, cannot interpret sound signals in poor acoustic environments[76].

2.1 Noise effects on patients

Noise is a source of awakenings and sleep disruption among patients. Studies by Slevin et al. in 2000[77], Johnson in 2001[78], and Zahr and de Traversay in 1995[79] show that in the NICU unit, loud noise levels decrease oxygen saturation (increasing need for oxygen therapy), elevate blood pressure, increase heart and respiration rate, and worsen sleep.

In 2000, Liu and Tan[80], found that elevated noise levels induce cardiovascular and endocrine effects. Minckley[81]observed that noise levels higher than 60 dB (A) increase the pain medication required by post-surgery patients. In Fife and Rappaport's[82] study in 1976, patients were found to need more recovery time after the cataract surgery when noise level were elevated due to construction.

2.2 Noise effects on staff

Unexpected noises may increase medication errors, perceived work pressure, stress, and annoyance. High levels of noise increases fatigue and emotional exhaustion. In better acoustical conditions, staff experienced less work demands and reported less pressure and strain. A study by Murthy et al.[83] showed under typical noise level in operating rooms (over 77 dB(A)), the threshold level for speech reception increased by 25%, meaning verbal communication was only possible when speaking in a raised voice, while speech discrimination level decreased by 23%. The same study also shows that anesthetists' short-term memory and efficiency declined under such noise conditions[84].

As Joseph and Ulrich cited Parsons and Hartig[85], adequate performance during elevated noise level is

Patient accomodation at the Bispebjerg Pychiatric Center, Copenhagen, Denmark,Henning Larsen Architects (2015)

maintained by increasing effort, as evidenced by heightened cardiovascular response and other physiological mobilization.

3. Air Quality

3.1 Ventilation and hospital safety

The rate at which the indoor air is renewed per unit of time is called “ventilation rate”. It is usually measured in liters per second (L/s). In all building types, a ventilation rate of less than 10 L/s per person is proven to lead to health problems and adversely affect the perception of the air quality[86].

Ventilation can be improved by both natural and artificial routes. Studies on artificial ventilation and its impact on health outcomes are mainly associated with the dissemination of infectious diseases while studies on natural ventilation are mainly related to window types and sizes[87].

Hospital air quality plays a decisive role in determining the concentration of pathogens in the air, and thereby has major effects on the frequency of airborne infectious diseases. During the SARS outbreak epidemic in Canada, higher ventilation rates resulted in a significantly lower infection rate among healthcare workers[88]. Boswell and Fox’s[89] study shows that the use of portable High Efficiency Particulate Air (HEPA) filters in a clinical setting significantly reduces environmental contamination by Methicillin-resistant Staphylococcus aureus (MRSA).

Immune-compromised and other high-acuity patients have a lower incidence of infection when housed in HEPA-filtered isolation. HEPA filters, combined with Laminar Air Flow (LAF) can reduce air contamination to the lowest level; thus it is recommended for operating rooms and areas with ultraclean room requirements. Airflow direction also has an impact on the rate of nosocomial infections. Rooms with infectious patients should have negative pressure to prevent the spread of contaminated air. The immune-compromised and immune-suppressed accommodation should have positive pressure to protect them from contaminated air[90].

3.2 Temperature and human health

Patients generally find a stable temperature between 21.5°C to 22°C and a humidity rate between 30 and 70% comfortable[91]. Extreme highs and lows in temperature lead to complaints and dissatisfaction among the staff in office environments and adversely affect their performance of duties[92].

Sick Building Syndrome (SBS) symptoms increase linearly at temperatures exceeding 22°C[93]. Hot temperatures can lead to negative social reactions such as crowding, aggression, and other negative reactions to others[94].

Architectural Factors

1. Stress reduction features

Ulrich, Borgren, and Lundin[95] developed a design theory which could reduce aggression in psychiatric facilities. The architectural features which reduce stress from involuntary admission, thereby reduce aggression are: single patient rooms with own bathrooms; smaller wards for smaller patient group size; moveable seating in spacious dayrooms or lounges; low noise level with good acoustics; views to the nature; art resembling nature; accessible gardens; daylight exposure; staff stations close to patients with good visibility; homelike qualities; and easy wayfinding, etc[96].

2. Elasticity and flexibility

Since early 2000s neuroscience and architecture has explored the broad range of human experiences with elements of space and design. Many have been the findings and results on improving disabilities due to brain damage or neurological disorders in general.

Unit and work environment at the Norwegian Radium Hospital for cancer research and treatment, Oslo, Norway, Henning Larsen Architects (2015) (photo: Adam Mørk)

Strategies emphasize the use of natural light and stimulating spaces to directly impact neuron growth thereby empower a person’s rehabilitation.

For example, in a neuro-rehabilitation facility for people with specific health issues from birth, accidents, and injury (which draw psycho-emotional differences), our purpose is not only to help them re-learn doing their everyday activities but evermore improve performance beyond expectations with renewed brain capacities. In order to foster this recovery and rehabilitation pathway, the design of healthcare facilities should consider its elasticity (the ability to expand and possibly reduce in size) and flexibility (the possibility to change room functions)[97].

3. Unit and work environment

There is a growing and convincing body of evidence suggesting that improved hospital design can make the jobs of staff easier. As found in studies by Burgio et al.[98] in 1990, walking accounted for 28.9% of nurses working time followed by patient-care activities that accounted for 56.9%. The time nursing staff spent on walking responds to the type of unit layout (e.g. radial, single corridor, double corridor). Time saved from walking can be translated into patient care activities and interaction with family members[99].

Radial type reduces walking time compared to single corridor and rectangular units because it provides better visual control of the patient from the nursing station. However radial designs might provide less flexibility in managing patient loads[100]. Decentralized nurse stations can reduce staff’s walking time only when a decentralized supply is placed near the nurse stations. Central location of supplies could double staff-walking even when nurse stations are decentralized. Decentralized pharmacy systems reduce medication delivery times more than 50%[101]. In 1990, Pierce et.al[102] redesigned an outpatient pharmacy layout to improve workflow, reduce waiting times, and increase patient satisfaction with service.

Pathwayfinding with natural light, main entrance to the University Hospital Bern, architects: bauzeit architekten GmbH (2017) (photo: © yves-andre.ch)

4. Patient accommodation

4.1 Single-bed versus multi-bed

Single accommodation is recommended for quality of care such as safety, privacy, dignity confidentiality, and flexibility. National Health Service Estates found out that 52% preferred to stay in a single room while 37% preferred a shared space[103]. Conflicting preferences in hospital accommodation among patients showed a link between the severity of illness and the desire for privacy[104].

4.2 Hospital acquired infection

Single-bed rooms, single-bed cubicles with partitions, and isolation rooms decrease the risk of hospital acquired infection by airborne, contact, and waterborne transmission compared to multiple-bed rooms. Multi-bed accommodations increase the probability and speed of outbreaks; for example, the SARS outbreak in Canada where multi-bed rooms failed in preventing and controlling hospital acquired infections. A study by Farquharson and Baguley[105] shows that approximately 75% of the SARS cases in Canada resulted from exposure to hospital settings.

Single-bed rooms facilitate cleaning and decontamination of rooms. On the contrary, cleaning of multi-bed patient rooms implies disruption in functionality and costly transportation of patients, i.e. the temporary removal of all patients from these rooms[106].

4.3 Medical errors

Single rooms might decrease the number of the medical errors due to patient transfer between rooms or units. NHS Estates[107] reported that transfers fell by 90% and medication errors by 67% when the US Clarian Hospital changed its coronary intensive care from 2-bed rooms to single acuity-adjustable family-centered rooms[108].

4.4 Sleep quality

Noises from other patients are the most disturbing factor and major cause of sleep loss in multi-bed rooms, whereas single-bed rooms can reduce noise disturbance from roommates, visitors and healthcare staff and thereby improve patient sleep[109].

4.5 Care quality

Single-bed rooms increase patient privacy through perception of control and autonomy. This facilitates good communication between patient, staff, and family. This is particularly important because patients are more likely to withhold information when they experience a lack of auditory and visual privacy[110]. This also applies to staff members. In multi-bed rooms, healthcare staff are reluctant to discuss patients' issues or give information when they are within hearing distance of a roommate, out of respect for patient privacy[111]. Single-bed rooms are thus better than multi-bed rooms in supporting or accommodating the presence of family and friends.

Patient-family interactions improve patients' physiological outcomes, facilitate progress, and help to deal with treatments effectively. The support from interacting with family lowers a patient's levels of stress, fear, anxiety, and depression. A study by Chatham[112] in 1978 shows that specific social interactions with families (such as eye contact, frequent touch, and verbal orientation to time, person, and place) can reduce disorientation, alertness, confusion, anxiety, and improve sleep quality of open-heart surgery patients. Restricted visiting hours in open-plan multi-bed rooms deter family visit and thereby reduce family members' social support.

5. Orientation and wayfinding

Illegible public buildings might confuse users and create a feeling of incompetence. As topological complexity increases, the overall legibility of the environment decreases, reducing understanding in spatial layout and wayfinding performance. A regular but asymmetrical layout is easier to remember and learn than a regular and symmetrical one. Continuity in paths, i.e. loop-like paths, is preferred over dead ends because the latter cause frustration for people[113].

The lack of differentiation in an environment affects orientation and wayfinding of both newcomers and more experienced users. Creating landmarks and spatial differentiation in appearance are thus essential for users' understanding of a building's spatial organization. Using color and shape, art, graphic information as reference points can improve building interior memory[114]. Good signposting combined with written and verbal information improves people's movements through complex buildings[115].

Clear routing system is especially important in healthcare settings for cognitive impaired patients, such as people with dementia. According to Marquard[116], the following four guidelines could be implemented in all designs to support the way finding abilities of people with dementia: 1. no need for new or higher skills; 2. allow visual access and overviews; 3. reduce decision making; and 4. increase architectural legibility.

6. Interior design

A study with telephone interviews realized to 380 discharged inpatients helped determine that environmental satisfaction was a significant predictor of overall satisfaction with healthcare, ranking only below perceived quality of nursing and clinical care[117]. The study also identified specific environmental factors that were perceived to be pleasing and satisfactory to patients, including: 1. color of the wall, artwork, comfortable bed, television working properly, and easy access to anything in the patient room; 2. a window with a nice view, an accessible bathroom in the room, and a room located away from noisier areas of unit; 3. adequate lighting, quiet surroundings, and a comfortable temperature; 4. a private room, environmental means for privacy (e.g. a closed door); and 5. cleanliness of the room[118].

Redecorating and renovating often lead to positive hospital evaluations. Changing the environment to improve comfort and appeal increases satisfaction in patient and their families. Appropriate interior design can also impact the patient and staff safety. Non-slippery floors, appropriate door openings, placement of rails and accessories, and appropriate heights of toilet and furniture decrease patient fall accidents in bathroom and bedroom areas. Available and appropriate ceiling lifts reduce the incidence of musculoskeletal injury of staff and the cost of injury claims. However, bedrails are ineffective for reducing falls. Appropriate numbers and locations of hand-washing facilities influence compliance and infection rates[119].

7. Interiors and social interaction

Lounges, day rooms, and waiting rooms with comfortable movable furniture facilitate social interactions and improve eating behaviors, as indicated by the increased food consumption of geriatric patients[120]. A study in 1972 found out that different seating arrangements of hospitalized male psychiatric patients can discourage or encourage social and personal interaction. Chairs in rows along the walls in waiting rooms discourage social interaction[121].

8. Materials

Sound-absorbing ceiling tiles and panels reduce noise levels and sound reverberation time perceptions, improving patient outcome, speech intelligibility, and lowering work pressure among staff[122]. Easily cleanable, nonporous material for floor and furniture coverings decrease the rate of the contact infections[123]. The use of homely material increases social interaction and the feeling of the control (carpeted flooring increases the time of visitor stay compared to vinyl flooring)[124].

9. Colors

Colors can manifest themselves in the interior in different ways: in the composition of the light and in the finishing of walls, floors, furniture, as others. There are four properties in color stimuli: the brightness/intensity (amount of light energy contained in the spectrum of the color), luminance (perceived brightness), hue (dominance wavelength), and saturation (determines the vibrancy of the color)[125].

Colors can affect people's perception and experience in certain environments (e.g. perception of spaciousness is attributed more to the brightness than the hue of a color) but there are no causal relationships between particular colors and health outcomes[126]. In Jacobs and Hustmyer's[127] study, no significant effects of red, yellow, and blue is found to affect respiration or heart rates. Besides, associations between certain colors and emotions are culturally learned and determined by the physiological and psychological makeup of people, it is ineffective to develop universal guidelines of color use in healthcare settings[128].

Interiors and social interaction at Herlev Hospital, Helev, Denmark, Henning Larsen Architects (2015)

10. Integrated Art

10.1 Visual art

The effect of visual arts in the form of live and video-recorded performances, drawings and paintings, and traditional and contemporary art on mental health are widely studied. A literature review by Daykin et al.[129] in 2006 suggests that art can have a therapeutic effect on people suffering with mental disorders by mitigating depression, anxiety, and low self-esteem, improving social integration, and alleviating isolation. However, Ulrich[130] revealed that inappropriate visual art styles are related to the disturbance of mental health condition; Staricoff and Loppert[131] also showed that the psychological effects of being engaged with creative arts, such as dance, drama, music, visual arts, and creative writing in mental health institutions can be too demanding for some patients.

10.2 Contemplative art

10.2.1 Music

Music can induce relaxation and pleasure to the human body. This lowers the activity levels of neuroendocrine and sympathetic nervous systems, creating decrease in anxiety level, heart rate, respiratory rate, and increase in body temperature[132]. Music may also have a calming, relaxing, and even therapeutic effect, as it has been used in different healthcawre settings such as oncology, maternity, postoperative, intensive care, pediatric care[133]. Listening to individualized music, based on personal preferences, is effective in decreasing behavioral problems and decreasing stress level significantly. In Gerdner's[134] study, classical music was found to reduce the level of agitation among patients with dementia.

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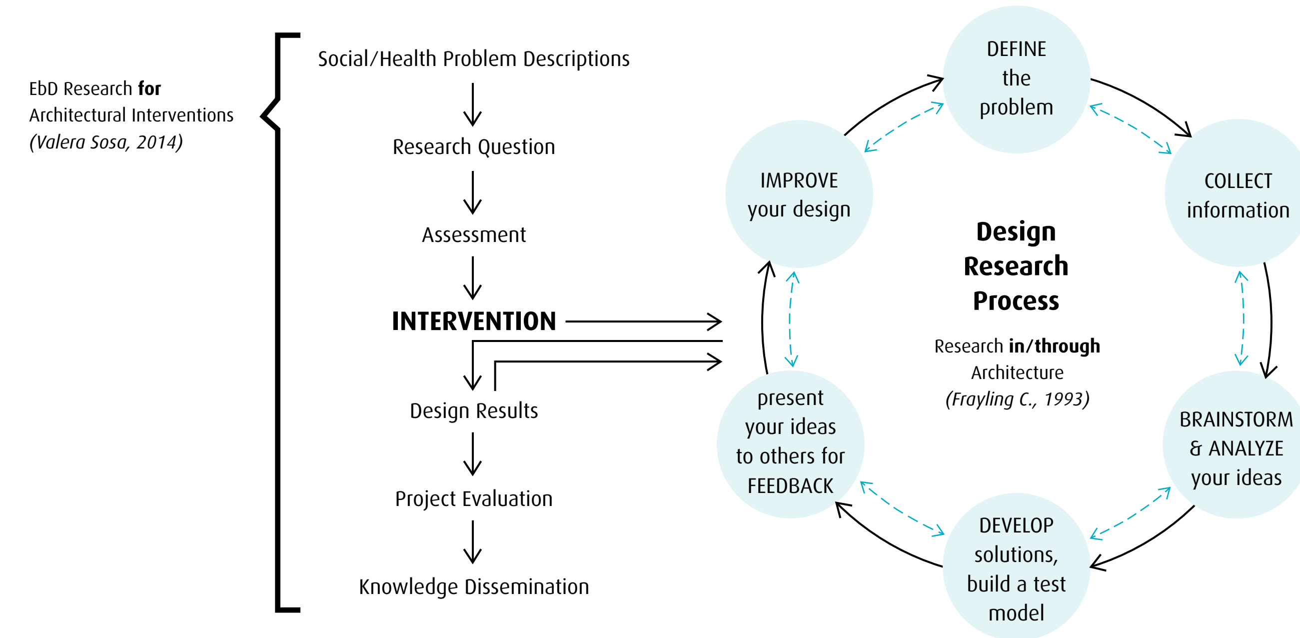

Evidence-based design research model for Architectural Interventions.
"Get your facts first, and then you can distort them as much as you please." – Mark Twain

Evidence-based design research, an evolving field

Since evidence-based design started offering insights and strategies to facility designers[135], it has received justified criticism for promoting solutions to the detriment of architectural quality. As professor Cor Wagenaar (University of Groningen) recently implied, "Architecture cannot be reduced to E-bD without it being destroyed"[136].

E-bD has insisted in breaking down the robustness of an architectural project into its elements expecting to find parts that induce a specific effect or impact on individuals' preferences. A task that brings along a very complex multivariable and multidisciplinary problem escaping the most skilled statisticians. As a result, when evaluating Healing Architecture, studies have attributed the healing process to measurable technical factors instead of spatial design quality.

Therein, E-bD has succeeded in offering a framework for technical solutions. Its rational and scientific approach for evaluation, has potential to help architects within transdisciplinary teams, in together assessing problems and embark in systematic research. This kind of exploration could permit artistic processes be recorded and verify if design as output complies with needs and requirements of problems; a viable path for Healing Architecture (see graph).

Both the actual shortcomings and potential of E-bD research, could lead to its future development in very different ways.

The statistical problem – of breaking down architecture into physical environmental factors – can partly be solved with machine learning (ML) technologies. Design processes in general, start with background data containing lists of factors and variables concerning a problem and frenzied sketching finding solutions. In trying to reach the "best" design possible, the sketching attempts are numerous often restarting from zero when a new problem is commissioned. Apparently not an issue for architect Renzo Piano who affirms: "one of the great beauties of architecture is that each time, it is like life, starting all over again."

ML systems find solutions using previous knowledge on problems by bridging extensive data bases from various sources. It is able to provide new insights without being explicitly programmed to do so[137].

Today these systems have reached sufficient multivariate processing power capable of offering optimal designs to the aerospace industry[138]. It avoids recurrent modeling procedures which are extremely expensive and time consuming by storing them for its convenient use when starting new tasks.

As for the field of architecture, Professor Patrick Hebron (New York University) affirms ML cannot replace human thinking or problem solving but sooner than expected will provide evidence to support the human decision-making process[139].

For Healing Architecture, Machine Learning could help cipher the multiple health and design related variables – from complex health delivery processes – and propose initial spatial arrangements for designers to start with.

As mentioned earlier, E-bD can also leap forward in a less algorithmic manner, as a research & practice framework for environmental interventions. In developing architecture for health (as for many transdisciplinary projects), possibly the most demanding implication is to establish a tight scientific and artistic dialogue free of translation issues.

To start with, what research is for artists, is fundamentally different for natural scientists, leaving architects more or less trapped in the middle. Systematic research is linear and straightforward, while design processes are sometimes ongoing and never-ending. In any case, there is a good chance for both to co-exist if we first recognize their particular differences and how these hamper communication and joint development.

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136 Cor Wagenaar et al., Hospitals: A Design Manual (Basel Birkhäuse, 2018).
137 Carlton E Sapp, "Preparing and Architecting for Machine Learning," Gartner Technical Professional Advice, no. ID: G00317328 (January 17, 2017): 37.
138 Alan Tan Wei Min et al., "Knowledge Transfer Through Machine Learning in Aircraft Design," IEEE Computational Intelligence Magazine 12, no. 4 (November 2017): 48–60, https://doi.org/10.1109/MCI.2017.2742781.
139 Kathleen M. O'Donnell, "Embracing Artificial Intelligence in Architecture," Embracing artificial intelligence in architecture, March 2, 2018, https://www.aia.org/articles/178511-embracing-artificial-intelligence-in-archit.

A major aspect is to reach consensus of terms and terminology within health sciences and design disciplines. Architects enjoy an extensive lexicon of creative buzz words e.g. pastiche, building envelope, fenestration, Corbusian, stylobate, permaculture, exurbia, blobitecture, and thousands more describing a parallel universe. It is frequent for greater audiences to find architectural phrases and full sentences, just incomprehensible. There was no better way for me to illustrate this than citing the testimony of Greg Hudspeth, a long-experienced builder dealing with architects:

"as a builder who has been in the industry for over 20 years, … I have a running list of words and phrases that the architects we work with are using. I spend a portion of each day stripping away the fluff and overly complicated explanations and descriptions for simple ideas. It is the biggest waste of time…[140]"

It seems developing a communication process across disciplines is fundamental. Transdisciplinarity as key for Healing Architecture, demands all team members work together in early planning phases to understand social and health problems relevant to the project and formulate questions that seek being answered through design. Working together from the beginning definitely raises the stakes of having excellent results, it avoids information loss along the serial chain of specialists – very typical for conventional planning.

As proposed in the graph above, E-bD research includes architectural designs as experiments that obeying its own nature and laws. It allows non-designers involved in previous steps, to concede objectively whether "the experiment" affects health-related outcomes or not. Certainly an avaluation step most architects for health are unwilling to do especially when working in silos.

Public health as a discipline can also benefit from this kind of research. It is a field with difficulties in conducting studies that include environmental interventions, therefore knowing little about the effectiveness of designs on health. Its traditional approaches usually focus on individual dispositions and socio-economic factors rather than state, condition and configuration of the physical environments (both natural and built) in which people live. The few studies that prove designed spaces (such as playgrounds) can enable and foster health behaviors (such as physical activity), also demand more detailed analyses be made[141].

In E-bD research we can ponder renewing knowledge between public health and urban studies to properly develop concepts until now lacking of scientific grounds e.g. healing gardens, healing landscape, and healing architecture.

Regardless how E-bD will develop, its importance is critical for standards and policy. Sustaining Healing Architecture principles scientifically will be useful to inform competition briefs (as the ones prepared by The Danish Architects Association); and to redefine accreditation mechanisms, such as BREEAM Healthcare; LEED for Healthcare; and Green Star Healthcare (licensed by the Green Building Council of Australia).

In the German context, this kind of systematic research would aid the German Sustainable Building Council (DGNB – Deutsche Gesellschaft für Nachhaltiges Bauen e.V.) in developing its certification profile called Neubau Krankenhäuser which integrates Healing Architecture as a concept.

In improving policy, E-bD research can update quality assurances on hospital design such as ASPECT (A Staff and Patient Environment Calibration Tool) or the NHS knowledge-based assessments, which support governmental agencies and healthcare providers in generating building guidelines. Some have been initially advanced upon systematic reviewson healthcare design, commissioned in England, Denmark, and Holland between 2000 and 2009[142].

140 Rory Scott, "150 Weird Words That Only Architects Use," 150 Weird Words That Only Architects Use, October 19, 2015, http://www.archdaily.com/775615/150-weird-words-that-only-architects-use.
141 Tobia Lakes and Katrin Burkart, "Childhood Overweight in Berlin: Intra-Urban Differences and Underlying Influencing Factors," *International Journal of Health Geographics* 15, no. 1 (March 22, 2016): 12, https://doi.org/10.1186/s12942-016-0041-0.
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