


Why hospital design matters: A narrative review of built environments research relevant to stroke care

Julie Bernhardt¹, Ruby Lipson-Smith¹ , Aaron Davis¹, Marcus White², Heidi Zeeman³, Natalie Pitt⁴, Michelle Shannon¹, Maria Crotty⁵, Leonid Churilov⁶ and Marie Elf⁷; on behalf of the NOVELL Redesign collaboration⁸

International Journal of Stroke
2022, Vol. 17(4) 370–377
© 2021 World Stroke Organization



Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/17474930211042485
journals.sagepub.com/home/wso



Abstract

Healthcare facilities are among the most expensive buildings to construct, maintain, and operate. How building design can best support healthcare services, staff, and patients is important to consider. In this narrative review, we outline why the healthcare environment matters and describe areas of research focus and current built environment evidence that supports healthcare in general and stroke care in particular. Ward configuration, corridor design, and staff station placements can all impact care provision, staff and patient behavior. Contrary to many new ward design approaches, single-bed rooms are neither uniformly favored, nor strongly evidence-based, for people with stroke. Green spaces are important both for staff (helping to reduce stress and errors), patients and relatives, although access to, and awareness of, these and other communal spaces is often poor. Built environment research specific to stroke is limited but increasing, and we highlight emerging collaborative multistakeholder partnerships (Living Labs) contributing to this evidence base. We believe that involving engaged and informed clinicians in design and research will help shape better hospitals of the future.

Keywords

Stroke, stroke rehabilitation, hospital design and construction, evidence-based design

Received: 17 May 2021; accepted: 10 August 2021

Introduction

Imagine (re-)designing the very hospital you work in. What would you design differently? What would you change, to benefit you, your patients, and their families? What evidence might help guide those design decisions?

Healthcare facilities are among the most expensive buildings to construct, maintain, and operate.¹ Once built, hospitals remain in service for decades and are difficult to modify. With stakes this high, considering how building design best supports healthcare services is important. In this narrative review, we outline why the built environment matters, with particular focus on stroke care. We also discuss challenges inherent in designing healthcare environments, undertaking research and evaluating completed architecture.

The planning and design process for new healthcare environments is incredibly complex, but, in general, it occurs in three overlapping stages: (1) the planning stage in which the healthcare provider describes the users' needs, model of care, and clinical program in

a functional brief that summarizes the requirements for the new hospital; (2) the design stage in which these requirements are interpreted by architects to develop an initial concept which is then refined to a more detailed design; and (3) the delivery stage in

¹Stroke, The Florey Institute of Neuroscience and Mental Health, Heidelberg, Australia

²Centre for Design Innovation, Swinburne University of Technology, Hawthorne, Australia

³Menzies Health Institute Queensland, Griffith University, Brisbane, Australia

⁴Silver Thomas Hanley (STH) Health Architecture, Australia

⁵Flinders Health and Medical Research Institute, Flinders University, Adelaide, Australia

⁶Melbourne Medical School, University of Melbourne, Parkville, Australia

⁷School of Education, Health and Social Studies, University of Dalarna, Falun, Sweden

⁸See novellredesign.com for the full list of NOVELL (Neuroscience Optimised Virtual Environment Living Lab) Redesign collaborators

Corresponding author:

Julie Bernhardt, 245 Burgundy Street, Heidelberg VIC 3084, Australia.
Email: julie.bernhardt@florey.edu.au

which the building is constructed. The extent to which hospital staff and patients are included at each stage of this process can vary significantly between projects.²

Healthcare professionals have long advocated for design features thought to benefit health and well-being, such as natural light, ventilation, and space between patients—for example, the circular hospital design proposed by the physician Antoine Petit³ and long “Nightingale wards” proposed by Florence Nightingale.⁴ Hospital design is now informed by a process termed “evidence-based design” (EBD), in which research evidence is used alongside other considerations such as the healthcare context, budget, and architects’ experience, to inform the design of the healthcare built environment.^{5,6} In this context, the “healthcare built environment” encompasses: (1) the physical construction (layout, room dimensions, doors and window placement, outdoor and community access, etc.), (2) ambient features (noise, air quality, light, temperature, etc.), and (3) interior design (furniture, signage, equipment, artwork, etc.).⁷ Analogous to evidence-based clinical practice, hospitals designed following best research evidence garnered from EBD processes have better safety, patient outcomes, staff retention, and operation costs.^{8,9} The Center for Health Design, established in 1993 to advance EBD, now maintains a repository of over 5,000 articles on healthcare design (<https://www.healthdesign.org>).

The field is growing; however, many healthcare contexts, including stroke, have a limited built environment evidence base.¹⁰ Establishing geographically organized stroke units has been an important focus¹¹; however, these studies rarely address specifics of the built environment, and we know little about optimal stroke unit design. Stroke clinical guidelines rarely mention the built environment nor provide guidance on how the environment might best support care. There are currently no stroke care-specific building standards, nor standardized checklists to evaluate the quality of these environments.¹²

Why is the built environment neglected? Clinicians may identify as knowing less about how the environment might influence patient care or staff well-being. They may also feel uninformed about the design process and how to contribute their clinical expertise to influence decision-making. To begin to address these gaps, our objectives for this review were: (1) to introduce readers to healthcare built environment research and (2) to highlight evidence that underpins acute, sub-acute, or rehabilitation stroke care facility design. This review is in three parts:

1. Overview of healthcare built environment research;
2. Stroke care built environment evidence; and

3. Planning and design of new healthcare environments: Challenges and opportunities.

We include research from recent, relevant systematic reviews, other evidence summaries, and selected qualitative and mixed-methods research focusing on healthcare environments and design. Healthcare environments are complex and context-specific, with many interdependent variables that can rarely be isolated. This complex system does not readily lend itself to highly controlled experimental research designs in real-life settings.¹³ Qualitative methods, such as case studies and pre- and post-occupancy evaluations (before and after a redesign or redevelopment), are common. With research still developing, heterogeneity exists in research designs, outcomes, environments, populations, and theoretical frameworks employed.¹⁴ Hence, robust summary evidence derived from meta-analyses is lacking.

Healthcare built environment research

Research is dominated by studies conducted in acute environments such as emergency, surgery, and intensive care units (ICUs) (Figure 1).^{6,15,16} Older people, including those in dementia care, are frequently studied post-acute populations.¹⁷

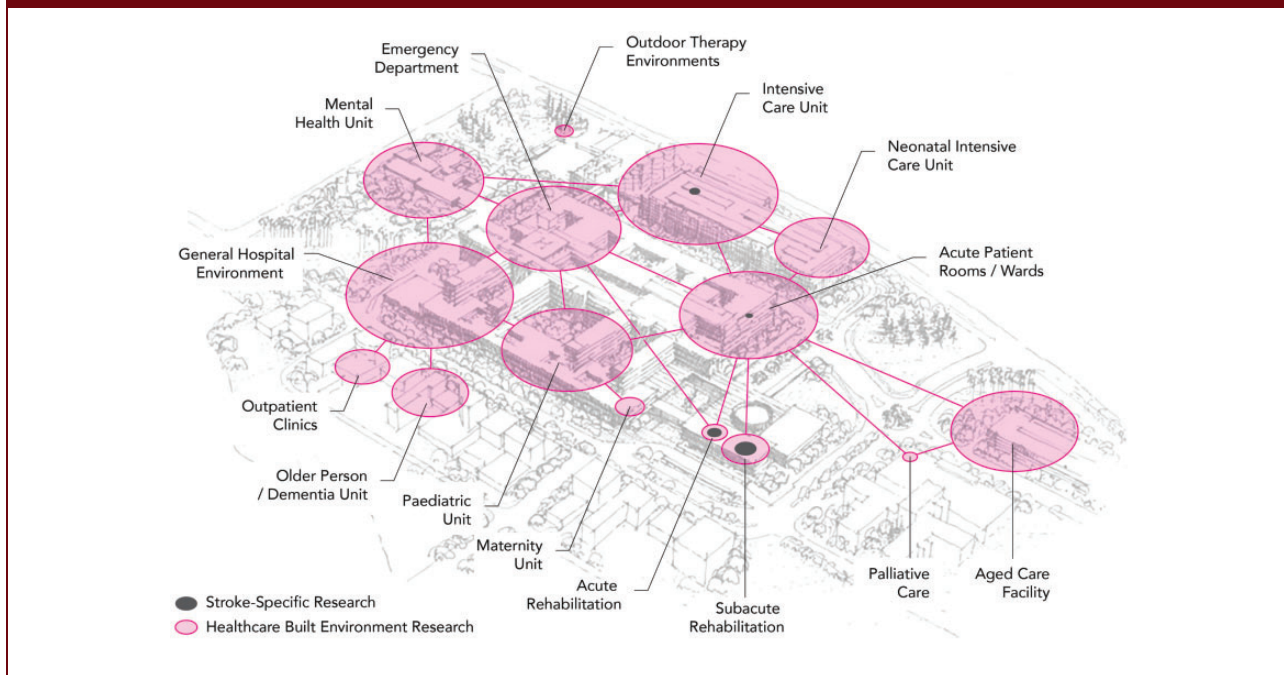
In this section, we introduce three topics relevant to most healthcare contexts: (1) design of internal spaces; (2) outdoor spaces; and (3) ambient features including light, noise, and air quality (with particular focus on infection control).

Internal spaces

The design of internal spaces, such as ward configuration, corridor design, and nurse station placements (centralized vs. decentralized), can influence patient visibility, safety, teamwork, distances staff walk in a shift, and time spent providing direct care to patients.¹⁰ For example, open-plan, larger convex spaces can lead to greater patient visibility, and corridor width impacts staff circulation, informal communication, and teamwork.¹⁹ In ICU, designs with centralized nurse stations and visibility of most patient rooms from that location are increasingly being replaced with decentralized nurses’ stations, arguably without strong evidence.¹⁹ In emergency departments, with similar critical visibility requirements for teamwork and patient monitoring, some authors argue that physically separated zones or “pods” are neither efficient nor safe.²⁰ Decentralized nursing stations can lead to more patient room visits by staff.^{21,22} This highlights current uncertainties.

The layout of hospital spaces and line of sight influences patient and visitor orientation and their ability to find their way around (“wayfinding”).²³ Signs,

Figure 1. The volume of built environment research conducted in different healthcare settings. Circle size indicates the number of published research articles based on systematic literature review in preparation¹⁸ and articles listed in the Centre for Healthcare Design research repository. Pink circles represent all built environment research, and the dark gray circles indicate stroke-specific research. (The aerial sketch in this image has been adapted with permission from Architectus + HDR.)



information boards, and “landmarks” (artwork, furniture, views, etc.) are typical wayfinding elements.^{24,25} Inadequate wayfinding leads to delays in accessing services or finding people or places, associated stress, and higher staff burden as they provide directions for lost individuals.²⁵ While some standards exist, wayfinding is often not optimized in healthcare.²⁶

The proportion of single versus multiple (two or more)-bed rooms is a prominent ward design consideration. There is evidence that single rooms can support staff/patient communication, privacy, infection control, and noise reduction, but they are also associated with patient isolation and increased falls risk.²⁷ This evidence is, however, of mixed quality, limited to certain populations, with neutral and/or contrary results.²⁷ A higher proportion of single rooms generally results in longer corridors, longer staff walking distances, perceived decrease in patient visibility due to compromised sightlines, and higher construction and cleaning costs.²⁸ The inherent trade-offs will be different in every healthcare context. Less controversial is location of sinks and hand sanitizers; highly visible and standardized positioning promotes more consistent use.^{29,30}

Outdoor spaces

Hospital gardens were historically commonplace³¹; however, less priority has been given to green space

over time. Access to the outdoors and time in nature has been linked to stress reduction, improved physical symptoms, and emotional well-being in many healthcare settings.³² Views of nature have been linked to reduced length of stay.³³ Good hospital garden design principles include creating opportunities for exercise, exploration, socialization, and to engage with and escape in nature.³² Surprisingly, patients and visitors are often not aware of hospital gardens, and proactive approaches to increasing patient and family use of gardens have been recommended.³⁴ Usually conceptualized as spaces for patients and visitors, staff are often their primary users.³² Outdoor spaces can be restorative for hospital staff, helping to reduce stress and improve attention, which may improve patient care and staff retention.³⁵

Ambient features

Ambient features, such as light and noise, can impact patient well-being and comfort, sleep, and communication with staff.^{36,37} Light and noise also impact staff well-being and attention³⁸ and contribute to medication errors and other safety concerns.³⁹

Air quality is important for both comfort and infection control. Infection control is particularly prioritized in acute environments and is receiving deserved attention in the COVID-19 pandemic. A recent review of

COVID-19 transmission showed that spatial configuration can affect patient density and thereby transmission.⁴⁰ Optimized systems for heating, ventilation, and air conditioning (HVAC) can filter microparticles such as viruses. Different HVAC systems also affect humidity, airflow velocities, air pressure—all important for exposure to active aerosols. Window ventilation, daylight, and electric UV light are recommended to aid disinfecting surfaces and use of surface materials that affect pathogen survival.⁴⁰

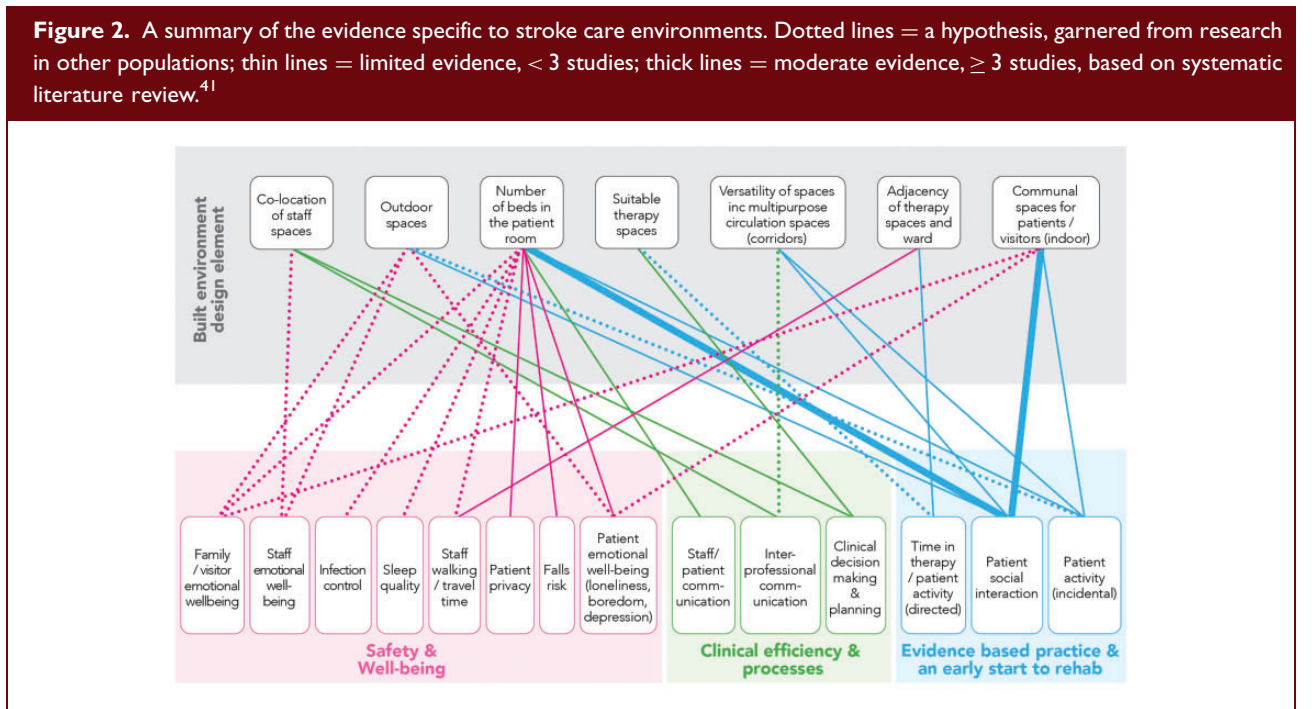
Stroke care built environment evidence

In this section, we outline how the built environment can influence important outcomes such as: (1) evidence-based stroke care, including rehabilitation; (2) efficiency of stroke care, staff processes, and communication; and (3) patient safety and well-being. The evidence-base specific to stroke care is small.⁴¹ In Figure 2, we summarize the design features and how they may influence a range of outcomes including patient and staff behavior. This should be considered illustrative rather than exhaustive. Where possible, we draw directly from stroke or brain injury-specific evidence, supplementing evidence from other populations where relevant.

Evidence-based practice including rehabilitation

We found no stroke-specific research to underpin built environment recommendations for optimal delivery of

either time-critical acute stroke treatments or evidence-based care, including rehabilitation. Guidelines recommend early commencement of both structured and incidental physical, cognitive, and social activity for all stroke patients,^{42,43} although recommended levels vary. Patients in both acute and subacute environments spend most of their day alone and inactive in their bedroom.^{44,45} While we can hypothesize that providing “draw-them-out” features on a ward may improve activity and engagement, evidence is limited. These features may include green spaces and indoor communal (social) spaces. Unfortunately, communal spaces, when present, often appear to be underutilized in both acute⁴⁶ and rehabilitation environments.⁴⁷ Many factors may influence whether patients use communal spaces, including not knowing they exist or where to find them, difficulty accessing them without help, or feeling they don’t have permission to use them.⁴⁸ In a Norwegian study across 11 stroke units with communal areas, patients were more active and spent less time in their bedroom in units where meals were served in the communal area.⁴⁹ Providing resources (games, music, books) in personalized activity packs and in communal spaces (“environmental enrichment”), with the aim to improve physical, social, and cognitive activity, has recently been tested in acute and subacute settings with mixed results.^{50–52} Importantly, this approach relies on staff to encourage use and engagement, rather than embedding activity opportunities into the building itself. Hallways and circulation spaces are



generally underrecognized as providing spaces for incidental activity and interaction.⁵³

There is limited stroke-specific research about the value or harm of single- versus multiple-bed rooms. A higher proportion of single rooms may be associated with lower levels of patient activity in acute stroke.^{54,55} A systematic review of single- versus multiple-bed rooms in older people and those with neurological disorders found potential benefits (e.g. infection control, patient satisfaction) and harms (e.g. falls, isolation) with single rooms.⁵⁶ In rehabilitation facilities with a high proportion of single rooms, patients emphasize the importance of communal areas.⁵⁷ Further work is needed to identify and test how modifications to layout and communal and circulations spaces could enhance patient engagement, activity, and optimal care provision.

Efficiency of care, staff processes, and communication

Interprofessional communication and teamwork between physicians, nurses, and allied health professionals supports best practice stroke care.¹¹ Shared staff spaces support team communication and collaboration, enabling better understanding of patient needs, and greater knowledge about other team roles.^{58,59}

Therapy spaces are often discrete locations (e.g. gym, occupational therapy rooms), rather than being holistic, context-based environments that reflect the connectivity and continuity necessary for rehabilitation and transition beyond discharge.^{60,61} Separation of clinical and therapy spaces can impact staff travel time, patient practice and activity, and even clinical decision-making. For example, Blennerhassett et al.⁴⁷ found that patients spent less time engaged in physical activity and more time in corridors when the ward was located further from the gym, on a separate floor. This also impacted wheelchair use and patient travel time.⁴⁷ Inaccessible therapy spaces can also change therapists' intervention choices.⁶²

Safety and well-being

Falls are common after stroke,⁶³ yet the relationship between the built environment and falls is largely unexplored. The presence of a fellow patient (multiple-bed room) may help reduce falls, especially for older patients with neurological injury.^{56,64} Roommates play an important role in monitoring the physical and mental health of others in stroke rehabilitation.⁴⁸ Stroke patients often experience loneliness when in hospital,^{65,66} and some patients will choose a shared room over the privacy of a single room.⁵⁷ Sleep is important for recovery. Unsurprisingly, visual and aural privacy is

less in multiple-bed rooms. However, noise traveling between corridors and bedrooms and lack of dedicated staff spaces for confidential conversations are also important.⁴⁸

Planning and design of new healthcare environments: Challenges and opportunities

Healthcare environments research and design is a multistakeholder endeavor involving government, healthcare providers, managers, clinical staff, patients, architects, quantity surveyors, construction companies, building managers, etc. This collaborative process can be challenging,^{67,68} considering interdisciplinary differences in knowledge and approaches.⁶⁹ The complexity of hospital procurement and the fact that design and construction processes are foreign to many healthcare professionals adds further challenge. Clinicians often do not understand what the "user group" consultation process is supposed to achieve, and their involvement may be inconsistent throughout the design process, which limits their contribution to the process and ability to influence decisions.⁶⁷ While collaboration between architects and healthcare professionals is not new,⁷⁰ limited evidence informs current consultation processes.^{67,71} High-quality healthcare environments are produced when shared decision-making and collaboration happens across healthcare, construction, and architecture to create designs based on evidence and end-users' perspectives.⁶⁹

A number of research approaches are suggested to facilitate this collaboration, including participatory design, co-design, and Living Labs.^{2,72,73} Over many years, our team has built partnerships between healthcare environment practitioners, clinicians, researchers, and people living with stroke, which have served to create a common understanding of the barriers and opportunities for redesigning and optimizing stroke care environments. With the creation of the Neuroscience Optimized Virtual Living Lab (NOVELL) for stroke rehabilitation redesign (www.novellredesign.com), we are working to develop new models for stakeholder engagement and research, and to contribute new evidence to stroke rehabilitation design.

In addition to collaboration challenges, research is infrequently embedded in the planning and design of new healthcare environments, and leaders in EBD have long called for appropriately funded, transparent, and freely available evaluations of completed buildings.^{74–76} Given the cost of constructing and running healthcare buildings, the absence, or non-disclosure, of evaluations to determine whether desired outcomes were met is concerning.^{77,78} Hospital design and construction is underpinned by technical and generic building

guidelines and standards that differ within and between countries. The degree to which these standards are “evidence-informed” varies. In stakeholder consultations, understanding what is evidence-based and what is open to change can be difficult. Design innovation is essential if hospital buildings are to respond to new healthcare models or processes. For example, the recent COVID-19 induced surge in utilization of telehealth and other e-health technologies for rehabilitation, other treatment, and communication with people with stroke has implications for healthcare design, increasing demand for spaces for videoconferencing, equipment storage, and potential changes to waiting rooms and on-site consultation spaces.^{79,80} Future design considerations for stroke recovery should also extend to the home environment.⁸¹

Conclusion

The built environment matters. It can impact healthcare delivery and patient and staff outcomes. An evidence base is growing in some areas of healthcare design, while others require significant further research. The potential for both hospital and health services design innovation is strong. By continuing to build this evidence base, EBD can complement architectural processes to deliver high-performing healthcare assets. Involving engaged and informed clinicians in built environment design and research will help shape hospitals of the future.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: NOVELL is funded by the Felton Bequest and the University of Melbourne. Julie Bernhardt is funded by an NHMRC Research Fellowship (1154904). The Florey Institute of Neuroscience and Mental Health acknowledges support from the Victorian government and in particular funding from the Operational Infrastructure Support Grant.

ORCID iD

Ruby Lipson-Smith  <https://orcid.org/0000-0002-1702-8144>

References

1. Chua G. New Royal Adelaide Hospital named third most expensive building in the world. *Architecture & Design*, 23 March 2015.
2. Donetto S, Pierri P, Tsianakas V, et al. Experience-based co-design and healthcare improvement: realizing participatory design in the public sector. *Des J* 2015; 18: 227–248.
3. Petit A, Cellot Li, La Gardette P-Cdg. *Mémoire sur la meilleure maniere de construire un hôpital de malades*. A Paris: de l'imprimerie de Louis Cellot, 1774.
4. Nightingale F. *Notes on hospitals*. 3d ed., enlarged and for the most part rewritten. London: Longman, Green, Longman, Roberts, and Green, 1863.
5. Hamilton DK. The four levels of evidence-based practice. *Healthc Des* 2003; 3: 18–26.
6. Ulrich RS, Zimring C, Zhu X, et al. A review of the research literature on evidence-based healthcare design. *HERD* 2008; 1: 61–125.
7. Harris PB, McBride G, Ross C, et al. A place to heal: environmental sources of satisfaction among hospital patients 1. *J Appl Soc Psychol* 2002; 32: 1276–1299.
8. Berry LL, Parker D, Coile R, et al. The business case for better buildings. *Front Health Serv Manag* 2004; 21: 3–24.
9. Sadler BL, Berry LL, Guenther R, et al. Fable hospital 2.0: the business case for building better health care facilities. *Hastings Cent Rep* 2011; 41: 13–23.
10. Halawa F, Madathil SC, Gittler A, et al. Advancing evidence-based healthcare facility design: a systematic literature review. *Health Care Manag Sci* 2020; 23: 453–480.
11. Langhorne P, Ramachandra S and Collaboration SUT. Organised inpatient (stroke unit) care for stroke: network meta-analysis. *Cochrane Database Syst Rev* 2020; 4: CD000197.
12. Elf M, Nordin S, Wijk H, et al. A systematic review of the psychometric properties of instruments for assessing the quality of the physical environment in healthcare. *J Adv Nurs* 2017; 73: 2796–2816.
13. Stichler JF and Hamilton DK. Rigor and replication. *HERD* 2008; 2: 3–5.
14. Shannon MM, Nordin S, Bernhardt J, et al. Application of theory in studies of healthcare built environment research. *HERD* 2020; 13: 154–170.
15. O'Callaghan N, Dee A and Philip RK. Evidence-based design for neonatal units: a systematic review. *Matern Health Neonatol Perinatol* 2019; 5: 1–9.
16. Papoulias C, Csipke E, Rose D, et al. The psychiatric ward as a therapeutic space: systematic review. *Br J Psychiatry* 2014; 205: 171–176.
17. Joseph A, Choi Y-S and Quan X. Impact of the physical environment of residential health, care, and support facilities (RHCSF) on staff and residents: a systematic review of the literature. *Environ Behav* 2016; 48: 1203–1241.
18. Elf M, Anåker A, Marcheschi E, et al. The built environment and its impact on health outcomes and experiences of patients, significant others and staff—a protocol for a systematic review. *Nurs Open* 2020; 7: 895–899.
19. Hadi K and Zimring C. Design to improve visibility: impact of corridor width and unit shape. *HERD* 2016; 9: 35–49.
20. Pati D, Harvey TE Jr and Pati S. Physical design correlates of efficiency and safety in emergency departments: a qualitative examination. *Crit Care Nurs Q* 2014; 37: 299–316.

21. Gurascio-Howard L and Malloch K. Centralized and decentralized nurse station design: an examination of caregiver communication, work activities, and technology. *HERD* 2007; 1: 44–57.
22. Fay L, Carll-White A, Schadler A, et al. Shifting landscapes: the impact of centralized and decentralized nursing station models on the efficiency of care. *HERD* 2017; 10: 80–94.
23. Rooke CN, Tzortzopoulos P, Koskela L, et al. Wayfinding: embedding knowledge in hospital environments. In: *HaCIRIC International Conference 2009 Improving healthcare infrastructures through innovation*, Hilton Metropole Hotel, Brighton, 23 April 2009.
24. Pati D, Harvey TE Jr, Willis DA, et al. Identifying elements of the health care environment that contribute to wayfinding. *HERD* 2015; 8: 44–67.
25. Devlin AS. Wayfinding in healthcare facilities: contributions from environmental psychology. *Behav Sci* 2014; 4: 423–436.
26. Augur H. Poor healthcare wayfinding has hidden cost for hospital kontaktio. <https://kontakt.io/blog/healthcare-wayfinding/> (2018, accessed 19 August 2021).
27. Taylor E, Card AJ and Piatkowski M. Single-occupancy patient rooms: a systematic review of the literature since 2006. *HERD* 2018; 11: 85–100.
28. Maben J, Griffiths P, Penfold C, et al. One size fits all? Mixed methods evaluation of the impact of 100% single-room accommodation on staff and patient experience, safety and costs. *BMJ Qual Saf* 2016; 25: 241–56.
29. Deyneko A, Cordeiro F, Berlin L, et al. Impact of sink location on hand hygiene compliance after care of patients with *Clostridium difficile* infection: a cross-sectional study. *BMC Infect Dis* 2016; 16: 1–7.
30. Neo JRJ and Sagha-Zadeh R. The influence of spatial configuration on the frequency of use of hand sanitizing stations in health care environments. *Am J Infect Control* 2017; 45: 615–9.
31. Hickman C. *Therapeutic landscapes: a history of English hospital gardens since 1800*. Manchester: Manchester University Press, 2013.
32. Marcus CC. Therapeutic landscapes. In: AS Devlin (ed) *Environmental psychology and human well-being*. London: Academic Press, 2018, pp.387–413.
33. Ulrich R. View through a window may influence recovery from surgery. *Science* 1984; 224: 420–421.
34. Whitehouse S, Varni JW, Seid M, et al. Evaluating a children's hospital garden environment: utilization and consumer satisfaction. *J Environ Psychol* 2001; 21: 301–314.
35. Nejati A, Rodiek S and Shepley M. The implications of high-quality staff break areas for nurses' health, performance, job satisfaction and retention. *J Nurs Manag* 2016; 24: 512–523.
36. Aries MB, Aarts MP and van Hoof J. Daylight and health: a review of the evidence and consequences for the built environment. *Light Res Technol* 2015; 47: 6–27.
37. Johansson L, Bergbom I, Wayne KP, et al. The sound environment in an ICU patient room—a content analysis of sound levels and patient experiences. *Intensive Crit Care Nurs* 2012; 28: 269–279.
38. Hadi K, DuBose JR and Ryherd E. Lighting and nurses at medical–surgical units: impact of lighting conditions on nurses' performance and satisfaction. *HERD* 2016; 9: 17–30.
39. Chaudhury H, Mahmood A and Valente M. The effect of environmental design on reducing nursing errors and increasing efficiency in acute care settings: a review and analysis of the literature. *Environ Behav* 2009; 41: 755–786.
40. Dietz L, Horve PF, Coil DA, et al. 2019 novel coronavirus (COVID-19) pandemic: built environment considerations to reduce transmission. *Msystems* 2020; 5: e00245–20.
41. Lipson-Smith R, Pflaumer L, Elf M, et al. Built environments for inpatient stroke rehabilitation services and care: a systematic literature review. *BMJ Open* 2021; 11: e050247.
42. Stroke Foundation. *Clinical guidelines for stroke management*. Melbourne, Australia, 2021.
43. Rudd A, Bowen A, Young G, et al. National clinical guideline for stroke: 5th edition 2016. *Clin Med* 2017; 17: 154–155.
44. Janssen H, Ada L, Bernhardt J, et al. Physical, cognitive and social activity levels of stroke patients undergoing rehabilitation within a mixed rehabilitation unit. *Clin Rehab* 2014; 28: 91–101.
45. Fini NA, Holland AE, Keating J, et al. How physically active are people following stroke? Systematic review and quantitative synthesis. *Phys Ther* 2017; 97: 707–717.
46. Shannon MM, Elf M, Churilov L, et al. Can the physical environment itself influence neurological patient activity? *Disabil Rehabil* 2019; 41: 1177–1189.
47. Blennerhassett JM, Borschmann KN, Lipson-Smith RA, et al. Behavioral mapping of patient activity to explore the built environment during rehabilitation. *HERD* 2018; 11: 109–123.
48. Lipson-Smith RA. *Space for recovery after stroke: exploring the role of the physical environment in inpatient rehabilitation facilities*. PhD Thesis, The University of Melbourne, 2020.
49. Hokstad A, Indredavik B, Bernhardt J, et al. Hospital differences in motor activity early after stroke: a comparison of 11 Norwegian stroke units. *J Stroke Cerebrovasc Dis* 2015; 24: 1333–1340.
50. Rosbergen IC, Grimley RS, Hayward KS, et al. The impact of environmental enrichment in an acute stroke unit on how and when patients undertake activities. *Clin Rehabil* 2019; 33: 784–795.
51. Rosbergen IC, Grimley RS, Hayward KS, et al. Embedding an enriched environment in an acute stroke unit increases activity in people with stroke: a controlled before–after pilot study. *Clin Rehabil* 2017; 31: 1516–1528.
52. Janssen H, Ada L, Middleton S, et al. Altering the rehabilitation environment to improve stroke survivor activity (AREISSA): a Phase II trial. *Int J Stroke* 2021; 17474930211006999.
53. Colley J, Zeeman H and Kendall E. “Everything happens in the hallways”: exploring user activity in the corridors at two rehabilitation units. *HERD* 2018; 11: 163–176.

54. Anåker A, von Koch L, Sjöstrand C, et al. A comparative study of patients' activities and interactions in a stroke unit before and after reconstruction—the significance of the built environment. *PLoS One* 2017; 12: e0177477.
55. Anåker A, von Koch L, Sjöstrand C, et al. The physical environment and patients' activities and care: a comparative case study at three newly built stroke units. *J Adv Nurs* 2018; 74: 1919–1931.
56. Shannon M, Lipson-Smith R, Elf M, et al. Bringing the single versus multi-patient room debate to vulnerable patient populations: a systematic review of the impact of room types on hospitalized older people and people with neurological disorders. *Intell Build Int* 2020; 12: 180–198.
57. Killington M, Fyfe D, Patching A, et al. Rehabilitation environments: service users' perspective. *Health Expect* 2019; 22: 396–404.
58. Paxino J, Denniston C, Woodward-Kron R, et al. Communication in interprofessional rehabilitation teams: a scoping review. *Disabil Rehabil* 2020: 1–17.
59. Anåker A, von Koch L, Eriksson G, et al. The physical environment and multi-professional teamwork in three newly built stroke units. *Disabil Rehabil* 2020: 1–9.
60. Thwaites K, Helleur E, Simkins I, et al. Restorative urban open space: exploring the spatial dimensions of human emotional fulfillment in urban open space. *Landscape research* 2005; 30: 525–547.
61. Wright CJ, Zeeman H and Biezaitis V. Holistic practice in traumatic brain injury rehabilitation: perspectives of health practitioners. *PLoS One* 2016; 11: e0156826.
62. Skubik-Peplaski C, Howell DM, Hunter EG, et al. Occupational therapists perceptions of environmental influences on practice at an inpatient stroke rehabilitation program: a pilot study. *Phys Occup Ther Geriatr* 2015; 33: 250–262.
63. Holloway RG, Tuttle D, Baird T, et al. The safety of hospital stroke care. *Neurology* 2007; 68: 550–555.
64. Singh I, Okeke J and Edwards C. Outcome of in-patient falls in hospitals with 100% single rooms and multi-bedded wards. *Age Ageing* 2015; 44: 1032–1035.
65. Anåker A, von Koch L, Heylighen A, et al. "It's lonely": patients' experiences of the physical environment at a newly built stroke unit. *HERD* 2019; 12: 1937586718806696.
66. Luker J, Lynch E, Bernhardsson S, et al. Stroke survivors' experiences of physical rehabilitation: a systematic review of qualitative studies. *Arch Phys Med Rehabil* 2015; 96: 1698–708.e10.
67. Carthey J. Interdisciplinary user groups and the design of healthcare facilities. *HERD* 2020; 13: 114–128.
68. Miller TR, Baird TD, Littlefield CM, et al. Epistemological pluralism: reorganizing interdisciplinary research. *Ecol Soc* 2008; 13: 46.
69. Elf M, Fröst P, Lindahl G, et al. Shared decision making in designing new healthcare environments—time to begin improving quality. *BMC Health Serv Res* 2015; 15: 1–7.
70. Ehrström M, Jetsonen S, Lindh T, et al. *Nomination of Paimio Hospital for inclusion in the world heritage list*. Helsinki: National Board of Antiquities, 2005.
71. Hamilton DK. Incorporating credible evidence into the design process. *HERD* 2018; 11: 11–16.
72. Hyysalo S and Hakkarainen L. What difference does a living lab make? Comparing two health technology innovation projects. *CoDesign* 2014; 10: 191–208.
73. Reay S, Collier G, Kennedy-Good J, et al. Designing the future of healthcare together: prototyping a hospital co-design space. *CoDesign* 2017; 13: 227–244.
74. Hamilton DK. *Every facility project and every building is a research opportunity*. Los Angeles, CA: SAGE Publications, 2009.
75. Preiser WF. Continuous quality improvement through post-occupancy evaluation feedback. *J Corp Real Estate* 2003; 5: 42–56.
76. Shepley MM. Design evaluation. In: Marberry SO (ed) *Healthcare design*. New York: John Wiley, 1997, pp.73–104.
77. Hadjri K and Crozier C. Post-occupancy evaluation: purpose, benefits and barriers. *Facilities* 2009; 27: 21–33.
78. Zimmerman A and Martin M. Post-occupancy evaluation: benefits and barriers. *Build Res Inf* 2001; 29: 168–174.
79. Hume R and Looney J. Designing for telemedicine spaces: planning for the next generation of health care delivery. *Health Facilities Management*, 3 February 2016, <https://www.hfmmagazine.com/articles/1889-designing-for-telemedicine-spaces> (accessed 18 August 2021).
80. Krupinski EA. Telemedicine workplace environments: designing for success. *Healthcare* 2014; 2: 115–122.
81. Kylén M, von Koch L, Pessah-Rasmussen H, et al. The importance of the built environment in person-centred rehabilitation at home: study protocol. *Int J Environ Res Public Health* 2019; 16: 2409.