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Built environments for inpatient stroke rehabilitation services and care: A systematic literature review

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Title

Built environments for inpatient stroke rehabilitation services and care: A systematic literature review

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Abstract

Objectives: To identify, appraise, and synthesise existing design evidence for inpatient stroke rehabilitation facilities; to identify impacts of these built environments on the outcomes and experiences of people recovering from stroke, their family/caregivers, and staff.

Design: A convergent segregated review design was used to conduct a systematic review.

Data sources: OVID Medline, SCOPUS, Web of Science, and CINAHL were searched between January 2000 and November 2020.

Eligibility criteria for selecting studies: Qualitative, quantitative, and mixed methods studies investigating the impact of the built environment of inpatient rehabilitation facilities on stroke survivors, their family/caregivers, and/or staff.

Data extraction and synthesis: Two authors separately completed title, abstract, full-text screening, data extraction, and quality assessment. Extracted data were categorised according to the aspect of the built environment explored and the outcomes reported. These categories were used to structure a narrative synthesis of the results from all included studies.

Results: Twenty-four articles were included, most qualitative and exploratory. Half of the included articles investigated a particular aspect of the built environment, including environmental enrichment and communal areas (*n* = 8), bedroom design (*n* = 3), and therapy spaces (*n* = 1). Findings related to one or more of the following outcome categories: 1) clinical outcomes; 2) patient activity; 3) patient well-being; 4) patient and/or staff safety; and 5) clinical practice. Heterogeneous designs and variables of interest meant results could not be compared, but some repeated findings suggest that attractive and accessible communal areas are important for patient activity and well-being.

Conclusions: Stroke rehabilitation is a unique healthcare context where patient activity, practice, and motivation are paramount. We found many evidence gaps that with more targeted research could better inform the design of rehabilitation spaces to optimise care.

PROSPERO registration number: CRD42020158006

Strengths and limitations of this study

- The review method allowed for all the current evidence regarding inpatient stroke rehabilitation built environments to be gathered and assessed in a systematic and rigorous way.
- The narrative synthesis and diagrams provide a succinct summary of the trends and gaps in stroke rehabilitation environments research.
- Results of the included studies could not be easily combined or compared due to heterogeneity of study designs and variables of interest.

- Stroke rehabilitation services vary globally, but the majority of the studies in this review were conducted in Australia (50% of included articles) and Sweden (21% of included articles).

Key words
Stroke rehabilitation; Hospital Design and Construction; Clinical outcomes

INTRODUCTION

The physical environment of healthcare facilities can influence clinical outcomes, patient and staff experiences, and the economic performance of the facility.[1, 2] Healthcare design research generates evidence to inform the design of healthcare facilities. Recent healthcare design research has focused on acute environments such as surgery and intensive care,[3] with significant attention paid to residential aged care[4] and mental health facilities.[5] Between these disparate sectors lies an important and expensive sector of healthcare: hospital-based inpatient rehabilitation.

Inpatient rehabilitation is essential for people recovering from serious injury or illness, such as stroke.[6] Stroke is a leading cause of death and disability worldwide.[7] As acute stroke treatments continue to improve, more people are expected to survive a stroke, and many will experience ongoing disability that requires hospital-based, or inpatient, rehabilitation. While recovery may continue for years post-stroke, initial rehabilitation usually begins in the acute phase of care, followed by sub-acute inpatient rehabilitation for some, and a gradual shift to outpatient and community care. Early supported discharge to home, more common in Europe, is suitable for only 30% of patients.[6, 8] The average length of stay in post-acute inpatient stroke rehabilitation varies globally, but is generally lengthy (for example, 27.2 days in Australia).[9] There is evidence that functional outcomes vary between rehabilitation facilities.[10] While variation may be due to differences in procedures and staffing, differences in environment could also contribute; we know that rehabilitation facility design is heterogeneous.[11]

Rehabilitation is defined as “a process of active change by which a person who has become disabled acquires the knowledge and skills needed for optimum physical, psychological and social function”.[12] Repetitive practice and targeted therapy – such as upper limb training, walking, speech exercises, and practicing activities of daily living – are integral to the rehabilitation process. Stroke patients are encouraged to engage in general physical, cognitive, and social activity outside of their structured therapy time in order to further promote their recovery.[13] This contrasts sharply with the priorities of acute care – to diagnose, stabilise the patient and, where possible, apply acute treatments such as thrombolysis or clot retrieval to prevent death and optimise outcomes.[14] During rehabilitation, patients must participate in activities and practice, but many patients experience boredom, lack of stimulation, fatigue, low mood, and feelings of disempowerment, which negatively impact their motivation.[15] The distinct function and priorities of rehabilitation, the importance of patient engagement, and the typically long length of stay, prompted this review of the healthcare design evidence specific to stroke rehabilitation to better understand how the design of these healthcare facilities could be optimised for their function.

The aim of this systematic literature review was to identify, appraise, and synthesise the existing literature related to the design of inpatient stroke rehabilitation facilities. Our research questions were: What aspects of the built environment have been investigated in inpatient stroke rehabilitation settings? What types of research methods have been used? What types of outcomes have been investigated? What are the impacts of the built environment on the outcomes and experiences of patients recovering from stroke, their family/caregivers, and staff?

METHODS

Design

We aimed to include all relevant research, so we elected to conduct a mixed studies systematic literature review which followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (see Supplementary file 1).[16] We used a convergent segregated review design so that results from qualitative, quantitative, and mixed methods studies could be synthesised in a narrative summary.[17] The protocol was prospectively registered on PROSPERO (CRD42020158006; date: 17 November 2019; see Supplementary file 2).

Patient and public involvement

An Advisory Committee including two stroke survivors reviewed the research questions and draft manuscript of this review.

Data sources

A systematic search was conducted in the following databases in January 2020, and updated in November 2020: OVID Medline, SCOPUS, Web of Science, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). A Boolean search strategy was used (see Supplementary file 3). Authors LP and RLS searched the reference lists of included articles, systematic literature reviews, relevant PhD theses, key journals (Health Environments Research & Design) and organisations (The Centre for Healthcare Design) for additional eligible studies.

Article selection

Publications that met the criteria outlined in Table 1 were considered eligible for inclusion. Following duplicate removal, two reviewers ([INITIALS]) independently screened titles and abstracts of the remaining articles using Covidence.[18] These authors then independently screened the full text of potentially eligible articles. Consensus was reached with whole team discussion.

Table 1. Eligibility criteria for articles in this systematic literature review

Criteria	Eligibility requirements
Publication year	Articles published between 2000 and 2020 (to reflect the rise of evidence-based design research in the past 20 years).
Article type	Peer reviewed, English language, journal article or conference paper; excluded conference abstracts, posters, and PhD theses.
Study design	Quantitative, qualitative, or mixed methods research designs; excluded opinion pieces, commentaries, single case studies, and systematic reviews with no meta-analysis or meta-synthesis.
Population	Stroke survivors, their family/caregivers, and/or staff who care for stroke survivors; included research reporting on mixed populations only if stroke results could be extracted, or the sample was ≥60% stroke; excluded paediatric populations.
Intervention or phenomenon of interest	Detailed information about the built environment, including ambient features, architectural and landscape features, interior design features, and/or maintenance features; excluded articles that mentioned aspects of the built environment without providing sufficient detail, for example, research that reported only the location of certain activities (e.g., time spent in the dining room) were not included, but research that provided details of said location (e.g., dimensions, adjacencies, etc.) were included.
Context	Inpatient rehabilitation hospital acute or sub-acute settings; research conducted in a virtual setting (e.g., using Virtual Reality) was eligible if the virtual environment depicted an inpatient rehabilitation hospital.
Outcome	Any outcome, experience, or perspective of any of the included populations.

Quality appraisal

Level of evidence and methodological quality were independently appraised by two reviewers.[19] For level of evidence, [INITIALS] and [INITIALS] used criteria adapted from Stichler (see Supplementary file 4),[20, 21] and reached consensus through discussion. Methodological quality was assessed using the Mixed Methods Appraisal Tool (MMAT).[22] To ensure consistent use of the MMAT, 25% of the included articles were assessed collaboratively by [INITIALS] and [INITIALS], before the remainder of the articles were independently assessed. Articles authored by reviewers were appraised by non-authors. Consensus was reached through discussion.

Data extraction and synthesis

Data were extracted using a standardized form (see Supplementary file 5). [INITIALS] categorised the studies according to: 1) the aspect of the built environment explored (e.g., bedrooms) or approaches to altering the environment (e.g., 'environmental enrichment' – i.e., setting up a communal activity area, encouraging communal dining, and providing patients with personalized 'enrichment packages' that include books, games, and activities of their choice), and 2) the outcomes reported in findings. The categories were reviewed by authors and were used to structure the narrative synthesis. For the environmental enrichment articles included in this review, only the results pertaining to the built environment components of the enrichment intervention are discussed, namely the availability and set-up of the communal activity areas.

RESULTS

After duplicate removal, our searches revealed 859 articles, 24 of which were included in the final review (see Figure 1). These 24 articles reported 18 studies from 14 research groups and 9 countries. Some articles were excluded because they were not specific to stroke rehabilitation (*n* = 14) or did not provide any details about the built environment (*n* = 21); see Categories A and B in Figure 2.

[Insert Figure 2 approximately here.]

[Insert Figure 3 approximately here.]

The study characteristics, article focus, outcomes of interest, level of evidence and methodological quality of the 24 included articles are outlined in Table 2 and their results are summarised in Supplementary file 6. Half of the articles (*n* = 12) did not focus on a particular aspect of the built environment, instead exploring the impact of the built environment as a whole (see Table 2). The remaining 12 articles investigated a particular aspect of the built environment, including environmental enrichment (*n* = 8), bedroom design (*n* = 3), and the location and availability of therapy spaces (*n* = 1). The aim of the environmental enrichment studies was to test, in humans, the long-established finding that laboratory rats who are housed with a rotating selection of toys, running wheels, and other rats are more active and recover more effectively from brain injury than single rats in standard cages.[23]

Table 2. The characteristics, focus, outcomes, and quality of the articles included in this review

Aspect of built environment	First author, year, country	Outcome categories 1	2	3	4	5	Participant type, *n*	Context	Study design	Level of evidence	Methodological quality
Enriched environment	Janssen, 2014, Australia		✓				Stroke patients, 29	Post-acute mixed rehabilitation ward pre-/post-EE intervention	Quant-NR	2	3
	Khan, 2016, Australia	✓		✓			Mixed rehab patients, 103 total (53 stroke)	Post-acute mixed rehabilitation ward pre-/post-EE intervention	Quant-R	2	5
	Robertson, 2020, Australia	✓					Stroke patients, 60	Acute stroke ward pre-/post-EE intervention	Quant-NR	2	4
	Rosbergen, 2017a, Australia		✓	✓		✓	Staff (nurses & AH), 10	Acute stroke ward pre-/post-EE intervention	Qual	3	5
	Rosbergen, 2017b, Australia	✓	✓				Stroke patients, 90	Acute stroke ward pre-/post-EE intervention	Quant-NR	2	4
	Rosbergen, 2019, Australia		✓			✓	Stroke patients, 90	Acute stroke ward pre-/post-EE intervention	Quant-NR	2	4
	White, 2014, Australia		✓	✓		✓	Staff (nurses), 11	Post-acute rehabilitation ward pre-/post-EE intervention	Qual	3	5
	White, 2015, Australia		✓	✓		✓	Stroke patients, 10	Post-acute rehabilitation ward pre-/post-EE intervention	Qual	3	5
Bedroom design	Arbel, 2019, Canada			✓			Stroke patients, 25 (10 in AHR; 15 in standard)	AHR and standard bedroom in post-acute stroke rehab ward	Mix	4	0
	Daemen, 2014a, Netherlands	✓				✓	Staff (nurses, doctors, AH, managers), 30	Mock-up of AHR	Mix	3	1
	Perovic, 2017, Montenegro			✓			Stroke patients, 100	Acute neurological ward pre/post-move	Quant-NR	2	4

Therapy spaces	Skubik-Peplaski, 2015, USA				✓	✓	Staff (OTs), 3	Post-acute rehabilitation ward	Qual	3	5
Whole of built environment	Anaker, 2017, Sweden		✓				Stroke patients, 59	Stroke ward pre/post-move	Mix	2	4
	Anaker, 2018, Sweden		✓				Stroke patients, 55	Comparison between 3 stroke wards	Mix	2	4
	Anaker, 2019, Sweden		✓	✓			Stroke patients, 16	Stroke ward	Qual	3	4
	Anaker, 2020, Sweden					✓	Staff, *n* not provided	Comparison between 3 stroke wards	Mix	2	2
	Daemen, 2014b, Belgium & Netherlands	✓		✓			Stroke patients, family & staff, *n* not provided	Two neurological wards	Qual	4	2
	Kevdzija, 2018, Germany		✓		✓		Stroke patients, 50; Staff, 46	Five neurological rehabilitation wards	Qual	3	5
	Lampinen, 2003, Sweden		✓				Stroke patients with visuospatial agnosia, 8	Stroke rehabilitation ward	Qual	3	5
	Lipson-Smith, 2019, Australia	✓	✓	✓	✓	✓	Patients, staff, researchers, designers, policy, 30	Hypothetical stroke rehabilitation ward	Qual	3	5
	O'Halloran, 2011, Australia					✓	Stroke patients, 65	Two acute stroke wards	Qual	3	4
	O'Halloran, 2012, Australia					✓	Stroke patients, 75; Staff (nurses, doctors, AH), 10	Metasynthesis of 3 studies in acute stroke wards	Qual	2	5
	Shannon, 2019, Australia		✓				Mixed neuro patients, 37 total (22 stroke)	Acute neurological ward pre/post-move	Quant-NR	2	3
	Turner, 2012, New Zealand			✓			Stroke patients with depression, 6	Rehabilitation ward	Qual	4	2

Outcome categories: 1 = patient clinical outcomes; 2 = patient activity (including physical, cognitive, and/or social activity); 3 = patient emotional well-being; 4 = patient and/or staff safety; and 5 = staff clinical practice and efficiency.

Level of evidence: 1 = systematic reviews, meta-analyses , and meta-syntheses; 2 = well-designed experimental, quasi-experimental, and multiple-case studies, and integrative or systematic reviews of observational or qualitative studies; 3 = well-designed observational and qualitative studies, poorly designed experimental, quasi-experimental, and multiple-case studies; 4 = poorly designed observational and qualitative studies.

Methodological quality: Measured using the Mixed Methods Appraisal Tool where 0 = low quality and 5 = high quality.

Study design: Qual = Qualitative, Quant-R = Quantitative randomised, Quant-NR = Quantitative non-randomised, Mix = Mixed methods.

Abbreviations: AHR = Adaptable Healing Room (specialised bedroom which incorporates technology to provided targeted levels of light and noise, orientation information, and positive distraction for the patient); AH = Allied Health professionals; EE = Environmental Enrichment (communal area, stimulating resources, and activities provided to patients); OT = Occupational Therapists.

In all included articles, one or more of the following five outcome categories were reported: 1) patient clinical outcomes (measurable changes in health or function, such a person's balance, mobility, or ability to perform everyday tasks); 2) patient activity (including physical, cognitive, and/or social activity); 3) patient emotional well-being (including mood, boredom, loneliness, sense of empowerment, and need for privacy); 4) patient and/or staff safety; and 5) staff clinical practice and efficiency (such as clinical decision making and use of staff time) (see Table 2). These outcome categories are described in detail in the narrative synthesis below.

Study design, research focus, and methodological quality of the included articles

Half of the included articles were qualitative studies (*n* = 12), the remainder were non-randomised quantitative studies (*n* = 6), mixed methods studies (*n* = 5), and randomized quantitative studies (*n* = 1) (see Table 2 and Figure 3). In 18 of the 24 studies patient outcomes or experiences were examined, rather than staff or family/caregivers (see Figure 3). In six articles targeted research questions were addressed, e.g., pre-specifying aspects of the built environment and/or specific outcomes of interest, while in other articles a more exploratory approach was taken (see top left quadrant Figure 3). The role of the built environment in general was the focus in nine articles, in relation to specific outcomes of interest (lower left quadrant of Figure 3), and the research questions in three articles were purely exploratory, with no predefined aspects of the built environment or outcomes of interest (bottom right quadrant of Figure 3).

[Insert Figure 3 approximately here.]

The qualitative studies appeared to be of higher methodological quality (*n* = 12, MMAT median score = 5), as did the one randomised quantitative study (MMAT score = 5), while the non-randomised quantitative studies and mixed methods studies were judged to be of lower methodological quality (non-randomised quantitative *n* = 6, MMAT median score = 4; mixed methods *n* = 5, MMAT median score = 2). Level of evidence classification is shown in Table 2. All of the articles that received a MMAT score < 2 (indicating low methodological quality) were also judged to provide the lowest level of evidence (level 4). The poorest scoring item on the MMAT was question 3.1 'Are the participants representative of the target population?' (see Supplementary file 7). We elected not to include one article[31] in the narrative synthesis as it was assessed as having very low methodological quality (MMAT = 0, see Table 2 and Supplementary file 7).

Narrative synthesis of results

Patient clinical outcomes

In six articles (total *n* = 263 participants), one or more clinical outcome(s) were discussed (see Table 2). Heterogeneity of outcomes, methods and environments prohibited comparison across studies.

In the only randomized trial, self-care and mobility functional independence at discharge were better in stroke patients with access to an enriched environment compared to patients without access (controls).[25] Differences were not sustained at 3-months post-discharge, however patients who experienced enrichment reported better health (measured using the EQ-5D) than controls.[25] Fewer adverse events (such as worsening of symptoms) were reported in patients experiencing enrichment compared to controls in another study, with no difference in serious adverse events (such as hospitalisation or death) or malnutrition.[27, 35]

One study explored staff opinion about the potential value of Adaptable Healing Rooms (AHRs) for stroke patients.[32] These specialised bedroom designs used timed lighting and multi-media technology to provide targeted levels of light and noise throughout the day, orientation information (e.g., clock, timetable, etc.) and positive distraction (e.g., family photos or nature scenes) for the patient. Staff suggested that AHRs may help to facilitate healing by promoting patient/staff relationships, being patient-centered, helping patients to wake-up naturally and improving sleep, providing more information and structure to the day, and providing stimulation at the right times.[32]

Expert elicitation conducted with a large stakeholder group of stroke patients and staff, researchers, architects, designers, and policy makers,[36] revealed four agreed 'fundamentally important' objectives that the built environment should meet in order to optimise stroke rehabilitation care: maximising efficiency of care, maximising effectiveness of care (i.e., clinical outcomes), maximising emotional well-being, and maximising safety. The experts identified a number of 'instrumentally important' objectives that the built environment could achieve to maximise patient activity and effective sleep and rest and thereby maximise clinical outcomes, including: maximising the versatility of the space, legibility (wayfinding), indoor environmental quality (air, light, noise, etc.), and patients' personal control over the space including accessibility to different spaces such as green and outdoor spaces and integration with the surrounding community.[36]

Physical, cognitive, and social activity

In over half of the included articles (13 articles, total *n* = 526 participants), patient activity, including physical activity (walking, using arm, etc.), cognitive activity (reading, listening to music, etc.), and/or social activity (talking, touch, etc.), was reported. Taken together, these studies provide some preliminary evidence that patient activity may increase in environments that are legible and easy to navigate, have attractive and accessible communal areas, and a smaller proportion of single-bed patient rooms.

In two studies (reported across three articles) stroke patients exposed to an enriched environment and a communal activity area participated in more activity than patients in a 'usual care' rehabilitation ward.[24, 27, 28] Variation in the type of activity enhanced with enrichment was found, with cognitive and social activity higher in one study,[24] and physical, cognitive, and social activity all were found to be higher in the other study.[27, 28] In qualitative studies associated with these projects, both staff[26, 29] and patients[30] reported that access to a communal activity area helped to promote patient activity.

In two studies, patient activity was measured before and after a ward was relocated to a new building.[37, 38] In a further study, patient activity was measured across three existing wards.[39] In these studies, a higher proportion of single-bed rooms was associated with lower levels of patient activity. Other aspects of the built environment thought to contribute to lower patient activity were the presence and attractiveness of communal areas and the ease of navigation. Communal areas that were unattractive or hard to find went unused.[38-40]

Kevdzija and Marquardt identified difficulty navigating (poor wayfinding), inappropriate dimensions of space (such as corridors that are too narrow for self-propelled wheelchairs), inappropriate distances between spaces (such as communal spaces being too far from the patient bedroom), uneven floor surfaces, and physical obstacles (such as equipment left in corridors) as barriers.[41] Similarly, legibility of the space, access to spaces beyond the bedroom (including communal and outdoor spaces), and patient control of the space were themes identified by Lipson-Smith et al. during expert elicitation.[36] In a small qualitative study by Lampinen and Tham in which the challenges of agnosia (changes in ability to recognise objects) were specifically considered, participants described how unrecognisable objects in the environment became obstacles and created barriers to their activity and performance of everyday tasks.[42]

Emotional well-being

Emotional well-being was explored in nine articles in this review (total n = 261 participants). Patient mood, boredom, empowerment, privacy, and loneliness were all raised as contributing to emotional well-being in inpatient rehabilitation. In several qualitative studies communal area access appeared important for patient emotional well-being, reducing boredom and loneliness and promoting patient empowerment.[26, 29, 30, 36, 40] Reduced levels of depression, anxiety, and stress at discharge were reported in patients with access to enrichment and communal areas compared to patients without access.[25]

Other built environment features thought to contribute to emotional well-being included: flexible space (e.g., having access to both single-bed and multi-bed patient rooms); connection to nature and the outside world; privacy and control over the space, and allowing for personal spaces within a clinical environment; aesthetics and appropriate light and noise levels; and ease of navigation, legibility, and access within the space.[36, 40, 43, 44] In one quantitative study, no difference in depression or anxiety was found between patients in an old rehabilitation ward and those in a new rehabilitation ward, which had fewer beds per room, more natural light, more colour, and a contemporary aesthetic.[33]

Staff and visitor/family emotional well-being were identified as important by Lipson-Smith et al.,[36] but were not explored directly in any studies.

Safety

The concept of safety within the environment was addressed in only three studies (total n = 129 participants).[36, 41, 45] In the study by Lipson-Smith et al., experts agreed that safety for patients, staff, and visitors/family could be maximised by: minimising manual handling, maximising sightlines between staff and patients; maximising legibility, accessibility and flexibility of the space; maximising indoor environmental quality (e.g., light and noise); and incorporating modern technology.[36] In a small qualitative study, Occupational Therapists felt safer treating patients in a gym environment than in one isolated and not purpose-built for therapy (such as a patient's bedroom) as there are always "extra hands" available from fellow therapists in a gym.[34] Obstacles in the environment (e.g., equipment in the hallway) and uneven floor surfaces were perceived barriers to patient mobility in the study by Kevdzija and Marquardt.[41] The actual safety, as opposed to perceived safety, of patients, staff, and/or visitors was not measured in any of the included studies.

Clinical practice and efficiency

Aspects of clinical practice and/or efficiency were mentioned in ten articles (total n = 334 participants).[26, 28-30, 32, 34, 36, 46-48] In four articles, communal activity areas were explored in the context of staff workload.[26, 28-30] Staff opinion varied about whether communal areas increased staff workload; some nurses felt obliged to facilitate patients' use of the area, while other nurses felt that activity areas kept patients occupied and so decreased staff workload.[26, 29] Quantitative studies in which staff time spent assisting patients in communal areas was measured suggested no change in staff workload when these activity areas were introduced.[28]

An observational study of multi-professional teamwork in three stroke units found that the design of the stroke units did not appear to foster multi-professional teamwork: Centrally-located staff workplaces, such as the nurses' stations, created visible hubs but were not appropriate for confidential discussions between staff; none of the stroke units had dedicated rooms for multi-professional meetings; and each profession worked mainly in their own dedicated offices.[48]

The qualitative meta-synthesis conducted by O'Halloran et al. addressed the question of patient/staff communication and concluded that high levels of background noise, visual distractions, and a lack of single-bed rooms acted as environmental barriers to communication between patients and staff.[46] In another qualitative study, Occupational Therapists reported adapting their treatment sessions according to the available space, indicating that the suitability of therapy spaces impacts treatment decision-making.[34]

Finally, in studies by Lipson-Smith at al.[36] and Daemon et al.[32] the role that the built environment, including AHRs, could play in contributing to care efficiency was raised in consultations with staff and other stakeholders.

DISCUSSION

This systematic review provides an overview of the existing research related to inpatient stroke rehabilitation built environments, a unique healthcare environment where patient activity, practice, and motivation are paramount. Our review revealed a research field in its early stages; the majority of the included articles were exploratory (see Figure 3), the quality of research varied, and there was no research to provide level 1 evidence (see Table 2). Heterogeneity of outcomes, methods and environmental variables of interest hindered comparison across studies but raised interesting questions about what drives research in this field and how this research is generated.

The few targeted research articles included in this review were limited to three aspects of the built environment: 1) environmental enrichment and associated communal activity areas; 2) bedroom design, including the impact of AHRs; and 3) the type and availability of therapy spaces. While these topics are important, they are hardly exhaustive. Access to nature and the outdoors was identified by Lipson-Smith et al.[36] as important for encouraging activity and emotional well-being in stroke rehabilitation environments, and the therapeutic impact of outdoor spaces is well-researched in other healthcare settings,[49] but our review revealed no targeted research studies addressing the impact of outdoor spaces in inpatient stroke rehabilitation.

Applying evidence-based design principles from other healthcare contexts to a rehabilitation setting is unlikely to fully address the unique priorities and purpose of rehabilitation environments.[11] Single-bed patient rooms, for example, have been found to improve patient-clinician communication, infection control, and noise reduction in other healthcare settings,[50] but evidence regarding the impact of single-bed rooms is lacking in patients with neurological injury.[51-53] Noise reduction and privacy are important considerations in stroke rehabilitation, especially considering the disabling experience of fatigue,[15] however, exploratory studies in this review suggest that stroke patients in single-bed rooms may be less active and spend more time alone than patients in shared bedrooms,[37, 38] which may impact their recovery and well-being.[36] More recently, Rosebergen et al. found that patients spent more time alone but were also more physically active in a rehabilitation facility with more single-bed rooms, but there was no change in cognitive or social activity.[54] Given the importance of both activity and rest in stroke rehabilitation, it is essential that the impact of single-bed rooms is further investigated in a rehabilitation-specific context so that a design solution can be achieved which facilitates activity and practice, while ensuring opportunity for privacy and rest.

Communal areas were the most frequently addressed environmental feature in this review (addressed in half of the articles, *n* = 12). Taken together, these articles allow some tentative conclusions to be drawn regarding the benefits of communal areas for patient activity and emotional well-being in stroke rehabilitation. This is in line with findings from a large qualitative study conducted in a general (not stroke-specific) rehabilitation setting, in which freedom of movement, access to facilities, and choice within the environment impacted patient motivation, activity, and social interaction.[55] Provision of communal dining and activity areas were particularly noted as helping to increase patient activity in the study by.[56] Importantly, the mere existence of a communal area is likely not sufficient to guarantee its use.[39] Future research could examine the optimal design of communal areas; whether their use should be flexible or structured, their optimal size, and their optimal placement in relation to the patient bedrooms and other key spaces.

Patient perceptions and outcomes were the targets of interest in most studies (see Figure 3). Variation in patient activity associated with the environment (*n* = 13) was explored in over half of the articles in this review. This is perhaps unsurprising since physical activity and fitness may predict outcomes after stroke.[13] Healthcare environments can impact staff efficiency, well-being, and retention,[1] with flow-on effects for patient care. Family and caregiver involvement can improve patient outcomes,[57] yet caregivers often feel ignored or alienated in inpatient stroke rehabilitation environments.[58] Future research should consider the impact of the built environment on staff and family/caregivers, and how the environmental needs and priorities of these groups can be balanced with patient need.

Twenty-one articles were excluded from this review because, although they provided some comments about the built environment in their results or discussion, the authors did not intend to study the built environment and did not provide any details about said environment (see Figures 1 and 2). For example, in some of these studies the level of patient physical activity was shown to vary in different locations of the rehabilitation facility and be especially low in the bedroom and lounge.[59] While these studies can help us understand, for example, high use activity areas, the absence of details about the environment makes it impossible to determine *in what way* the environment is important.

This review showcases the wide array of study designs in this field. The authors of the one randomized study in this review acknowledged difficulties with conducting randomized trials of built environment interventions. This includes the inability to blind participants to randomization outcome (because the environmental change is obvious), which can introduce bias. While Khan et al. found significant between-group differences with their enrichment intervention, they recommended the study be repeated in different settings with larger sample sizes to confirm their findings.[25] In three studies the authors took advantage of renovations or rebuilds to conduct comparative studies. While these natural experiments can be informative, rebuilds usually involve more than one design change and often coincide with significant procedural or social change in the healthcare service, making it difficult for environmental variables to be isolated. Standardised description of rehabilitation environments as well as replication of studies showing promising findings should be important goals for all healthcare built environment research. Innovative research approaches are needed to overcome the challenges of researching healthcare environments. Emergent research approaches in rehabilitation environments research include using Virtual Reality to model and test different designs in controlled experiment (for example see The NOVELL Redesign project, www.novellredesign.com).

The quality of the studies in this review varied according to the MMAT, with the qualitative studies achieving the highest scores (indicating higher quality). This may in part be a reflection of the scoring system used in the MMAT. The MMAT was, however, designed to be used for all study types, including mixed methods, and has precedent in healthcare environments research.[19, 50] It is possible that our search may have missed some relevant research because the physical environment is defined differently in different disciplines, and some disciplines frequently publish in non-peer-reviewed mediums such as professional architecture magazines and books. However, we are confident that our search terms were sufficient to capture peer-reviewed research relating to the built environment as it is defined in this review. Our search was limited to articles published since the year 2000. We consider it unlikely that many relevant articles were published before this time. Indeed, only one (4%) of the articles included in this review was published prior to 2010. The rate of research in this field is increasing; we are aware of relevant articles that are in preparation or that were published after our searches were completed.[54] This review should therefore be updated in the coming years.

The 24 articles in this review were produced by 14 research groups. Many of these groups have previously collaborated and the authors of this review were involved in a number of the included studies. Evidence-based healthcare design research is inherently interdisciplinary, and the field will benefit as more diverse research groups bring innovative methods and approaches. The majority of the studies in this review were conducted either in Australia (50% of included articles) or Sweden (21% of included articles). As mentioned in the introduction, stroke rehabilitation services vary globally, and the design of rehabilitation facilities should reflect the local service. There is therefore a need to bring a more diverse international perspective to stroke rehabilitation environments research.

To effectively grow the research field and provide evidence-based design for patient well-being and health, it is essential that important factors (such as outdoor spaces, single-bed rooms, patient and staff safety, and staff well-being) are not overlooked. We recommend that future researchers use the findings from the exploratory studies included in this review to provide a rationale and framework for their research in rehabilitation design. These exploratory studies identify aspects of the built environment and outcomes that are worthy of further investigation and provide a framework for future stroke rehabilitation environments research. This may encourage a more unified approach to the discipline and help researchers to identify aspects of the built environment and outcomes that are worthy of targeted study.

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Contributors: JB, ME, SMB, MW, and HZ conceived and planned the protocol for this study. SMB developed and executed the search strategy. RLS and LP assessed the articles for eligibility and conducted the data extraction. RLS conducted the analysis and synthesis of the included studies. RLS, LP, SMB, ME, AD, MW, HZ and JB prepared the draft of the manuscript, and edited, read, and approved the final version of the manuscript.

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Patient consent for publication: Not required.

Ethics approval: Not required.

Provenance and peer review: Not commissioned; externally peer reviewed.

Data availability: The results from the articles included in this systematic review are summarised in the supplementary material.

References

1. Sadler BL, Berry LL, Guenther R, Hamilton D, Hessler FA, Merritt C, et al. Fable hospital 2.0: The business case for building better health care facilities. *Hastings Center Report*. 2011;41(1):13-23.

2. Ulrich R, Zimring C, Zhu X, DuBose J, Seo H-B, Choi Y-S, et al. A review of the research literature on evidence-based healthcare design. *Health Environments Research & Design Journal (HERD)*. 2008;1(3):61-125.

3. Joseph A, Bayramzadeh S, Zamani Z, Rostenberg B. Safety, performance, and satisfaction outcomes in the operating room: A literature review. *Health Environments Research & Design Journal (HERD)*. 2018;11(2):137-50.

4. Chaudhury H, Cooke HA, Cowie H, Razaghi L. The influence of the physical environment on residents with dementia in long-term care settings: A review of the empirical literature. *The Gerontologist*. 2017;58(5):e325-e37.

5. Connellan K, Gaardboe M, Riggs D, Due C, Reinschmidt A, Mustillo L. Stressed spaces: Mental health and architecture. *Health Environments Research & Design Journal (HERD)*. 2013;6(4):127-68.

6. Norrving B, Barrick J, Davalos A, Dichgans M, Cordonnier C, Guekht A, et al. Action Plan for Stroke in Europe 2018-2030. *Eur Stroke J*. 2018;3(4):309-36.

7. World Health Organization. World health statistics 2019: Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2019.

8. Langhorne P, Baylan S, Trialists ESD. Early supported discharge services for people with acute stroke. *Cochrane Database of Systematic Reviews*. 2017(7).

9. Australasian Rehabilitation Outcomes Centre. The AROC Annual Report: The state of rehabilitation in Australia in 2019.: Australian Health Services Research Institute, University of Wollongong. Accessed from: https://www.uow.edu.au/ahsri/aroc/dataset/reports-benchmarks/; 2019.

10. Reistetter TA, Kuo Y-F, Karmarkar AM, Eschbach K, Teppala S, Freeman JL, et al. Geographic and facility variation in inpatient stroke rehabilitation: multilevel analysis of functional status. *Archives of Physical Medicine and Rehabilitation*. 2015;96(7):1248-54.

11. Lipson-Smith R, Zeeman H, Bernhardt J. What's in a building? A descriptive survey of adult inpatient rehabilitation facility buildings in Victoria, Australia. *Archives of Rehabilitation Research and Clinical Translation*. 2020;2(1).

12. Bernhardt J, Hayward KS, Kwakkel G, Ward NS, Wolf SL, Borschmann K, et al. Agreed definitions and a shared vision for new standards in stroke recovery research: The Stroke Recovery and Rehabilitation Roundtable taskforce. *International Journal of Stroke*. 2017;12(5):444-50.

13. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery: A guideline for healthcare professionals from the

American Heart Association/American Stroke Association. *Stroke*. 2016;47(6):e98-e169.

14. Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC, Becker K, et al. Guidelines for the early management of patients with acute ischemic stroke: 2019 update to the 2018 guidelines for the early management of acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2019;50(12):e344-e418.

15. Luker J, Lynch E, Bernhardsson S, Bennett L, Bernhardt J. Stroke survivors' experiences of physical rehabilitation: a systematic review of qualitative studies. *Archives of Physical Medicine and Rehabilitation*. 2015;96(9):1698-708. e10.

16. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.

17. Lizarondo L, Stern C, Carrier J, Godfrey C, Rieger K, Salmond S, et al. Chapter 8: Mixed methods systematic reviews. In: Aromataris E, Munn Z, editors. *JBI Manual for Evidence Synthesis*: JBI; 2020.

18. Covidence systematic review software. Melbourne, Australia: Veritas Health Innovation; 2020.

19. Taylor E, Hignett S. Evaluating evidence: Defining levels and quality using critical appraisal mixed methods tools. *Health Environments Research & Design Journal (HERD)*. 2014;7(3):144-51.

20. Stichler JF. Weighing the evidence. SAGE Publications Sage CA: Los Angeles, CA; 2010.

21. Marquardt G, Motzek T. How to rate the quality of a research paper: introducing a helpful algorithm for architects and designers. *Health Environments Research & Design Journal (HERD)*. 2013;6(2):119-27.

22. Hong Q, Pluye P, Fàbregues S, Bartlett G, Boardman F, Cargo M, et al. Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552). Canadian Intellectual Property Office: Industry Canada; 2018.

23. Nithianantharajah J, Hannan AJ. Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience*. 2006;7(9):697-709.

24. Janssen H, Ada L, Bernhardt J, McElduff P, Pollack M, Nilsson M, et al. An enriched environment increases activity in stroke patients undergoing rehabilitation in a mixed rehabilitation unit: A pilot non-randomized controlled trial. *Disability and Rehabilitation*. 2014;36(3):255-62.

25. Khan F, Amatya B, Elmalik A, Lowe M, Ng L, Reid I, et al. An enriched environmental programme during inpatient neuro-rehabilitation: A randomized controlled trial. *Journal of rehabilitation medicine*. 2016;48(5):417-25.

26. Rosbergen ICM, Brauer SG, Fitzhenry S, Grimley RS, Hayward KS. Qualitative investigation of the perceptions and experiences of nursing and allied health professionals involved in the implementation of an enriched environment in an Australian acute stroke unit. *BMJ Open*. 2017;7(12).

27. Rosbergen ICM, Grimley RS, Hayward KS, Walker KC, Rowley D, Campbell AM, et al. Embedding an enriched environment in an acute stroke unit increases activity in people with stroke: A controlled before-after pilot study. *Clinical Rehabilitation*. 2017;31(11):1516-28.

28. Rosbergen ICM, Grimley RS, Hayward KS, Brauer SG. The impact of environmental enrichment in an acute stroke unit on how and when patients undertake activities. *Clinical Rehabilitation*. 2019;33(4):784-95.

29. White JH, Alborough K, Janssen H, Spratt N, Jordan L, Pollack M. Exploring staff experience of an "enriched environment" within stroke rehabilitation: A qualitative sub-study. *Disability and Rehabilitation*. 2014;36(21):1783-9.

30. White JH, Bartley E, Janssen H, Jordan LA, Spratt N. Exploring stroke survivor experience of participation in an enriched environment: A qualitative study. *Disability and Rehabilitation*. 2015;37(7):593-600.

31. Arbel I, Ye B, Mihailidis A. Stroke Patients' Experiences in an Adaptive Healing Room in a Stroke Rehabilitation Unit. *Health Environments Research & Design Journal (HERD)*. 2019;13(2):170-85.

32. Daemen EML, Flinsenberg ICM, van Loenen EJ, Cuppen RPG, Rajae-Joordens RJE. Adaptable Healing Patient Room for Stroke Patients A Staff Evaluation. *METHODS OF INFORMATION IN MEDICINE*. 2014;53(5):406-15.

33. Perovic Z, Perovic S. Influence of hospital room environment on the reduction of anxiety and depression in the

early stage of stroke. *Journal of Environmental Protection and Ecology*. 2017;18(2):710-9.

34. Skubik-Peplaski C, Howell DM, Hunter EG, Harrison A. Occupational Therapists' Perceptions of Environmental Influences on Practice at an Inpatient Stroke Rehabilitation Program: A Pilot Study. *Physical and Occupational Therapy in Geriatrics*. 2015;33(3):250-62.

35. Robertson ST, Grimley RS, Anstey C, Rosbergen IC. Acute stroke patients not meeting their nutrition requirements: investigating nutrition within the enriched environment. *Clinical Nutrition*. 2020:1470-7.

36. Lipson-Smith R, Churilov L, Newton C, Zeeman H, Bernhardt J. A Framework for Designing Inpatient Stroke Rehabilitation Facilities: A New Approach Using Interdisciplinary Value-Focused Thinking. *Health Environments Research & Design Journal (HERD)*. 2019;12(4):142-58.

37. Shannon MM, Elf M, Churilov L, Olver J, Pert A, Bernhardt J. Can the physical environment itself influence neurological patient activity? *Disability and Rehabilitation*. 2019;41(10):1177-89.

38. Anaker A, von Koch L, Sjostrand C, Bernhardt J, Elf M. 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(7):e0177477.

39. Anaker A, von Koch L, Sjostrand C, Heylighen A, Elf M. The physical environment and patients' activities and care: A comparative case study at three newly built stroke units. *Journal of Advanced Nursing*. 2018;74(8):1919-31.

40. Anaker A, von Koch L, Heylighen A, Elf M. "It's Lonely": Patients' Experiences of the Physical Environment at a Newly Built Stroke Unit. *Health Environments Research & Design Journal (HERD)*. 2019;12(3):141-52.

41. Kevdzija M, Marquardt G, editors. Physical Barriers to Mobility of Stroke Patients in Rehabilitation Clinics. Cambridge Workshop on Universal Access and Assistive Technology; 2018: Springer.

42. Lampinen J, Tham K. Interaction with the physical environment in everyday occupation after stroke: A phenomenological study of persons with visuospatial agnosia. *Scandinavian Journal of Occupational Therapy*. 2003;10(4):147-56.

43. Turner J. Environmental Factors of Hospitalisation which contribute to Post-stroke Depression during Rehabilitation for over 65 year olds. *Journal of the Australasian Rehabilitation Nurses' Association (JARNA)*. 2012;15(1):11-5.

44. Daemen E, van Loenen E, Cuppen R. The impact of the environment on the experience of hospitalized stroke patients - An exploratory study. In: *European Conference on Ambient Intelligence 2014 Nov 11*. pp. 114-24: Springer, Cham.

45. Skubik-Peplaski C, Rowles GD, Hunter EG. Toward a physical environmental continuum for occupational intervention in a rehabilitation hospital. *Occupational therapy in health care*. 2012;26(1):33-47.

46. O'Halloran R, Grohn B, Worrall L. Environmental factors that influence communication for patients with a communication disability in acute hospital stroke units: a qualitative metasynthesis. *Archives of Physical Medicine and Rehabilitation*. 2012;93(1 Suppl):S77-85.

47. O'Halloran R, Worrall L, Hickson L. Environmental factors that influence communication between patients and their healthcare providers in acute hospital stroke units: An observational study. *International Journal of Language and Communication Disorders*. 2011;46(1):30-47.

48. Anaker A, von Koch L, Eriksson G, Sjostrand C, Elf M. The physical environment and multi-professional teamwork in three newly built stroke units. *Disability and Rehabilitation*. 2020:1-9.

49. Marcus CC, Sachs NA. *Therapeutic landscapes: An evidence-based approach to designing healing gardens and restorative outdoor spaces*: John Wiley & Sons; 2013.

50. Taylor E, Card AJ, Piatkowski M. Single-Occupancy Patient Rooms: A Systematic Review of the Literature Since 2006. *Health Environments Research & Design Journal (HERD)*. 2018;11(1):85-100.

51. Shannon MM, Lipson-Smith R, Elf M, Olver J, Kramer S, Bernhardt J. 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. *Intelligent Buildings International*. 2018:1-19.

52. Bernhardt J, Cumming T. The elephant in the single room debate: keeping patients active. *British Medical Journal*. 2013;347:f6333.

53. Maben J, Griffiths P, Penfold C, Simon M, Anderson JE, Robert G, 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 Quality & Safety*. 2016;25(4):241-56.

54. Rosebergen I, Tonello I, Clark R, Grimley R. Does hospital design impact on patient activity levels and time spent alone? *Disability and Rehabilitation*. 2020.

55. Killington M, Fyfe D, Patching A, Habib P, McNamara A, Kay R, et al. Rehabilitation environments: Service users' perspective. *Health Expectations*. 2019;22(3):396-404.

56. Scrivener K, Pocovi N, Jones T, Dean B, Gallagher S, Henrisson W, et al. Observations of Activity Levels in a Purpose-Built, Inpatient, Rehabilitation Facility. *Health Environments Research & Design Journal (HERD)*. 2019;12(4):26-38.

57. van Dijk M, Vreven J, Deschodt M, Verheyden G, Tournoy J, Flamaing J. Can in-hospital or post discharge caregiver involvement increase functional performance of older patients? A systematic review. *BMC Geriatrics*. 2020;20(1):362.

58. Luker J, Murray C, Lynch E, Bernhardsson S, Shannon M, Bernhardt J. Carers' Experiences, Needs, and Preferences During Inpatient Stroke Rehabilitation: A Systematic Review of Qualitative Studies. *Archives of Physical Medicine and Rehabilitation*. 2017.

59. Sjöholm A, Skarin M, Churilov L, Nilsson M, Bernhardt J, Lindén T. Sedentary Behaviour and Physical Activity of People with Stroke in Rehabilitation Hospitals. *Stroke Research and Treatment*. 2014(2014):163.

Figure legends

Figure 1. Article identification and screening flow diagram

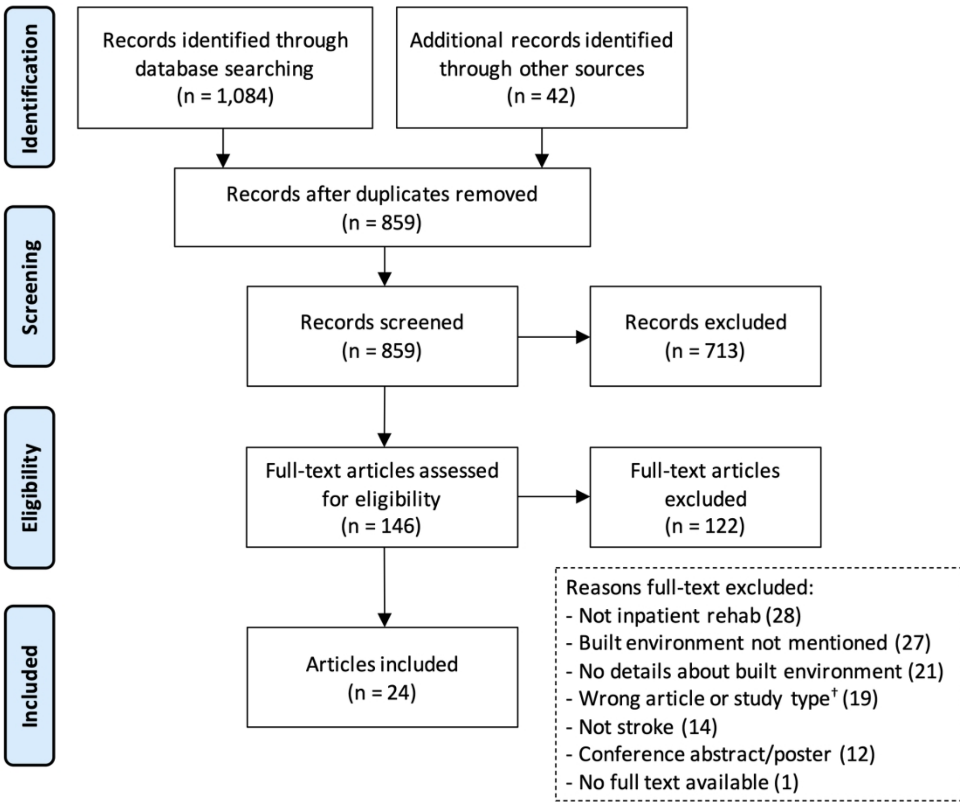
[†]*The following types of articles were excluded from this review, but their reference lists were searched for relevant articles: opinion pieces or commentaries, unpublished studies in PhD theses, single case studies, and systematic reviews with no meta-analysis, meta-synthesis, or integrative component.*

Figure 2. The overlapping categories of research which may provide evidence relevant to stroke rehabilitation healthcare facility design.

Category A: Evidence from other healthcare settings which may support research findings from stroke rehabilitation environments (but are not specific to stroke rehabilitation).
Category B: Evidence from stroke rehabilitation research which may highlight the importance of the built environment (but not describe it in any detail). This systematic literature review included only evidence from Category C.

Figure 3. Research method and focus of included articles.

Articles are clustered according to the extent to which they pre-specified the specific aspects of the built environment or outcomes to be investigated (targeted vs exploratory research).



Article identification and screening flow diagram

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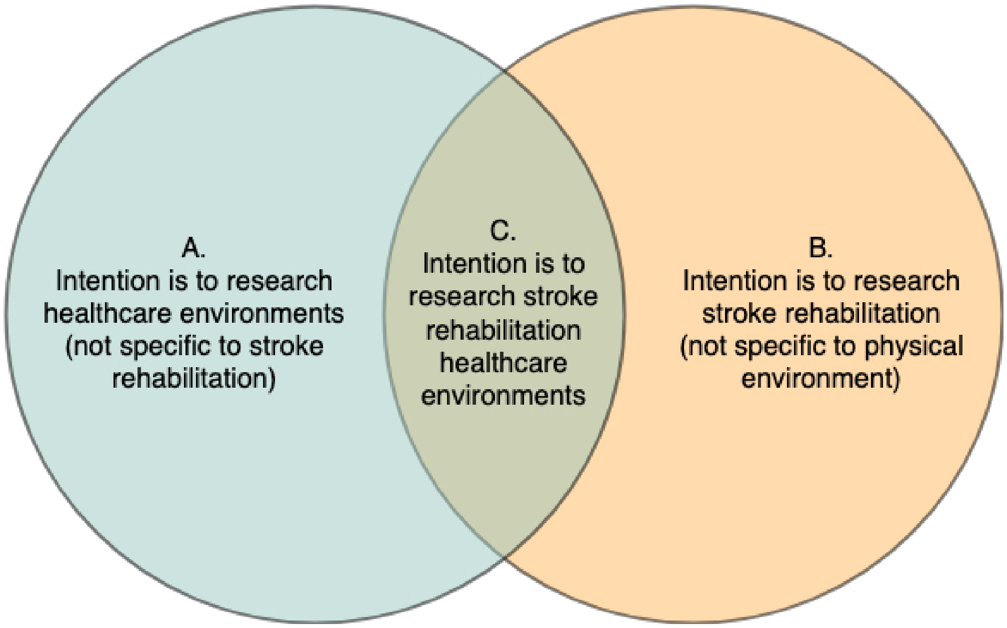
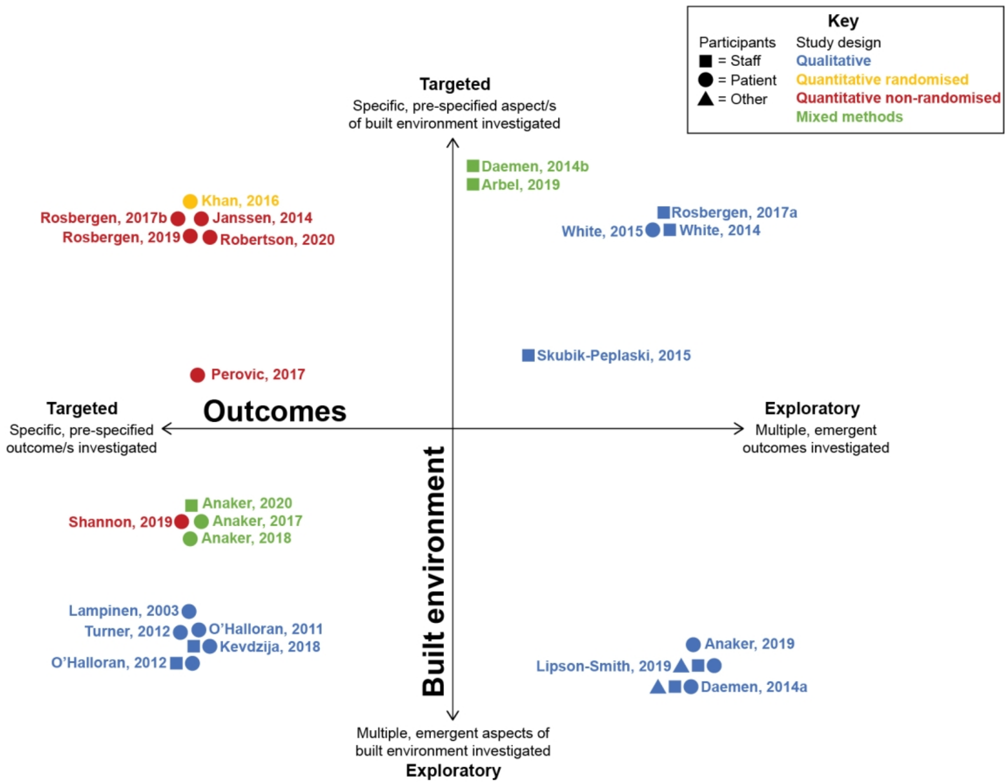
173x145mm (300 x 300 DPI)



The overlapping categories of research which may provide evidence relevant to stroke rehabilitation healthcare facility design.
Category A: Evidence from other healthcare settings which may support research findings from stroke rehabilitation environments (but are not specific to stroke rehabilitation). Category B: Evidence from stroke rehabilitation research which may highlight the importance of the built environment (but not describe it in any detail). This systematic literature review included only evidence from Category C.

205x127mm (72 x 72 DPI)



Research method and focus of included articles.
Articles are clustered according to the extent to which they pre-specified the specific aspects of the built environment or outcomes to be investigated (targeted vs exploratory research).

286x223mm (150 x 150 DPI)

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supp material 3
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Supp material 5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supp material 7
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Supp material 6
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	14-19
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	20-21
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	23
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	23
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	24

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

The impacts of the physical environment of inpatient rehabilitation settings on outcomes and experiences of patients recovering from stroke, their family/carers, and staff: a mixed methods systematic review protocol

Keywords: Stroke; Rehabilitation; Brain Recovery; Built Environment; Physical environment

1. Background

Research-driven architecture or evidence-based design is a new field of endeavor that aims to inform health facility design. To date, the focus of research has been on hyper acute (Intensive Care Unit, surgery) environments [1], with some attention paid to institutional care for older people [2] and mental health facilitates [3]. Between these disparate sectors lies an important and expensive area of healthcare: that of hospital-based rehabilitation. Rehabilitation, particularly for those with acquired neurological injury, traumatic brain injury or stroke, is slow and expensive.

Research-driven or evidence informed design refers to the act of creating healthcare environments based on the judicious use of best evidence from research and practice together with an informed client's view. Evidence-based design results in improvements in patient outcomes and safety, economic performance and productivity of the organization, and user satisfaction [4]. Evidence-based design has driven an exciting new era of questioning how healthcare design (the buildings, interiors, wayfinding, etc.) impacts on patient care and healthcare outcomes. To date, most research has explored the effect of the acute healthcare environment on patient and staff outcomes. While the evidence base is growing, empirical research in healthcare environments has been described as minimal [5].

In the last decade, primary care hospital design has been the focus for innovation [6]. In the US alone, over the next decade over $200 billion will be spent on the development of new healthcare facilities [7]. In Australia, the new Royal Adelaide Hospital has been named the eighth most expensive building in the world at US$2.1 billion [https://www.emporis.com]. In contrast, the post-acute rehabilitation environment has received little attention and research focus, despite the fact that rehabilitation care is expensive and a critical element of the recovery trajectory after serious injury.

Survivors of stroke may spend between 2 weeks and 2 or more months in hospital-based inpatient rehabilitation (mean 27.7 days for stroke and 39.2 days for brain injury) [8]. In 2016, the provision of rehabilitation grew in volume as there was a 2.8% increase in inpatient episodes of rehabilitation [8]. Rehabilitation often continues for months to years with gradual shift from hospital-based to outpatient care to community care. The environment is an important element that has the potential to help or harm brain recovery [9]. In 2011, Sadler et al conservatively calculated the economic benefits of introducing evidence-based design improvement in healthcare facility design as providing a return on investment within 3 years [5].

A major challenge of providing stroke care and rehabilitation is to determine how the physical environment should be designed and utilized to best address specific patient needs and rehabilitation goals.

2. Aim

The aim of this systematic review is to identify, appraise, and synthesize the existing literature related to evidence-based design (EBD) of rehabilitation facilities, and identify the recorded impacts of the physical environment of rehabilitation settings on the outcomes and experiences of patients recovering from stroke, their family/carers, and staff.

Overarching research question

What is the current state of knowledge about evidence-based design in the stroke rehabilitation setting?

Specifically this review will address the following research questions

- What types of outcomes have been investigated in relation to the physical environment in the stroke rehabilitation setting?
- What are the impacts of the physical rehabilitation environment on the outcomes and experiences of patients recovering from stroke, their family/carers, and staff?
- What aspects of the physical environment has shown to impact on outcomes and experiences of patients recovering from stroke, their family/carers, and staff?
- What are the research methods used to investigate the impact of the physical environment on outcomes and experiences of patient recovering from stroke, their family/carers, and staff?

3. Method

This mixed studies systematic literature review will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [10]. A convergent segregated review design will be used whereby the results from qualitative, quantitative, and mixed-methods studies were integrated in a narrative summary [11].

This mixed studies review applies a systematic strategy for identifying, retrieving, assessing, and appraising the available literature reporting on the **impacts** of the physical environment in the stroke rehabilitation setting. The review will consider a range of research designs including qualitative, quantitative and mixed-method studies in order to report comprehensively on the topic. The data synthesis will use descriptive statistics and qualitative content analysis [12] as appropriate to the type of data retrieved. An inter-rater reliability process [13] will be included in the search and retrieval stages whereby the processes will be performed by two researchers and any ambiguity or disagreement about the inclusion or exclusion of articles will be discussed until agreement is reached.

3.1. Search Strategy

Search terms will be reviewed by a professional research librarian. A systematic search of the following electronic databases will be conducted: OVID Medline, SCOPUS, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Web of Science. The two key concepts "Stroke" and "Healthcare facility design" will determine the search terms used (see Table 1). Boolean searches using the operators "AND" / "OR" / "NOT" will be constructed with selected search terms and combination of search terms as appropriate for each database following respective guidelines. Figure 1 shows an example of the OVID Medline Boolean search strategy. Any additional, search terms identified during the screening process will be added as appropriate. The reference lists of key articles will be additionally hand-searched ("snowballing"). Two researchers will perform the searches.

Table 1 Search terms

Key concept	Search terms
Stroke	Stroke or neurologic* or brain injur* or brain recovery or Stroke Rehabilitation or brain injur* rehabilitation or stroke recovery or neurologic* rehabilitation or brain injur* recovery
Healthcare facility design	facility or facilities or environment* or rehabilitation environment* or rehabilitation setting* or buil* design or architecture* or evidence-based design or garden* or hospital design or outdoor setting or outdoor environment or interior design or environment* factor* or physical environment or built environment or

Database: Ovid MEDLINE(R) ALL <1946 to July 29, 2019>
Search Strategy:
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1 (("environment* factor*" or "physical environment*" or "built environment*" or facility or facilities or architecture* or "evidence-based design" or garden* or "outdoor setting*" or "outdoor environment*" or "facilit* design*" or "hospital design" or "interior design") not "nursing facilit*").m_titl. (53548)
2 ((stroke or neurologic* or "brain injur*" or "brain recovery" or "stroke rehabilitation" or "neurologic* rehabilitation" or "brain injur* rehabilitation" or "stroke recovery" or "neurologic* recovery" or "brain injur* recovery") not gene* not robot* not pharmacol* not non-pharmacol* not delirium not ulcer* not pollution not syndrome* not wildlife not dementia not sepsis not pneumonia not "spinal cord injur*" not mouse* not rat* not "animal model*" not ventilat* not transfer not multidrug* not drug* not malnutrition* not cardi* not kidney not fracture* not thrombolys* not "aged care" not "nursing home" not Parkinson* not fibrillat* not tomograph* not ecology* not incontinen* not continen* not urin* not ultrasound not geograph* not treadmill not "muscle architecture" not "sleep architecture" not "clot architecture" not "pagodian architecture" not "brain architecture" not influenza not payment not "systematic review" not "meta-synthesis" not "meta-analysis" not "methicillin*").m_titl. (133295)
3 1 and 2 (123)
4 limit 3 to (english language and yr="2000 - 2020") (90)

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Figure 1 OVID Medline Boolean search strategy

3.2. Inclusion criteria

The inclusion criteria are outlined in Table 2. Research addressing any aspect of the physical environment in inpatient rehabilitation settings and its impact on the outcomes or experiences of adult patients recovering from stroke or their family/carers or staff will be considered for inclusion, as long as sufficient detail is provided about the physical environment (see Table 2).

Table 2 Included articles must meet all the below criteria.

Inclusion criteria
1. Peer-reviewed
2. Published between 2000 and 2020
3. Written in English language

4. Quantitative, qualitative or mixed method research design. Protocol papers will only be included if the study results have not yet been published. Opinion pieces, commentaries, single case studies, and systematic reviews with no meta-analysis or meta-synthesis will not be included, but will be searched for relevant references (snowballing).

5. Journal article or conference paper. Conference posters and conference abstracts will not be included.

6. Population:
Adult stroke survivors, their family/carers, and/or staff who care for adult stroke survivors. Research reporting on mixed populations will only be included if one or more of the populations listed above make up the vast majority of the sample (>60%) or their results are reported separately so that they can be extracted from the mixed population.

7. Intervention/phenomenon of interest:
Research reporting on the physical environment of acute or sub-acute inpatient rehabilitation hospital settings where the physical environment is described in sufficient detail. For example, research that reports only on the location of certain activities (e.g., time spent in the dining room) or the position of a rehab ward in relation to an acute ward would not be included, but research that reports the dimensions, features, and etc. of said locations or wards (i.e., 'dining room was 10m2, with south facing windows and positioned adjacent to a courtyard and the nurses station') will be included.

For the purposes of this review, the physical environment is defined as comprising the following (this definition of the physical environment is adapted from Harris et al. (2002) [14] – studies that provide *details* about any of the following will be included:
   a. ambient features (e.g., noise, air quality, odours, light, temperature);
   b. architectural and landscape features (e.g., position and layout of the building, relationship between the building and its surroundings, dimensions of a room, placement of doors and windows, views and outdoor areas);
   c. interior design features (e.g., furniture, artwork, signage, colours, equipment and technology); and
   d. maintenance and housekeeping (e.g., cleanliness, repair and upkeep of architectural and interior features).

Both of the following types of studies will be included: 1) research where the intent is to describe or investigate any aspect of a physical environment of inpatient rehabilitation settings, and 2) research where findings concerning the physical environment of inpatient rehabilitation settings are reported (even if this was not the original intent of the research).

Research conducted in a virtual setting (e.g. using Virtual Reality) will be included as long as the virtual environment meets all of the criteria outlined above.

8. Outcome:
Research reporting on the outcomes, experiences, or perspectives of any of the populations specified above will be included.

3.3. Screening

Figure 2 provides a flowchart illustrating the 4-step process used for screening and assessing the retrieved literature. Each step will be conducted by two researchers independently who will discuss any disagreement until consensus is reached before proceeding to the next step (inter-rater reliability process) [13]. Covidence will be used to manage the screening and inter-rater process [15].

1. All duplicates eliminated
2. Title and abstracts screened for topic relevance
3. Full text articles of all included abstracts will be retrieved and read in full to confirm topic relevance
4. Quality of eligible articles will be assessed using a mixed studies review scoring system [16]

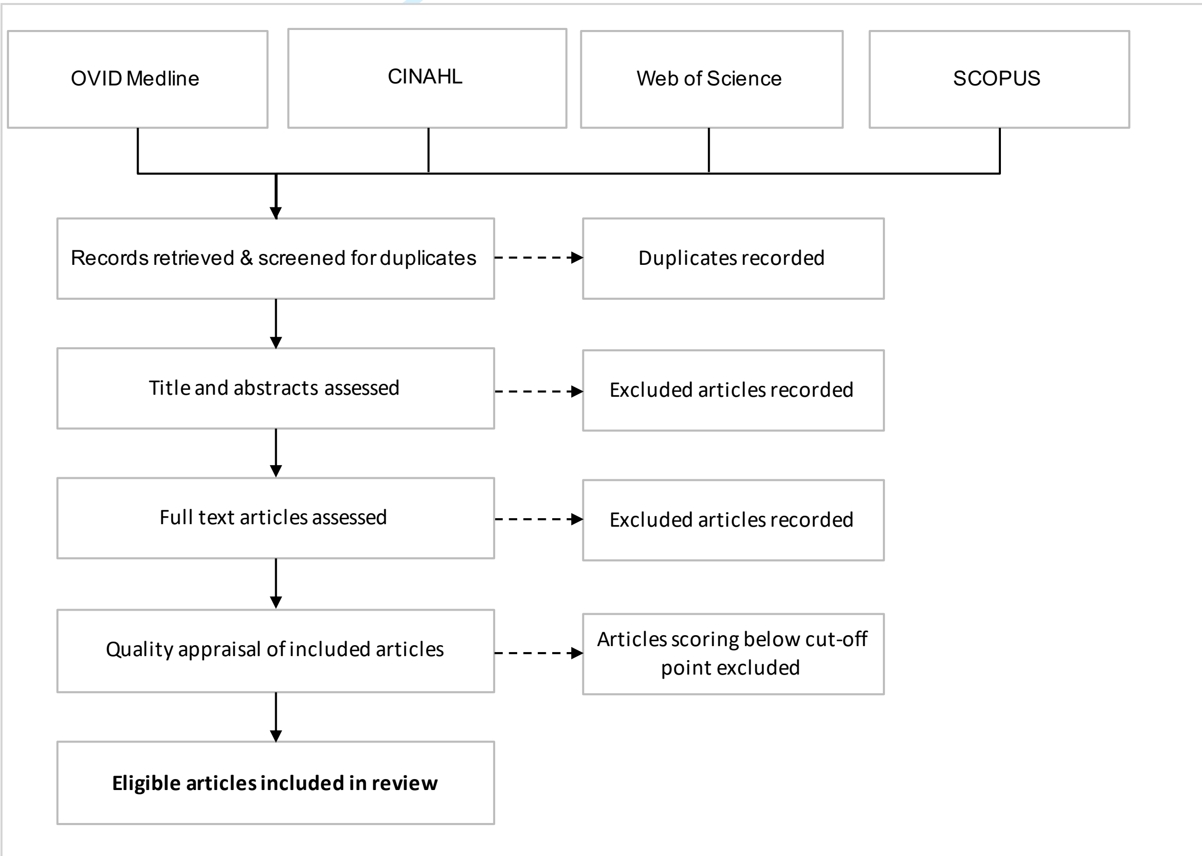

Figure 2 Flowchart of literature search and assessment process

3.4. Quality appraisal

The quality of articles will be assessed using the Mixed Methods Appraisal Tool (MMAT) [16]. This framework provides a system for appraising mixed studies reviews, which are reviews that include qualitative, quantitative and mixed-method research. The level of evidence of the included studies will be assessed following recommendations from Marquardt and Motzek (2013) [17], adapted from Stichler (2010) [18].

3.5. Data extraction and synthesis

A purpose-designed data extraction form will be used to retrieve all data relevant to answering the research questions (see Appendix 1). The form will include variables describing study characteristics in order to descriptively summarize the included studies.

The following variables will be collected:

First author, Year of publication, Country where research conducted, Study focus, Research design and methodology, Sample size, Participant characteristics, Setting characteristics, Type of outcome, Impact of physical environment, Aspects of physical environment.

References

1. Shepley, M.M., et al., *The impact of daylight and views on ICU patients and staff.* HERD: Health Environments Research & Design Journal, 2012. **5**(2): p. 46-60.
2. Connellan, K., et al., *Stressed spaces: mental health and architecture.* HERD: Health Environments Research & Design Journal, 2013. **6**(4): p. 127-168.
3. Papoulias, C., et al., *The psychiatric ward as a therapeutic space: systematic review.* The British Journal of Psychiatry, 2014. **205**(3): p. 171-176.
4. Hamilton, D.K. and J. Stichler, *Evidence-based design: What is it.* Health Environments Research & Design Journal, 2008. **1**(2): p. 3-4.
5. Sadler, B.L., et al., *Fable hospital 2.0: the business case for building better health care facilities.* Hastings Center Report, 2011. **41**(1): p. 13-23.
6. Hamilton, D.K. and M.M. Shepley, *Design for critical care: An evidence-based approach*. 2010: Routledge.
7. Siddiqui, Z.K., et al., *Changes in patient satisfaction related to hospital renovation: experience with a new clinical building.* Journal of hospital medicine, 2015. **10**(3): p. 165-171.
8. Australian Health Services Research Institute, U.o.W., *The AROC Annual Report: The state of rehabilitation in Australia in 2016.* 2017.
9. Muenchberger, H. and M. Shepley, *Buildings That Heal - Contributions from neuroscience in designing the built environment.* The Australian Hospital Health Care Bulletin, 2015.
10. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* PLoS med, 2009. **6**(7): p. e1000097.
11. Lizarondo, L., et al., *Chapter 8: Mixed methods systematic reviews*, in *JBI Manual for Evidence Synthesis*, E. Aromataris and Z. Munn, Editors. 2020, JBI.
12. Elo, S. and H. Kyngäs, *The qualitative content analysis process.* Journal of advanced nursing, 2008. **62**(1): p. 107-115.
13. Pope, C., S. Ziebland, and N. Mays, *Qualitative research in health care: analysing qualitative data.* BMJ: British Medical Journal, 2000. **320**(7227): p. 114.
14. Harris, P.B., et al., *A Place to Heal: Environmental Sources of Satisfaction Among Hospital Patients 1.* Journal of Applied Social Psychology, 2002. **32**(6): p. 1276-1299.
15. Covidence systematic review software, *Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org*.
16. Hong, Q., et al., *Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552)*. 2018, Industry Canada: Canadian Intellectual Property Office.
17. Marquardt, G. and T. Motzek, *How to rate the quality of a research paper: introducing a helpful algorithm for architects and designers.* HERD: Health Environments Research & Design Journal, 2013. **6**(2): p. 119-127.
18. Stichler, J.F., *Weighing the evidence*. 2010, SAGE Publications Sage CA: Los Angeles, CA.

Appendix 1 Sample data extraction form

First author (year), country [ref]	Study focus	Research design and methodology	Sample size (n)	Participants characteristics	Setting characteristics	Primary outcomes	Secondary outcomes

Supplementary material 3

OVID Medline Boolean search strategy

Database: Ovid MEDLINE(R) ALL <1946 to July 29, 2019>
Search Strategy:
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1 (("environment* factor*" or "physical environment*" or "built environment*" or facility or facilities or architecture* or "evidence-based design" or garden* or "outdoor setting*" or "outdoor environment*" or "facilit* design*" or "hospital design" or "interior design") not "nursing facilit*").m_titl. (53548)

2 ((stroke or neurologic* or "brain injur*" or "brain recovery" or "stroke rehabilitation" or "neurologic* rehabilitation" or "brain injur* rehabilitation" or "stroke recovery" or "neurologic* recovery" or "brain injur* recovery") not gene* not robot* not pharmacol* not non-pharmacol* not delirium not ulcer* not pollution not syndrome* not wildlife not dementia not sepsis not pneumonia not "spinal cord injur*" not mouse* not rat* not "animal model*" not ventilat* not transfer not multidrug* not drug* not malnutrition* not cardi* not kidney not fracture* not thrombolys* not "aged care" not "nursing home" not Parkinson* not fibrillat* not tomograph* not ecology* not incontinen* not continen* not urin* not ultrasound not geograph* not treadmill not "muscle architecture" not "sleep architecture" not "clot architecture" not "pagodian architecture" not "brain architecture" not influenza not payment not "systematic review" not "meta-synthesis" not "meta-analysis" not "methicillin*").m_titl. (133295)

3 1 and 2 (123)

4 limit 3 to (english language and yr="2000 - 2020") (90)

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Supplementary material 4

Levels of evidence

Level	Criteria
Level 1	Systematic reviews, meta-analyses of qualitative studies, and meta-syntheses of multiple qualitative studies leading to an integrative interpretation.
Level 2	Well-designed experimental (randomized), quasi-experimental (nonrandomized), and multiple-case studies. Integrative or systematic reviews of observational or qualitative studies.
Level 3	Well-designed observational and qualitative studies, and poorly designed experimental, quasi-experimental, and multiple-case studies.
Level 4	Poorly designed observational and qualitative studies, and professional standards or guidelines with studies to support recommendations.
Level 5	Opinions of recognized experts, single case studies.
Level 6	Recommendations from manufacturers or consultants who may have a financial interest or bias.

Adapted from Marquardt & Motzek (58) and Stichler (20)

Articles authored by reviewers were appraised by non-authors

Following the eligibility criteria for this review (see Table 1), systematic reviews with no meta-analysis or integrative component were not included, nor were non-peer reviewed articles, such as professional standards and guidelines, nor were any of the article types at Levels 5 and 6.

Supplementary material 5

Standardised form for data extraction.

Variable	**Description**
Author	First author of article
Year	Year article published
Title	Title of article
Aim	Aim as stated in the article
Study type	Qualitative | Quantitative randomized controlled trials | Quantitative nonrandomized | Quantitative descriptive | Mixed methods
Study design	Study design as stated in the article
Year data collected	
Participant type	Patients (acute, rehab, all stroke, or mixed population, etc.), or staff, or family/visitors. Include eligibility criteria if provided.
Mixed population	Are other patient/carer/staff types included besides stroke? Y/N
Stroke data extracted	If Y to 'mixed population', can the stroke-specific data be extracted? Y/N
Participant number	Number of participants
Participant age	Mean age
Time since stroke	Only relevant for patient participants
Other participant characteristics	
Country	Country or countries where the study was completed
Setting	Setting in which the study was completed, i.e., acute hospital, rehab hospital, etc. Include definition of this setting if provided in the paper.
Intervention/Exposure	Was an intervention conducted by the researchers? Or did they expose the participants to different environments? Y/N
Observational pre/post	Was this an observational study of an environment pre/post a move? Y/N
Details of physical environment	Include the details of the physical environment of the setting of this study.

Variable	Description
Aspect of physical environment	What aspect of the physical environment was of interest in this study? A particular room/location? Access to nature? Particular design or architectural feature? Or whole environment considered?
Floorplans provided?	Y/N
Photographs provided?	Y/N
Outcomes measured	Which outcomes were measured in this study
Method of data collection	How the data were collected
Method of data analysis	How the data were analysed
Findings	Ensure that the summary you provide for this variable refers to both the physical environment and the outcomes as they were measured in this study.
Conclusions	Our conclusions might not be the same as the conclusions in the paper - we need to think about the conclusions that we can draw from their results about the relationship between physical environment and patient/staff outcomes.
Comments	

Supplementary material 6

Summaries of the results of the included articles

Aspect of built environment	First author, year	Results summary
Enriched environment	Janssen, 2014	Participants in the enrichment group were 1.7 (95% CI 1.1 to 2.5, $p = 0.02$) times more likely to be engaged in cognitive activity, 1.2 (95% CI 1.0 to 1.5, $p = 0.04$) times more likely to be engaged in social activity, 0.7 (95% CI 0.6 to 0.9, $p < 0.001$) times as likely to be inactive and alone and 0.5 (95% CI 0.4 to 0.7, $p < 0.001$) times as likely to be asleep compared to the usual care group. Physical activity was not different between groups.
	Khan, 2016	At discharge, stroke participants in enrichment group had improved mood (DASS total mean difference = –24.1, CI = –40.1, –7.2, $p = 0.006$) and functional independence for self-care (FIM self-care mean difference = 3.5, CI = 0.4, 6.6, $p = 0.028$) and mobility (FIM mobility mean difference = 2.0, CI = 0.3, 3.8, $p = 0.024$) compared to the control group. At 3-months follow-up, stroke participants in enrichment group showed improvement in "overall health" section of EQ-5D (total mean difference = 11.4, CI = 0.1, 22.7, $p = 0.047$) compared to control group.
	Robertson, 2020	Neither standard care nor enriched environment participants met daily requirements for energy (70.7% ± SD 16.8 vs. 70.7% ± SD 17.3, $p = 0.94$) or protein intake (73.2% ± SD 18.6 vs. 69.8% ± SD 17.3, $p = 0.70$). Mean body weight dropped for both groups; standard care 0.92 kg ± SD 2.47 vs. enriched 0.64 kg ± SD 3.12 ($p = 0.53$) and malnutrition increased; standard care 3.3% - 26.6% vs. enriched 6.6% - 13.3% ($p = 0.07$). Predictors of malnutrition on discharge in logistic regression models were length of stay ($p < 0.01$) and protein ($p < 0.01$) or energy intake ($p = 0.02$).
	Rosbergen, 2017a	Staff felt that the activity area helped to increase activity, empowerment, and psychological well-being for patients. Activity area led to increased workload for some nurses (esp. with higher acuity patients) but others experienced reduced workload because patient kept occupied (esp. if other staff cooperated). The activity area was not purpose-built, which was challenging; staff converted therapy area to dining area daily.
	Rosbergen, 2017b	Participants in the enrichment group a spent a greater proportion of their day in physical (33% vs. 22%, $p < 0.001$), social (40% vs. 29%, $p = 0.003$) and cognitive activity (59% vs. 45%, $p < 0.001$) compared to usual care group. Changes were sustained six months post-implementation. Participants with an activity area experienced fewer adverse events (0.4 ± 0.7 vs.1.3 ± 1.6, $p = 0.001$), but no differences in serious adverse events (0.5 ± 1.6 vs.1.0 ± 2.0, $p = 0.309$).
	Rosbergen, 2019	Participants in enrichment group had higher activity levels during scheduled communal activity ($p < 0.001$), weekday non-scheduled activity ($p = 0.007$) and weekends ($p = 0.018$) compared to control group, but no difference between groups on weekdays after 5 p.m. ($p = 0.324$). Participants in enrichment group spent more time on upper limb ($p < 0.001$), communal

		socializing ($p < 0.001$), listening ($p = 0.007$) and iPad activities ($p = 0.002$) compared to control group. There was no difference in staff assistance during activities ($p = 0.055$).
	White, 2014	Staff felt that the activity area promoted patient activity, participation, and moral. Some nurses felt obliged to facilitate patients' use of activity area, other nurses were unsure how to facilitate use or did not consider this their responsibility. Some nurses felt too busy to facilitate, others experienced reduced workload because activity area kept patient occupied. Suggested having dedicated staff to facilitate use of activity area.
	White, 2015	Patients felt that the activity area helped to increase their physical and social activity and reduce boredom. Activity area may have been used more by internally motivated patients. Access to activity area was difficult for those with mobility restrictions, and patients hesitant to ask for help.
Bedroom design	Arbel, 2019	The AHR was rated more positively on all aspects compared to the standard room, and participants in the AHR reported more positive feelings and fewer negative feelings. More participants in the AHR reported a satisfactory overall experience compared to participants in standard rooms (100% [$n = 10$] vs 46.7% [$n = 7$], $p = 0.016$) and more reported a satisfactory experience of waking-up from sleep (90% [$n = 9$] vs 53.3% [$n = 8$], $p = 0.046$). Most felt that the orientation screen helped them to feel oriented (80% [$n = 8$]) and that the nature screen positively impacted their mood (70% [$n = 7$]).
	Daemen, 2014a	All participants rated the AHR positively for impact on clinical outcomes and workflow (score of 5 or over on a 7-point Likert scale). Participants felt that the AHR would promote patient/staff relationship, be patient-centered, help patients wake-up naturally, give more structure to the day, give stimulation at the right times and so be beneficial for both healing and workflow. Participants noted that patients would also be impacted by stimuli outside the AHR (e.g. sounds in hallway).
	Perovic, 2017	There was no significant difference in depression or anxiety (HADS) between participants in the bedrooms pre-refurbishment (many beds per room, poor light, poor aesthetics, old; mean HADS score = 9.14) and those in the bedroom post-refurbishment (fewer beds per room, more colour and light, new; mean HADS score = 7.18).
Therapy spaces	Skubik-Peplaski, 2015	Participants felt that they choose to treat in whichever space they are used to going to (habit), that the environment influenced their intervention choices ("see it use it"), and that they felt safer and so more confident treating in a gym environment versus an environment that was more isolated and was not purpose built for therapy.
Whole of built environment	Anaker, 2017	Participants were more inactive and alone post-move and spent more time in their bedrooms compared to pre-move (inactive for 25.3% of day pre-move, 54.1% post-move; alone 49.6% vs. 82.8%; in bedroom 54.8% vs. 83.1%). Authors suggest that the following factors contributed to the decreased activity and increased time alone and time in bedroom: increase in single-bed rooms post-move, more therapy in the bedroom, doors to bedrooms were always kept shut, lounge difficult to locate, and built environment hard to navigate.
	Anaker 2018	Participants in the ward with a combination of single- and multi-bedrooms were more active than participants in the wards with mostly single-bed rooms (31.6% of the day inactive vs 54.1% and 54.4%), but multi-bed rooms appeared to have less privacy and more noise. In all wards, participants spent very little time in the lounge and therapy areas (between 0.2% and 8.6% of the day),

	possibly because these rooms were difficult to locate or because they were not attractive spaces. Overall, three main aspects of the built environment appeared to have an impact on patients' activities and care: (1) Ease of navigation; (2) Responsiveness, flexibility and variety; and (3) Privacy and respect for personal integrity.
Anaker, 2019	Interviews with participants revealed two themes: 1) there is incongruence between community and privacy in the environment (single rooms promote privacy and control but also loneliness, and there is a lack of communal areas); 2) Connectedness with the outside world provides distraction and a sense of normality (nature and outdoors facilitate well-being and view of outdoor activities evoke memories and bring positive distraction).
Anaker, 2020	Staff rarely worked in teams of two or more while with patients, but when they do it is usually in the bedroom, indicating a need for large bedrooms with access to privacy. None of the included stroke units had a co-location for all the members of the multi-professional team. Three main categories were common across the stroke units: the units all contained a central hub; places were divided by profession and did not facilitate teamwork; the power imbalance between different staff groups and between staff and patients appears to be accentuated by the environment (e.g., meeting rooms being too small to accommodate all staff).
Daemen, 2014b	Authors state that patients' experiences and recovery could be improved if the following environmental needs are met: dosing stimulus load, having social support, having access to both single and multiple patient rooms, balancing a clinical and personal environment, providing structure to the day, undisturbed sleep, access to information.
Kevdzija, 2018	Staff and patients identified the following issues in the built environment that are barriers to patients' independent mobility: wayfinding problems, insufficient dimensions of spaces (corridors), physical obstacles, uneven floor surfaces and large distances between patient rooms and therapy rooms. Patients in the earlier stages of rehabilitation, especially those using a wheelchair, appeared to experience more barriers related to the built environment.
Lampinen, 2003	Participants described 3 main aspects of the built environment that impact their performance of everyday tasks: 1) Everything seems unfamiliar, familiar characteristics become unrecognizable, perceptions and sensations changed; 2) Interacting with the physical world can be difficult, objects can be obstacles and seem to have a mind of their own; and 3) Experiences of adaptation to the new problematic world, striving for mastery over things in the environment which used to be easy.
Lipson-Smith, 2019	Participants identified 4 fundamentally important things that the built environment must achieve for stroke rehabilitation: 1) maximise efficiency (by minimising time, cost and maximising responsiveness of the space), 2) maximise clinical outcomes (by maximising patient activity, sleep and rest), 3) maximise emotional well-being for all users, and 4) maximise safety for all users. Participants also identified 14 means by which these 4 things could be achieved: Maximise adaptability, versatility, adequate technology, multipurpose circulation spaces, outdoor and green space, personal control over space, integration with community, aesthetics, indoor environmental quality, legibility, accessibility, and sight lines, adhere to safety guidelines and minimize manual handling.
O'Halloran, 2011	The medical chart (visible in the patient bedroom) was observed to facilitate communication between patients and healthcare providers. All the other observed physical environmental factors appeared to create barriers to communication, including background noise, lack of physical aids, small print on food menus, and lack of written information to aid recall.

O'Halloran, 2012	The physical environment predominantly acted as a barrier to communication between patients and health care providers via e.g., high levels of background noise, visual distractions. Assistive communication devices were absent or frequently inaccessible. The lack of single-bed rooms made it more difficult to have conversations with patients.
Shannon, 2019	Higher proportion of single-bed rooms post-move. Overall, there was no difference in time spent in social activity between the two wards, but there was more in-bed social activity in the pre-move ward than in the post-move ward (33% of time vs 8%, p = 0.03). Participants were more physically active in their bedrooms post-move compared to pre-move (47% of time vs 2%, p = 0.001).
Turner, 2012	Participants identified that the rehabilitation environment contributed to their feelings of disempowerment, lack of control, and feeling of being in a time capsule, all of which they felt contributed to their post-stroke depression.

Abbreviations: AHR = Adaptable Healing Room; DASS = Depression Anxiety, Stress Scales; CI = Confidence Interval; FIM = Functional Independence Measure; EQ-5D = Euro-Quality of Life-5D questionnaire.

Supplementary material 7

Details of the results of methodological appraisal using the Mixed Methods Appraisal Tool (21).

Quality appraisal ratings of each study

First author, year	Criteria from the Mixed Methods Appraisal Tool																									
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	5.4	5.5
Anaker, 2017	1	0	1	1	1											1	1	[illegible]	1	1	0	1	1	1	1
Anaker, 2018	1	0	1	1	1											1	1	[illegible]	1	1	1	1	1	1	1
Anaker, 2019	1	1	1	0	1																				
Anaker, 2020	1	1	1	1	1											0	0	1	0	1	1	1	1	1	0
Arbel, 2019	1	0	0	0	1						0	0	0	0	0						1	1	1	1	0
Daemen, 2014a	1	1	0	1	1											0	0	1	0	0	1	0	0	0	0
Daemen, 2014b	1	1	0	0	0																				
Janssen, 2014											0	1	0	1	1										
Kevdzija, 2018	1	1	1	1	1																				
Khan, 2016						1	1	1	1	1															
Lampinen, 2003	1	1	1	1	1																				
Lipson-Smith, 2019	1	1	1	1	1																				
O'Halloran, 2011	1	1	0	1	1																				
O'Halloran, 2012	1	1	1	1	1																				
Perovic, 2017											0	1	1	1	1										
Robertson, 2020											0	1	1	1	1										
Rosbergen, 2017a	1	1	1	1	1																				
Rosbergen, 2017b											0	1	1	1	1										
Rosbergen, 2019											0	1	1	1	1										
Shannon, 2019											0	1	1	0	1										
Skubik-Peplaski, 2015	1	1	1	1	1																				
Turner, 2012	1	1	0	0	0																				
White, 2014	1	1	1	1	1																				
White, 2015	1	1	1	1	1																				

1 = a score of ‘yes’; 0 = a score of ‘no’ or ‘can’t tell’

Mixed methods studies were given the score of their lowest scoring criterion, as recommended by MMAT

Criteria within the Mixed Methods Appraisal Tool

Category of study designs	Methodological quality criteria
1. Qualitative	1.1. Is the qualitative approach appropriate to answer the research question?
	1.2. Are the qualitative data collection methods adequate to address the research question?
	1.3. Are the findings adequately derived from the data?
	1.4. Is the interpretation of results sufficiently substantiated by data?
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?
2. Quantitative randomized controlled trials	2.1. Is randomization appropriately performed?
	2.2. Are the groups comparable at baseline?
	2.3. Are there complete outcome data?
	2.4. Are outcome assessors blinded to the intervention provided?
	2.5 Did the participants adhere to the assigned intervention?
3. Quantitative nonrandomized	3.1. Are the participants representative of the target population?
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?
	3.3. Are there complete outcome data?
	3.4. Are the confounders accounted for in the design and analysis?
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?
4. Quantitative descriptive	4.1. Is the sampling strategy relevant to address the research question?
	4.2. Is the sample representative of the target population?
	4.3. Are the measurements appropriate?
	4.4. Is the risk of nonresponse bias low?
	4.5. Is the statistical analysis appropriate to answer the research question?
5. Mixed methods	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?
	5.2. Are the different components of the study effectively integrated to answer the research question?
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
	5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

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Built environments for inpatient stroke rehabilitation services and care: A systematic literature review

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Title

Built environments for inpatient stroke rehabilitation services and care: A systematic literature review

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Abstract

Objectives: To identify, appraise, and synthesise existing design evidence for inpatient stroke rehabilitation facilities; to identify impacts of these built environments on the outcomes and experiences of people recovering from stroke, their family/caregivers, and staff.

Design: A convergent segregated review design was used to conduct a systematic review.

Data sources: OVID Medline, SCOPUS, Web of Science, and CINAHL were searched between January 2000 and November 2020.

Eligibility criteria for selecting studies: Qualitative, quantitative, and mixed methods studies investigating the impact of the built environment of inpatient rehabilitation facilities on stroke survivors, their family/caregivers, and/or staff.

Data extraction and synthesis: Two authors separately completed title, abstract, full-text screening, data extraction, and quality assessment. Extracted data were categorised according to the aspect of the built environment explored and the outcomes reported. These categories were used to structure a narrative synthesis of the results from all included studies.

Results: Twenty-four articles were included, most qualitative and exploratory. Half of the included articles investigated a particular aspect of the built environment, including environmental enrichment and communal areas (n = 8), bedroom design (n = 3), and therapy spaces (n = 1). Findings related to one or more of the following outcome categories: 1) clinical outcomes; 2) patient activity; 3) patient well-being; 4) patient and/or staff safety; and 5) clinical practice. Heterogeneous designs and variables of interest meant results could not be compared, but some repeated findings suggest that attractive and accessible communal areas are important for patient activity and well-being.

Conclusions: Stroke rehabilitation is a unique healthcare context where patient activity, practice, and motivation are paramount. We found many evidence gaps that with more targeted research could better inform the design of rehabilitation spaces to optimise care.

PROSPERO registration number: CRD42020158006

Strengths and limitations of this study

- The review method allowed for all the current evidence regarding inpatient stroke rehabilitation built environments to be gathered and assessed in a systematic and rigorous way.
- The narrative synthesis and diagrams provide a succinct summary of the trends and gaps in stroke rehabilitation environments research.
- Results of the included studies could not be easily combined or compared due to heterogeneity of study designs and variables of interest.
- Stroke rehabilitation services vary globally, but the majority of the studies in this review were conducted in Australia (50% of included articles) and Sweden (21% of included articles).

Key words

Stroke rehabilitation; Hospital Design and Construction; Clinical outcomes

INTRODUCTION

The physical environment of healthcare facilities can influence clinical outcomes, patient and staff experiences, and the economic performance of the facility.[1, 2] Healthcare design research generates evidence to inform the design of healthcare facilities. Recent healthcare design research has focused on acute environments such as surgery and intensive care,[3] with significant attention paid to residential aged care[4] and mental health facilities.[5] Between these disparate sectors lies an important and expensive sector of healthcare: hospital-based inpatient rehabilitation.

Inpatient rehabilitation is essential for people recovering from serious injury or illness, such as stroke.[6] Stroke is a leading cause of death and disability worldwide.[7] As acute stroke treatments continue to improve, more people are expected to survive a stroke, and many will experience ongoing disability that requires hospital-based, or inpatient, rehabilitation. While recovery may continue for years post-stroke, initial rehabilitation usually begins in the acute phase of care, followed by sub-acute inpatient rehabilitation for some, and a gradual shift to outpatient and community care. Early supported discharge to home, more common in Europe, is suitable for only 30% of patients.[6, 8] The average length of stay in post-acute inpatient stroke rehabilitation varies globally, but is generally lengthy (for example, 27.2 days in Australia).[9] There is evidence that functional outcomes vary between rehabilitation facilities.[10] While variation may be due to differences in procedures and staffing, differences in environment could also contribute; we know that rehabilitation facility design is heterogeneous.[11]

Rehabilitation is defined as “a process of active change by which a person who has become disabled acquires the knowledge and skills needed for optimum physical, psychological and social function”.[12] Repetitive practice and targeted therapy – such as upper limb training, walking, speech exercises, and practicing activities of daily living – are integral to the rehabilitation process. People who have experienced a stroke are encouraged to engage in general physical, cognitive, and social activity outside of their structured therapy time in order to further promote their recovery.[13] This contrasts sharply with the priorities of acute care – to diagnose, stabilise the patient and, where possible, apply acute treatments such as thrombolysis or clot retrieval to prevent death and optimise outcomes.[14] During rehabilitation, patients must participate in activities and practice, but many patients experience boredom, lack of stimulation, fatigue, low mood, and feelings of disempowerment, which negatively impact their motivation.[15] The distinct function and priorities of rehabilitation, the importance of patient engagement, and the typically long length of stay, prompted this review of the healthcare design evidence specific to stroke rehabilitation to better understand how the design of these healthcare facilities could be optimised for their function.

The aim of this systematic literature review was to identify, appraise, and synthesise the existing literature related to the design of inpatient stroke rehabilitation facilities. Our research questions were: What aspects of the built environment have been investigated in inpatient stroke rehabilitation settings? What types of research methods have been used? What types of outcomes have been investigated? What are the impacts of the built environment on the outcomes and experiences of patients recovering from stroke, their family/caregivers, and staff?

METHODS

Design

We aimed to include all relevant research, so we elected to conduct a mixed studies systematic literature review which followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement (see Supplementary file 1).[16] We used a convergent segregated review design so that results from qualitative, quantitative, and mixed methods studies could be synthesised in a narrative summary.[17] The protocol was prospectively registered on PROSPERO (CRD42020158006; date: 17 November 2019; see Supplementary file 2).

Patient and public involvement

An Advisory Committee including two stroke survivors reviewed the research questions and draft manuscript of this review.

Data sources

A systematic search was conducted in the following databases in January 2020, and updated in November 2020: OVID Medline, SCOPUS, Web of Science, and Cumulative Index to Nursing and Allied Health Literature (CINAHL). A Boolean search strategy was used (see Supplementary file 3). Authors LP and RLS searched the reference lists of included articles, systematic literature reviews, relevant PhD theses, key journals (Health Environments Research & Design) and organisations (The Centre for Healthcare Design) for additional eligible studies.

Article selection

Publications that met the criteria outlined in Table 1 were considered eligible for inclusion. Following duplicate removal, two reviewers ([INITIALS]) independently screened titles and abstracts of the remaining articles using Covidence.[18] These authors then independently screened the full text of potentially eligible articles. Consensus was reached with whole team discussion.

Table 1. Eligibility criteria for articles in this systematic literature review

Criteria	Eligibility requirements
Publication year	Articles published between 2000 and 2020 (to reflect the rise of evidence-based design research in the past 20 years).
Article type	Peer reviewed, English language, journal article or conference paper; excluded conference abstracts, posters, and PhD theses.
Study design	Quantitative, qualitative, or mixed methods research designs; excluded opinion pieces, commentaries, single case studies, and systematic reviews with no meta-analysis or meta-synthesis.
Population	Stroke survivors, their family/caregivers, and/or staff who care for stroke survivors; included research reporting on mixed populations only if stroke results could be extracted, or the sample was ≥60% stroke; excluded paediatric populations.
Intervention or phenomenon of interest	Detailed information about the built environment, including ambient features, architectural and landscape features, interior design features, and/or maintenance features; excluded articles that mentioned aspects of the built environment without providing sufficient detail, for example, research that reported only the location of certain activities (e.g., time spent in the dining room) were not included, but research that provided details of said location (e.g., dimensions, adjacencies, etc.) were included.
Context	Inpatient rehabilitation hospital acute or sub-acute settings; research conducted in a virtual setting (e.g., using Virtual Reality) was eligible if the virtual environment depicted an inpatient rehabilitation hospital.
Outcome	Any outcome, experience, or perspective of any of the included populations.

Quality appraisal

Level of evidence and methodological quality were independently appraised by two reviewers.[19] For level of evidence, [INITIALS] and [INITIALS] used criteria adapted from Stichler (see Supplementary file 4),[20, 21] and reached consensus through discussion. Methodological quality was assessed using the Mixed Methods Appraisal Tool (MMAT).[22] To ensure consistent use of the MMAT, 25% of the included articles were assessed collaboratively by [INITIALS] and [INITIALS], before the remainder of the articles were independently assessed. Articles authored by reviewers were appraised by non-authors. Consensus was reached through discussion.

Data extraction and synthesis

Data were extracted using a standardized form (see Supplementary file 5). [INITIALS] categorised the studies according to: 1) the aspect of the built environment explored (e.g., bedrooms) or approaches to altering the environment (e.g., 'environmental enrichment' – i.e., setting up a communal activity area, encouraging communal dining, and providing patients with personalized 'enrichment packages' that include books, games, and activities of their choice), and 2) the outcomes reported in findings. The categories were reviewed by authors and were used to structure the narrative synthesis. For the environmental enrichment articles included in this review, only the results pertaining to the built environment components of the enrichment intervention are discussed, namely the availability and set-up of the communal activity areas.

RESULTS

After duplicate removal, our searches revealed 859 articles, 24 of which were included in the final review (see Figure 1). These 24 articles reported 18 studies from 14 research groups and 9 countries. We included only articles that focused on inpatient stroke rehabilitation healthcare built environments. Some articles were excluded because they were not specific to stroke rehabilitation (*n* = 14) or did not provide any details about the built environment (*n* = 21).

[Insert Figure 1 approximately here.]

The study characteristics, article focus, outcomes of interest, level of evidence and methodological quality of the 24 included articles are outlined in Table 2 and their results are summarised in Supplementary file 6. Half of the articles (*n* = 12) did not focus on a particular aspect of the built environment, instead exploring the impact of the built environment as a whole (see Table 2). The remaining 12 articles investigated a particular aspect of the built environment, including environmental enrichment (*n* = 8), bedroom design (*n* = 3), and the location and availability of therapy spaces (*n* = 1). The aim of the environmental enrichment studies was to test, in humans, the long-established finding that laboratory rats who are housed with a rotating selection of toys, running wheels, and other rats are more active and recover more effectively from brain injury than single rats in standard cages.[23]

Table 2. The characteristics, focus, outcomes, and quality of the articles included in this review

Aspect of built environment	First author, year, country	Outcome categories 1	2	3	4	5	Participant type, *n*	Context	Study design	Level of evidence	Methodological quality
Enriched environment	Janssen, 2014, Australia		✓				Stroke patients, 29	Post-acute mixed rehabilitation ward pre-/post-EE intervention	Quant-NR	2	3
	Khan, 2016, Australia	✓		✓			Mixed rehab patients, 103 total (53 stroke)	Post-acute mixed rehabilitation ward pre-/post-EE intervention	Quant-R	2	5
	Robertson, 2020, Australia	✓					Stroke patients, 60	Acute stroke ward pre-/post-EE intervention	Quant-NR	2	4
	Rosbergen, 2017a, Australia		✓	✓		✓	Staff (nurses & AH), 10	Acute stroke ward pre-/post-EE intervention	Qual	3	5
	Rosbergen, 2017b, Australia	✓	✓				Stroke patients, 90	Acute stroke ward pre-/post-EE intervention	Quant-NR	2	4
	Rosbergen, 2019, Australia		✓			✓	Stroke patients, 90	Acute stroke ward pre-/post-EE intervention	Quant-NR	2	4
	White, 2014, Australia		✓	✓		✓	Staff (nurses), 11	Post-acute rehabilitation ward pre-/post-EE intervention	Qual	3	5
	White, 2015, Australia		✓	✓		✓	Stroke patients, 10	Post-acute rehabilitation ward pre-/post-EE intervention	Qual	3	5
Bedroom design	Arbel, 2019, Canada			✓			Stroke patients, 25 (10 in AHR; 15 in standard)	AHR and standard bedroom in post-acute stroke rehab ward	Mix	4	0
	Daemen, 2014a, Netherlands	✓				✓	Staff (nurses, doctors, AH, managers), 30	Mock-up of AHR	Mix	3	1
	Perovic, 2017, Montenegro			✓			Stroke patients, 100	Acute neurological ward pre/post-move	Quant-NR	2	4

Therapy spaces	Skubik-Peplaski, 2015, USA				✓	✓	Staff (OTs), 3	Post-acute rehabilitation ward	Qual	3	5
Whole of built environment	Anaker, 2017, Sweden		✓				Stroke patients, 59	Stroke ward pre/post-move	Mix	2	4
	Anaker, 2018, Sweden		✓				Stroke patients, 55	Comparison between 3 stroke wards	Mix	2	4
	Anaker, 2019, Sweden		✓	✓			Stroke patients, 16	Stroke ward	Qual	3	4
	Anaker, 2020, Sweden					✓	Staff, *n* not provided	Comparison between 3 stroke wards	Mix	2	2
	Daemen, 2014b, Belgium & Netherlands	✓		✓			Stroke patients, family & staff, *n* not provided	Two neurological wards	Qual	4	2
	Kevdzija, 2018, Germany		✓		✓		Stroke patients, 50; Staff, 46	Five neurological rehabilitation wards	Qual	3	5
	Lampinen, 2003, Sweden		✓				Stroke patients with visuospatial agnosia, 8	Stroke rehabilitation ward	Qual	3	5
	Lipson-Smith, 2019, Australia	✓	✓	✓	✓	✓	Patients, staff, researchers, designers, policy, 30	Hypothetical stroke rehabilitation ward	Qual	3	5
	O'Halloran, 2011, Australia					✓	Stroke patients, 65	Two acute stroke wards	Qual	3	4
	O'Halloran, 2012, Australia					✓	Stroke patients, 75; Staff (nurses, doctors, AH), 10	Metasynthesis of 3 studies in acute stroke wards	Qual	2	5
	Shannon, 2019, Australia		✓				Mixed neuro patients, 37 total (22 stroke)	Acute neurological ward pre/post-move	Quant-NR	2	3
	Turner, 2012, New Zealand			✓			Stroke patients with depression, 6	Rehabilitation ward	Qual	4	2

Outcome categories: 1 = patient clinical outcomes; 2 = patient activity (including physical, cognitive, and/or social activity); 3 = patient emotional well-being; 4 = patient and/or staff safety; and 5 = staff clinical practice and efficiency.

Level of evidence: 1 = systematic reviews, meta-analyses , and meta-syntheses; 2 = well-designed experimental, quasi-experimental, and multiple-case studies, and integrative or systematic reviews of observational or qualitative studies; 3 = well-designed observational and qualitative studies, poorly designed experimental, quasi-experimental, and multiple-case studies; 4 = poorly designed observational and qualitative studies.

Context: Pre/post move = outcomes were compared before and after (i.e., pre and post) a ward was moved to a new building, or before and after a ward redesign or redevelopment.

Study design: Qual = Qualitative, Quant-R = Quantitative randomised, Quant-NR = Quantitative non-randomised, Mix = Mixed methods.

Methodological quality: Measured using the Mixed Methods Appraisal Tool where 0 = low quality and 5 = high quality.

Abbreviations: AHR = Adaptable Healing Room (specialised bedroom which incorporates technology to provided targeted levels of light and noise, orientation information, and positive distraction for the patient); AH = Allied Health professionals; EE = Environmental Enrichment (communal area, stimulating resources, and activities provided to patients); OT = Occupational Therapists.

In all included articles, one or more of the following five outcome categories were reported: 1) patient clinical outcomes (measurable changes in health or function, such a person's balance, mobility, or ability to perform everyday tasks); 2) patient activity (including physical, cognitive, and/or social activity); 3) patient emotional well-being (including mood, boredom, loneliness, sense of empowerment, and need for privacy); 4) patient and/or staff safety; and 5) staff clinical practice and efficiency (such as clinical decision making and use of staff time) (see Table 2). These outcome categories are described in detail in the narrative synthesis below.

Study design, research focus, and methodological quality of the included articles

Half of the included articles were qualitative studies (*n* = 12), the remainder were non-randomised quantitative studies (*n* = 6), mixed methods studies (*n* = 5), and randomized quantitative studies (*n* = 1) (see Table 2 and Figure 2). In 18 of the 24 studies patient outcomes or experiences were examined, rather than staff or family/caregivers (see Figure 2). In six articles targeted research questions were addressed, e.g., pre-specifying aspects of the built environment and/or specific outcomes of interest, while in other articles a more exploratory approach was taken (see top left quadrant Figure 2). The role of the built environment in general was the focus in nine articles, in relation to specific outcomes of interest (lower left quadrant of Figure 2), and the research questions in three articles were purely exploratory, with no predefined aspects of the built environment or outcomes of interest (bottom right quadrant of Figure 2).

[Insert Figure 2 approximately here.]

The qualitative studies appeared to be of higher methodological quality (*n* = 12, MMAT median score = 5), as did the one randomised quantitative study (MMAT score = 5), while the non-randomised quantitative studies and mixed methods studies were judged to be of lower methodological quality (non-randomised quantitative *n* = 6, MMAT median score = 4; mixed methods *n* = 5, MMAT median score = 2). Level of evidence classification is shown in Table 2. All of the articles that received a MMAT score < 2 (indicating low methodological quality) were also judged to provide the lowest level of evidence (level 4). The poorest scoring item on the MMAT was question 3.1 'Are the participants representative of the target population?' (see Supplementary file 7). We elected not to include one article[24] in the narrative synthesis as it was assessed as having very low methodological quality (MMAT = 0, see Table 2 and Supplementary file 7).

Narrative synthesis of results

Patient clinical outcomes

In six articles (total *n* = 263 participants), one or more clinical outcome(s) were discussed (see Table 2). Heterogeneity of outcomes, methods and environments prohibited comparison across studies.

In the only randomized trial, self-care and mobility functional independence at discharge were better in stroke patients with access to an enriched environment compared to patients without access (controls).[25] Differences were not sustained at 3-months post-discharge, however patients who experienced enrichment reported better health (measured using the EQ-5D) than controls.[25] Fewer adverse events (such as worsening of symptoms) were reported in patients experiencing enrichment compared to controls in another study, with no difference in serious adverse events (such as hospitalisation or death) or malnutrition.[26, 27]

One study explored staff opinion about the potential value of Adaptable Healing Rooms (AHRs) for patients who had experienced a stroke.[28] These specialised bedroom designs used timed lighting and multi-media technology to provide targeted levels of light and noise throughout the day, orientation information (e.g., clock, timetable, etc.) and positive distraction (e.g., family photos or nature scenes) for the patient. Staff suggested that AHRs may help to facilitate healing by promoting patient/staff relationships, being patient-centered, helping patients to wake-up naturally and improving sleep, providing more information and structure to the day, and providing stimulation at the right times.[28]

Expert elicitation conducted with a large stakeholder group of people who had experienced a stroke and staff, researchers, architects, designers, and policy makers,[29] revealed four agreed 'fundamentally important' objectives that the built environment should meet in order to optimise stroke rehabilitation care: maximising efficiency of care, maximising effectiveness of care (i.e., clinical outcomes), maximising emotional well-being, and maximising safety. The experts identified a number of 'instrumentally important' objectives that the built environment could achieve to maximise patient activity and effective sleep and rest and thereby maximise clinical outcomes, including: maximising the versatility of the space, legibility (wayfinding), indoor environmental quality (air, light, noise, etc.), and patients' personal control over the space including accessibility to different spaces such as green and outdoor spaces and integration with the surrounding community.[29]

Physical, cognitive, and social activity

In over half of the included articles (13 articles, total n = 526 participants), patient activity, including physical activity (walking, using arm, etc.), cognitive activity (reading, listening to music, etc.), and/or social activity (talking, touch, etc.), was reported. Taken together, these studies provide some preliminary evidence that patient activity may increase in environments that are legible and easy to navigate, have attractive and accessible communal areas, and a smaller proportion of single-bed patient rooms.

In two studies (reported across three articles) stroke patients exposed to an enriched environment and a communal activity area participated in more activity than patients in a 'usual care' rehabilitation ward.[26, 30, 31] Variation in the type of activity enhanced with enrichment was found, with cognitive and social activity higher in one study,[30] and physical, cognitive, and social activity all were found to be higher in the other study.[26, 31] In qualitative studies associated with these projects, both staff[32, 33] and patients[34] reported that access to a communal activity area helped to promote patient activity.

In two studies, patient activity was measured before and after a ward was relocated to a new building.[35, 36] In a further study, patient activity was measured across three existing wards.[37] In these studies, a higher proportion of single-bed rooms was associated with lower levels of patient activity. Other aspects of the built environment thought to contribute to lower patient activity were the presence and attractiveness of communal areas and the ease of navigation. Communal areas that were unattractive or hard to find went unused.[36-38]

Kevdzija and Marquardt identified difficulty navigating (poor wayfinding), inappropriate dimensions of space (such as corridors that are too narrow for self-propelled wheelchairs), inappropriate distances between spaces (such as communal spaces being too far from the patient bedroom), uneven floor surfaces, and physical obstacles (such as equipment left in corridors) as barriers.[39] Similarly, legibility of the space, access to spaces beyond the bedroom (including communal and outdoor spaces), and patient control of the space were themes identified by Lipson-Smith et al. during expert elicitation.[29] In a small qualitative study by Lampinen and Tham in which the challenges of agnosia (changes in ability to recognise objects) were specifically considered, participants described how unrecognisable objects in the environment became obstacles and created barriers to their activity and performance of everyday tasks.[40]

Emotional well-being

Emotional well-being was explored in nine articles in this review (total *n* = 261 participants). Patient mood, boredom, empowerment, privacy, and loneliness were all raised as contributing to emotional well-being in inpatient rehabilitation. In several qualitative studies communal area access appeared important for patient emotional well-being, reducing boredom and loneliness and promoting patient empowerment.[29, 32-34, 38] Reduced levels of depression, anxiety, and stress at discharge were reported in patients with access to enrichment and communal areas compared to patients without access.[25]

Other built environment features thought to contribute to emotional well-being included: flexible space (e.g., having access to both single-bed and multi-bed patient rooms); connection to nature and the outside world; privacy and control over the space, and allowing for personal spaces within a clinical environment; aesthetics and appropriate light and noise levels; and ease of navigation, legibility, and access within the space.[29, 38, 41, 42] In one quantitative study, no difference in depression or anxiety was found between patients in an old rehabilitation ward and those in a new rehabilitation ward, which had fewer beds per room, more natural light, more colour, and a contemporary aesthetic.[43]

Staff and visitor/family emotional well-being were identified as important by Lipson-Smith et al.,[29] but were not explored directly in any studies.

Safety

The concept of safety within the environment was addressed in only three studies (total n = 129 participants).[29, 39, 44] In the study by Lipson-Smith et al., experts agreed that safety for patients, staff, and visitors/family could be maximised by: minimising manual handling, maximising sightlines between staff and patients; maximising legibility, accessibility and flexibility of the space; maximising indoor environmental quality (e.g., light and noise); and incorporating modern technology.[29] In a small qualitative study, Occupational Therapists felt safer treating patients in a gym environment than in one isolated and not purpose-built for therapy (such as a patient's bedroom) as there are always "extra hands" available from fellow therapists in a gym.[45] Obstacles in the environment (e.g., equipment in the hallway) and uneven floor surfaces were perceived barriers to patient mobility in the study by Kevdzija and Marquardt.[39] The actual safety, as opposed to perceived safety, of patients, staff, and/or visitors was not measured in any of the included studies.

Clinical practice and efficiency

Aspects of clinical practice and/or efficiency were mentioned in ten articles (total *n* = 334 participants).[28, 29, 31-34, 45-48] In four articles, communal activity areas were explored in the context of staff workload.[31-34] Staff opinion varied about whether communal areas increased staff workload; some nurses felt obliged to facilitate patients' use of the area, while other nurses felt that activity areas kept patients occupied and so decreased staff workload.[32, 33] Quantitative studies in which staff time spent assisting patients in communal areas was measured suggested no change in staff workload when these activity areas were introduced.[31]

An observational study of multi-professional teamwork in three stroke units found that the design of the stroke units did not appear to foster multi-professional teamwork: Centrally-located staff workplaces, such as the nurses' stations, created visible hubs but were not appropriate for confidential discussions between staff; none of the stroke units had dedicated rooms for multi-professional meetings; and each profession worked mainly in their own dedicated offices.[48]

The qualitative meta-synthesis conducted by O'Halloran et al. addressed the question of patient/staff communication and concluded that high levels of background noise, visual distractions, and a lack of single-bed rooms acted as environmental barriers to communication between patients and staff.[46] In another qualitative study, Occupational Therapists reported adapting their treatment sessions according to the available space, indicating that the suitability of therapy spaces impacts treatment decision-making.[45]

Finally, in studies by Lipson-Smith at al.[29] and Daemon et al.[28] the role that the built environment, including AHRs, could play in contributing to care efficiency was raised in consultations with staff and other stakeholders.

DISCUSSION

This systematic review provides an overview of the existing research related to inpatient stroke rehabilitation built environments, a unique healthcare environment where patient activity, practice, and motivation are paramount. Our review revealed a research field in its early stages; the majority of the included articles were exploratory (see Figure 2), the quality of research varied, and there was no research to provide level 1 evidence (see Table 2). Heterogeneity of outcomes, methods and environmental variables of interest hindered comparison across studies but raised interesting questions about what drives research in this field and how this research is generated.

The few targeted research articles included in this review were limited to three aspects of the built environment: 1) environmental enrichment and associated communal activity areas; 2) bedroom design, including the impact of AHRs; and 3) the type and availability of therapy spaces. While these topics are important, they are hardly exhaustive. Access to nature and the outdoors was identified by Lipson-Smith et al.[29] as important for encouraging activity and emotional well-being in stroke rehabilitation environments, and the therapeutic impact of outdoor spaces is well-researched in other healthcare settings,[49] but our review revealed no targeted research studies addressing the impact of outdoor spaces in inpatient stroke rehabilitation.

Applying evidence-based design principles from other healthcare contexts to a rehabilitation setting is unlikely to fully address the unique priorities and purpose of rehabilitation environments.[11] Single-bed patient rooms, for example, have been found to improve patient-clinician communication, infection control, and noise reduction in other healthcare settings,[50] but evidence regarding the impact of single-bed rooms is lacking in patients with neurological injury.[51-53] Noise reduction and privacy are important considerations in stroke rehabilitation, especially considering the disabling experience of fatigue,[15] however, exploratory studies in this review suggest that stroke patients in single-bed rooms may be less active and spend more time alone than patients in shared bedrooms,[35, 36] which may impact their recovery and well-being.[29] More recently, Rosebergen et al. found that patients spent more time alone but were also more physically active in a rehabilitation facility with more single-bed rooms, but there was no change in cognitive or social activity.[54] Given the importance of both activity and rest in stroke rehabilitation, it is essential that the impact of single-bed rooms is further investigated in a rehabilitation-specific context so that a design solution can be achieved which facilitates activity and practice, while ensuring opportunity for privacy and rest.

Communal areas were the most frequently addressed environmental feature in this review (addressed in half of the articles, *n* = 12). Taken together, these articles allow some tentative conclusions to be drawn regarding the benefits of communal areas for patient activity and emotional well-being in stroke rehabilitation. This is in line with findings from a large qualitative study conducted in a general (not stroke-specific) rehabilitation setting, in which freedom of movement, access to facilities, and choice within the environment impacted patient motivation, activity, and social interaction.[55] Provision of communal dining and activity areas were particularly noted as helping to increase patient activity in the study by.[56] Importantly, the mere existence of a communal area is likely not sufficient to guarantee its use.[37] Future research could examine the optimal design of communal areas; whether their use should be flexible or structured, their optimal size, and their optimal placement in relation to the patient bedrooms and other key spaces.

Patient perceptions and outcomes were the targets of interest in most studies (see Figure 2). Variation in patient activity associated with the environment (*n* = 13) was explored in over half of the articles in this review. This is perhaps unsurprising since physical activity and fitness may predict outcomes after stroke.[13] Healthcare environments can impact staff efficiency, well-being, and retention,[1] with flow-on effects for patient care. Family and caregiver involvement can improve patient outcomes,[57] yet caregivers often feel ignored or alienated in inpatient stroke rehabilitation environments.[58] Future research should consider the impact of the built environment on staff and family/caregivers, and how the environmental needs and priorities of these groups can be balanced with patient need.

Twenty-one articles were excluded from this review because, although they provided some comments about the built environment in their results or discussion, the authors did not intend to study the built environment and did not provide any details about said environment (see Figure 1). For example, in some of these studies the level of patient physical activity was shown to vary in different locations of the rehabilitation facility and be especially low in the bedroom and lounge.[59] While these studies can help us understand, for example, high use activity areas, the absence of details about the environment makes it impossible to determine *in what way* the environment is important.

This review showcases the wide array of study designs in this field. The authors of the one randomized study in this review acknowledged difficulties with conducting randomized trials of built environment interventions. This includes the inability to blind participants to randomization outcome (because the environmental change is obvious), which can introduce bias. While Khan et al. found significant between-group differences with their enrichment intervention, they recommended the study be repeated in different settings with larger sample sizes to confirm their findings.[25] In three studies the authors took advantage of renovations or rebuilds to conduct comparative studies. While these natural experiments can be informative, rebuilds usually involve more than one design change and often coincide with significant procedural or social change in the healthcare service, making it difficult for environmental variables to be isolated. Standardised description of rehabilitation environments as well as replication of studies showing promising findings should be important goals for all healthcare built environment research. Innovative research approaches are needed to overcome the challenges of researching healthcare environments. Emergent research approaches in rehabilitation environments research include using Virtual Reality to model and test different designs in controlled experiment (for example see The NOVELL Redesign project, www.novellredesign.com).

The quality of the studies in this review varied according to the MMAT, with the qualitative studies achieving the highest scores (indicating higher quality). This may in part be a reflection of the scoring system used in the MMAT. The MMAT was, however, designed to be used for all study types, including mixed methods, and has precedent in healthcare environments research.[19, 50] It is possible that our search may have missed some relevant research because the physical environment is defined differently in different disciplines, and some disciplines frequently publish in non-peer-reviewed mediums such as professional architecture magazines and books. However, we are confident that our search terms were sufficient to capture peer-reviewed research relating to the built environment as it is defined in this review. Our search was limited to articles published since the year 2000. We consider it unlikely that many relevant articles were published before this time. Indeed, only one (4%) of the articles included in this review was published prior to 2010. The rate of research in this field is increasing; we are aware of relevant articles that are in preparation or that were published after our searches were completed.[54, 60, 61] This review should therefore be updated in the coming years.

The 24 articles in this review were produced by 14 research groups. Many of these groups have previously collaborated and the authors of this review were involved in a number of the included studies. Evidence-based healthcare design research is inherently interdisciplinary, and the field will benefit as more diverse research groups bring innovative methods and approaches. The majority of the studies in this review were conducted either in Australia (50% of included articles) or Sweden (21% of included articles). As mentioned in the introduction, stroke rehabilitation services vary globally, and the design of rehabilitation facilities should reflect the local service. There is therefore a need to bring a more diverse international perspective to stroke rehabilitation environments research.

To effectively grow the research field and provide evidence-based design for patient well-being and health, it is essential that important factors (such as outdoor spaces, single-bed rooms, patient and staff safety, and staff well-being) are not overlooked. We recommend that future researchers use the findings from the exploratory studies included in this review to provide a rationale and framework for their research in rehabilitation design. These exploratory studies identify aspects of the built environment and outcomes that are worthy of further investigation and provide a framework for future stroke rehabilitation environments research. This may encourage a more unified approach to the discipline and help researchers to identify aspects of the built environment and outcomes that are worthy of targeted study.

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Contributors: JB, ME, SMB, MW, and HZ conceived and planned the protocol for this study. SMB developed and executed the search strategy. RLS and LP assessed the articles for eligibility and conducted the data extraction. RLS conducted the analysis and synthesis of the included studies. RLS, LP, SMB, ME, AD, MW, HZ and JB prepared the draft of the manuscript, and edited, read, and approved the final version of the manuscript.

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Ethics approval: Not applicable. This study was a systematic review and ethics approval was not required.

Provenance and peer review: Not commissioned; externally peer reviewed.

Data availability: The results from the articles included in this systematic review are summarised in the supplementary material.

References

1. Sadler BL, Berry LL, Guenther R, Hamilton D, Hessler FA, Merritt C, et al. Fable hospital 2.0: The business case for building better health care facilities. *Hastings Center Report*. 2011;41(1):13-23.

2. Ulrich R, Zimring C, Zhu X, DuBose J, Seo H-B, Choi Y-S, et al. A review of the research literature on evidence-based healthcare design. *Health Environments Research & Design Journal (HERD)*. 2008;1(3):61-125.

3. Joseph A, Bayramzadeh S, Zamani Z, Rostenberg B. Safety, performance, and satisfaction outcomes in the operating room:

A literature review. *Health Environments Research & Design Journal (HERD)*. 2018;11(2):137-50.

4. Chaudhury H, Cooke HA, Cowie H, Razaghi L. The influence of the physical environment on residents with dementia in long-term care settings: A review of the empirical literature. *The Gerontologist*. 2017;58(5):e325-e37.

5. Connellan K, Gaardboe M, Riggs D, Due C, Reinschmidt A, Mustillo L. Stressed spaces: Mental health and architecture. *Health Environments Research & Design Journal (HERD)*. 2013;6(4):127-68.

6. Norrving B, Barrick J, Davalos A, Dichgans M, Cordonnier C, Guekht A, et al. Action Plan for Stroke in Europe 2018-2030. *Eur Stroke J*. 2018;3(4):309-36.

7. World Health Organization. World health statistics 2019: Monitoring health for the SDGs, sustainable development goals. Geneva: World Health Organization; 2019.

8. Langhorne P, Baylan S, Trialists ESD. Early supported discharge services for people with acute stroke. *Cochrane Database of Systematic Reviews*. 2017(7).

9. Australasian Rehabilitation Outcomes Centre. The AROC Annual Report: The state of rehabilitation in Australia in 2019.: Australian Health Services Research Institute, University of Wollongong. Accessed from: https://www.uow.edu.au/ahsri/aroc/dataset/reports-benchmarks/; 2019.

10. Reistetter TA, Kuo Y-F, Karmarkar AM, Eschbach K, Teppala S, Freeman JL, et al. Geographic and facility variation in inpatient stroke rehabilitation: multilevel analysis of functional status. *Archives of Physical Medicine and Rehabilitation*. 2015;96(7):1248-54.

11. Lipson-Smith R, Zeeman H, Bernhardt J. What's in a building? A descriptive survey of adult inpatient rehabilitation facility buildings in Victoria, Australia. *Archives of Rehabilitation Research and Clinical Translation*. 2020;2(1).

12. Bernhardt J, Hayward KS, Kwakkel G, Ward NS, Wolf SL, Borschmann K, et al. Agreed definitions and a shared vision for new standards in stroke recovery research: The Stroke Recovery and Rehabilitation Roundtable taskforce. *International Journal of Stroke*. 2017;12(5):444-50.

13. Winstein CJ, Stein J, Arena R, Bates B, Cherney LR, Cramer SC, et al. Guidelines for adult stroke rehabilitation and recovery: A guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2016;47(6):e98-e169.

14. Powers WJ, Rabinstein AA, Ackerson T, Adeoye OM, Bambakidis NC, Becker K, et al. Guidelines for the early management of patients with acute ischemic stroke: 2019 update to the 2018 guidelines for the early management of acute ischemic stroke: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. *Stroke*. 2019;50(12):e344-e418.

15. Luker J, Lynch E, Bernhardsson S, Bennett L, Bernhardt J. Stroke survivors' experiences of physical rehabilitation: a systematic review of qualitative studies. *Archives of Physical Medicine and Rehabilitation*. 2015;96(9):1698-708. e10.

16. Moher D, Liberati A, Tetzlaff J, Altman DG, Prisma Group. Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement. *PLoS Med*. 2009;6(7):e1000097.

17. Lizarondo L, Stern C, Carrier J, Godfrey C, Rieger K, Salmond S, et al. Chapter 8: Mixed methods systematic reviews. In: Aromataris E, Munn Z, editors. *JBI Manual for Evidence Synthesis*: JBI; 2020.

18. Covidence systematic review software. Melbourne, Australia: Veritas Health Innovation; 2020.

19. Taylor E, Hignett S. Evaluating evidence: Defining levels and quality using critical appraisal mixed methods tools. *Health Environments Research & Design Journal (HERD)*. 2014;7(3):144-51.

20. Stichler JF. Weighing the evidence. SAGE Publications Sage CA: Los Angeles, CA; 2010.

21. Marquardt G, Motzek T. How to rate the quality of a research paper: introducing a helpful algorithm for architects and designers. *Health Environments Research & Design Journal (HERD)*. 2013;6(2):119-27.

22. Hong Q, Pluye P, Fàbregues S, Bartlett G, Boardman F, Cargo M, et al. Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552). Canadian Intellectual Property Office: Industry Canada; 2018.

23. Nithianantharajah J, Hannan AJ. Enriched environments, experience-dependent plasticity and disorders of the nervous system. *Nature Reviews Neuroscience*. 2006;7(9):697-709.

24. Arbel I, Ye B, Mihailidis A. Stroke Patients' Experiences in an Adaptive Healing Room in a Stroke Rehabilitation Unit. *Health Environments Research & Design Journal (HERD)*. 2019;13(2):170-85.

25. Khan F, Amatya B, Elmalik A, Lowe M, Ng L, Reid I, et al. An enriched environmental programme during inpatient neuro-rehabilitation: A randomized controlled trial. *Journal of rehabilitation medicine*. 2016;48(5):417-25.

26. Rosbergen ICM, Grimley RS, Hayward KS, Walker KC, Rowley D, Campbell AM, et al. Embedding an enriched environment in an acute stroke unit increases activity in people with stroke: A controlled before-after pilot study. *Clinical Rehabilitation*. 2017;31(11):1516-28.

27. Robertson ST, Grimley RS, Anstey C, Rosbergen IC. Acute stroke patients not meeting their nutrition requirements: investigating nutrition within the enriched environment. *Clinical Nutrition*. 2020:1470-7.

28. Daemen EML, Flinsenberg ICM, van Loenen EJ, Cuppen RPG, Rajae-Joordens RJE. Adaptable Healing Patient Room for Stroke Patients A Staff Evaluation. *METHODS OF INFORMATION IN MEDICINE*. 2014;53(5):406-15.

29. Lipson-Smith R, Churilov L, Newton C, Zeeman H, Bernhardt J. A Framework for Designing Inpatient Stroke Rehabilitation Facilities: A New Approach Using Interdisciplinary Value-Focused Thinking. *Health Environments Research & Design Journal (HERD)*. 2019;12(4):142-58.

30. Janssen H, Ada L, Bernhardt J, McElduff P, Pollack M, Nilsson M, et al. An enriched environment increases activity in stroke patients undergoing rehabilitation in a mixed rehabilitation unit: A pilot non-randomized controlled trial. *Disability and Rehabilitation*. 2014;36(3):255-62.

31. Rosbergen ICM, Grimley RS, Hayward KS, Brauer SG. The impact of environmental enrichment in an acute stroke unit on how and when patients undertake activities. *Clinical Rehabilitation*. 2019;33(4):784-95.

32. Rosbergen ICM, Brauer SG, Fitzhenry S, Grimley RS, Hayward KS. Qualitative investigation of the perceptions and experiences of nursing and allied health professionals

involved in the implementation of an enriched environment in an Australian acute stroke unit. *BMJ Open*. 2017;7(12).

33. White JH, Alborough K, Janssen H, Spratt N, Jordan L, Pollack M. Exploring staff experience of an "enriched environment" within stroke rehabilitation: A qualitative sub-study. *Disability and Rehabilitation*. 2014;36(21):1783-9.

34. White JH, Bartley E, Janssen H, Jordan LA, Spratt N. Exploring stroke survivor experience of participation in an enriched environment: A qualitative study. *Disability and Rehabilitation*. 2015;37(7):593-600.

35. Shannon MM, Elf M, Churilov L, Olver J, Pert A, Bernhardt J. Can the physical environment itself influence neurological patient activity? *Disability and Rehabilitation*. 2019;41(10):1177-89.

36. Anaker A, von Koch L, Sjostrand C, Bernhardt J, Elf M. 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(7):e0177477.

37. Anaker A, von Koch L, Sjostrand C, Heylighen A, Elf M. The physical environment and patients' activities and care: A comparative case study at three newly built stroke units. *Journal of Advanced Nursing*. 2018;74(8):1919-31.

38. Anaker A, von Koch L, Heylighen A, Elf M. "It's Lonely": Patients' Experiences of the Physical Environment at a Newly Built Stroke Unit. *Health Environments Research & Design Journal (HERD)*. 2019;12(3):141-52.

39. Kevdzija M, Marquardt G, editors. Physical Barriers to Mobility of Stroke Patients in Rehabilitation Clinics. Cambridge Workshop on Universal Access and Assistive Technology; 2018: Springer.

40. Lampinen J, Tham K. Interaction with the physical environment in everyday occupation after stroke: A phenomenological study of persons with visuospatial agnosia. *Scandinavian Journal of Occupational Therapy*. 2003;10(4):147-56.

41. Turner J. Environmental Factors of Hospitalisation which contribute to Post-stroke Depression during Rehabilitation for over 65 year olds. *Journal of the Australasian Rehabilitation Nurses' Association (JARNA)*. 2012;15(1):11-5.

42. Daemen E, van Loenen E, Cuppen R. The impact of the environment on the experience of hospitalized stroke patients

- An exploratory study. In: *European Conference on Ambient Intelligence 2014 Nov 11*. pp. 114-24: Springer, Cham.

43. Perovic Z, Perovic S. Influence of hospital room environment on the reduction of anxiety and depression in the early stage of stroke. *Journal of Environmental Protection and Ecology*. 2017;18(2):710-9.

44. Skubik-Peplaski C, Rowles GD, Hunter EG. Toward a physical environmental continuum for occupational intervention in a rehabilitation hospital. *Occupational therapy in health care*. 2012;26(1):33-47.

45. Skubik-Peplaski C, Howell DM, Hunter EG, Harrison A. Occupational Therapists' Perceptions of Environmental Influences on Practice at an Inpatient Stroke Rehabilitation Program: A Pilot Study. *Physical and Occupational Therapy in Geriatrics*. 2015;33(3):250-62.

46. O'Halloran R, Grohn B, Worrall L. Environmental factors that influence communication for patients with a communication disability in acute hospital stroke units: a qualitative metasynthesis. *Archives of Physical Medicine and Rehabilitation*. 2012;93(1 Suppl):S77-85.

47. O'Halloran R, Worrall L, Hickson L. Environmental factors that influence communication between patients and their healthcare providers in acute hospital stroke units: An observational study. *International Journal of Language and Communication Disorders*. 2011;46(1):30-47.

48. Anaker A, von Koch L, Eriksson G, Sjostrand C, Elf M. The physical environment and multi-professional teamwork in three newly built stroke units. *Disability and Rehabilitation*. 2020:1-9.

49. Marcus CC, Sachs NA. *Therapeutic landscapes: An evidence-based approach to designing healing gardens and restorative outdoor spaces*: John Wiley & Sons; 2013.

50. Taylor E, Card AJ, Piatkowski M. Single-Occupancy Patient Rooms: A Systematic Review of the Literature Since 2006. *Health Environments Research & Design Journal (HERD)*. 2018;11(1):85-100.

51. Shannon MM, Lipson-Smith R, Elf M, Olver J, Kramer S, Bernhardt J. 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. *Intelligent Buildings International*. 2018:1-19.

52. Bernhardt J, Cumming T. The elephant in the single room debate: keeping patients active. *British Medical Journal*. 2013;347:f6333.

53. Maben J, Griffiths P, Penfold C, Simon M, Anderson JE, Robert G, 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 Quality & Safety*. 2016;25(4):241-56.

54. Rosebergen I, Tonello I, Clark R, Grimley R. Does hospital design impact on patient activity levels and time spent alone? *Disability and Rehabilitation*. 2020.

55. Killington M, Fyfe D, Patching A, Habib P, McNamara A, Kay R, et al. Rehabilitation environments: Service users' perspective. *Health Expectations*. 2019;22(3):396-404.

56. Scrivener K, Pocovi N, Jones T, Dean B, Gallagher S, Henrisson W, et al. Observations of Activity Levels in a Purpose-Built, Inpatient, Rehabilitation Facility. *Health Environments Research & Design Journal (HERD)*. 2019;12(4):26-38.

57. van Dijk M, Vreven J, Deschodt M, Verheyden G, Tournoy J, Flamaing J. Can in-hospital or post discharge caregiver involvement increase functional performance of older patients? A systematic review. *BMC Geriatrics*. 2020;20(1):362.

58. Luker J, Murray C, Lynch E, Bernhardsson S, Shannon M, Bernhardt J. Carers' Experiences, Needs, and Preferences During Inpatient Stroke Rehabilitation: A Systematic Review of Qualitative Studies. *Archives of Physical Medicine and Rehabilitation*. 2017.

59. Sjöholm A, Skarin M, Churilov L, Nilsson M, Bernhardt J, Lindén T. Sedentary Behaviour and Physical Activity of People with Stroke in Rehabilitation Hospitals. *Stroke Research and Treatment*. 2014(2014):163.

60. Janssen H, Ada L, Middleton S, Pollack M, Nilsson M, Churilov L, et al. Altering the rehabilitation environment to improve stroke survivor activity (AREISSA): a Phase II trial. *International Journal of Stroke*. 2021:17474930211006999.

61. Kevdzija M, Marquardt G. Stroke patients' nonscheduled activity during inpatient rehabilitation and its relationship with the architectural layout: A multicenter shadowing study. *Topics in Stroke Rehabilitation*. 2021:1-7.

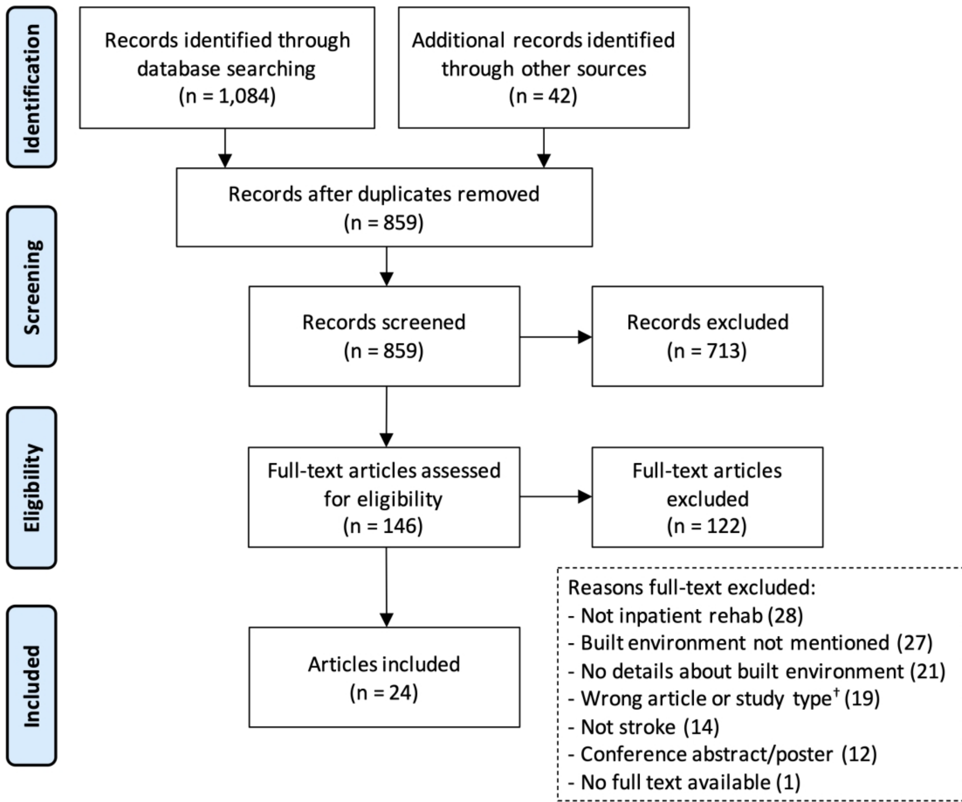
Figure legends

Figure 1. Article identification and screening flow diagram

[†]*The following types of articles were excluded from this review, but their reference lists were searched for relevant articles: opinion pieces or commentaries, unpublished studies in PhD theses, single case studies, and systematic reviews with no meta-analysis, meta-synthesis, or integrative component.*

Figure 2. Research method and focus of included articles.

Articles are clustered according to the extent to which they pre-specified the specific aspects of the built environment or outcomes to be investigated (targeted vs exploratory research).



Article identification and screening flow diagram
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173x145mm (400 x 400 DPI)

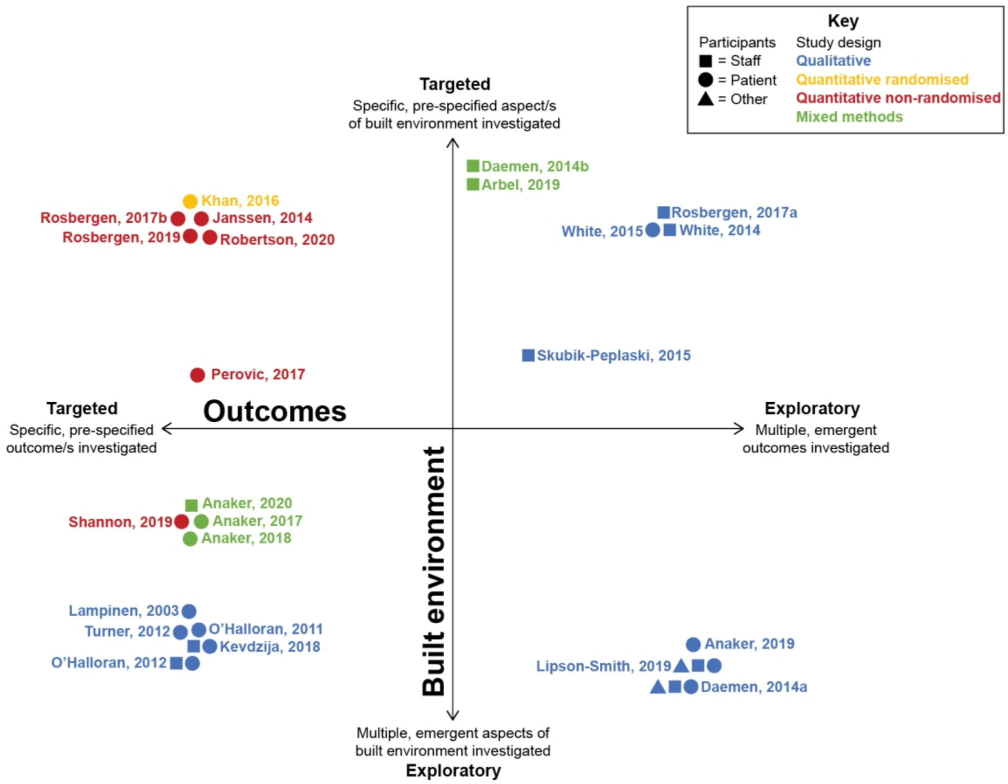

Figure 2. Research method and focus of included articles.
Articles are clustered according to the extent to which they pre-specified the specific aspects of the built environment or outcomes to be investigated (targeted vs exploratory research).

286x223mm (150 x 150 DPI)

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supp material 3
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Supp material 5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supp material 7
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Supp material 6
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	14-19
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	20-21
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	23
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	23
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	24

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

The impacts of the physical environment of inpatient rehabilitation settings on outcomes and experiences of patients recovering from stroke, their family/carers, and staff: a mixed methods systematic review protocol

Keywords: Stroke; Rehabilitation; Brain Recovery; Built Environment; Physical environment

1. Background

Research-driven architecture or evidence-based design is a new field of endeavor that aims to inform health facility design. To date, the focus of research has been on hyper acute (Intensive Care Unit, surgery) environments [1], with some attention paid to institutional care for older people [2] and mental health facilitates [3]. Between these disparate sectors lies an important and expensive area of healthcare: that of hospital-based rehabilitation. Rehabilitation, particularly for those with acquired neurological injury, traumatic brain injury or stroke, is slow and expensive.

Research-driven or evidence informed design refers to the act of creating healthcare environments based on the judicious use of best evidence from research and practice together with an informed client's view. Evidence-based design results in improvements in patient outcomes and safety, economic performance and productivity of the organization, and user satisfaction [4]. Evidence-based design has driven an exciting new era of questioning how healthcare design (the buildings, interiors, wayfinding, etc.) impacts on patient care and healthcare outcomes. To date, most research has explored the effect of the acute healthcare environment on patient and staff outcomes. While the evidence base is growing, empirical research in healthcare environments has been described as minimal [5].

In the last decade, primary care hospital design has been the focus for innovation [6]. In the US alone, over the next decade over $200 billion will be spent on the development of new healthcare facilities [7]. In Australia, the new Royal Adelaide Hospital has been named the eighth most expensive building in the world at US$2.1 billion [https://www.emporis.com]. In contrast, the post-acute rehabilitation environment has received little attention and research focus, despite the fact that rehabilitation care is expensive and a critical element of the recovery trajectory after serious injury.

Survivors of stroke may spend between 2 weeks and 2 or more months in hospital-based inpatient rehabilitation (mean 27.7 days for stroke and 39.2 days for brain injury) [8]. In 2016, the provision of rehabilitation grew in volume as there was a 2.8% increase in inpatient episodes of rehabilitation [8]. Rehabilitation often continues for months to years with gradual shift from hospital-based to outpatient care to community care. The environment is an important element that has the potential to help or harm brain recovery [9]. In 2011, Sadler et al conservatively calculated the economic benefits of introducing evidence-based design improvement in healthcare facility design as providing a return on investment within 3 years [5].

A major challenge of providing stroke care and rehabilitation is to determine how the physical environment should be designed and utilized to best address specific patient needs and rehabilitation goals.

2. Aim

The aim of this systematic review is to identify, appraise, and synthesize the existing literature related to evidence-based design (EBD) of rehabilitation facilities, and identify the recorded impacts of the physical environment of rehabilitation settings on the outcomes and experiences of patients recovering from stroke, their family/carers, and staff.

Overarching research question

What is the current state of knowledge about evidence-based design in the stroke rehabilitation setting?

Specifically this review will address the following research questions

- What types of outcomes have been investigated in relation to the physical environment in the stroke rehabilitation setting?
- What are the impacts of the physical rehabilitation environment on the outcomes and experiences of patients recovering from stroke, their family/carers, and staff?
- What aspects of the physical environment has shown to impact on outcomes and experiences of patients recovering from stroke, their family/carers, and staff?
- What are the research methods used to investigate the impact of the physical environment on outcomes and experiences of patient recovering from stroke, their family/carers, and staff?

3. Method

This mixed studies systematic literature review will follow the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [10]. A convergent segregated review design will be used whereby the results from qualitative, quantitative, and mixed-methods studies were integrated in a narrative summary [11].

This mixed studies review applies a systematic strategy for identifying, retrieving, assessing, and appraising the available literature reporting on the **impacts** of the physical environment in the stroke rehabilitation setting. The review will consider a range of research designs including qualitative, quantitative and mixed-method studies in order to report comprehensively on the topic. The data synthesis will use descriptive statistics and qualitative content analysis [12] as appropriate to the type of data retrieved. An inter-rater reliability process [13] will be included in the search and retrieval stages whereby the processes will be performed by two researchers and any ambiguity or disagreement about the inclusion or exclusion of articles will be discussed until agreement is reached.

3.1. Search Strategy

Search terms will be reviewed by a professional research librarian. A systematic search of the following electronic databases will be conducted: OVID Medline, SCOPUS, Cumulative Index to Nursing and Allied Health Literature (CINAHL), and Web of Science. The two key concepts “Stroke” and “Healthcare facility design” will determine the search terms used (see Table 1). Boolean searches using the operators “AND” / “OR” / ”NOT” will be constructed with selected search terms and combination of search terms as appropriate for each database following respective guidelines. Figure 1 shows an example of the OVID Medline Boolean search strategy. Any additional, search terms identified during the screening process will be added as appropriate. The reference lists of key articles will be additionally hand-searched (“snowballing”). Two researchers will perform the searches.

Table 1 Search terms

Key concept	Search terms
Stroke	Stroke or neurologic* or brain injur* or brain recovery or Stroke Rehabilitation or brain injur* rehabilitation or stroke recovery or neurologic* rehabilitation or brain injur* recovery
Healthcare facility design	facility or facilities or environment* or rehabilitation environment* or rehabilitation setting* or buil* design or architecture* or evidence-based design or garden* or hospital design or outdoor setting or outdoor environment or interior design or environment* factor* or physical environment or built environment or

Database: Ovid MEDLINE(R) ALL <1946 to July 29, 2019>
Search Strategy:
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1 (("environment* factor*" or "physical environment*" or "built environment*" or facility or facilities or architecture* or "evidence-based design" or garden* or "outdoor setting*" or "outdoor environment*" or "facilit* design*" or "hospital design" or "interior design") not "nursing facilit*").m_titl. (53548)
2 ((stroke or neurologic* or "brain injur*" or "brain recovery" or "stroke rehabilitation" or "neurologic* rehabilitation" or "brain injur* rehabilitation" or "stroke recovery" or "neurologic* recovery" or "brain injur* recovery") not gene* not robot* not pharmacol* not non-pharmacol* not delirium not ulcer* not pollution not syndrome* not wildlife not dementia not sepsis not pneumonia not "spinal cord injur*" not mouse* not rat* not "animal model*" not ventilat* not transfer not multidrug* not drug* not malnutrition* not cardi* not kidney not fracture* not thrombolys* not "aged care" not "nursing home" not Parkinson* not fibrillat* not tomograph* not ecology* not incontinen* not continen* not urin* not ultrasound not geograph* not treadmill not "muscle architecture" not "sleep architecture" not "clot architecture" not "pagodian architecture" not "brain architecture" not influenza not payment not "systematic review" not "meta-synthesis" not "meta-analysis" not "methicillin*").m_titl. (133295)
3 1 and 2 (123)
4 limit 3 to (english language and yr="2000 - 2020") (90)

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Figure 1 OVID Medline Boolean search strategy

3.2. Inclusion criteria

The inclusion criteria are outlined in Table 2. Research addressing any aspect of the physical environment in inpatient rehabilitation settings and its impact on the outcomes or experiences of adult patients recovering from stroke or their family/carers or staff will be considered for inclusion, as long as sufficient detail is provided about the physical environment (see Table 2).

Table 2 Included articles must meet all the below criteria.

Inclusion criteria
1. Peer-reviewed
2. Published between 2000 and 2020
3. Written in English language

4. Quantitative, qualitative or mixed method research design. Protocol papers will only be included if the study results have not yet been published. Opinion pieces, commentaries, single case studies, and systematic reviews with no meta-analysis or meta-synthesis will not be included, but will be searched for relevant references (snowballing).
5. Journal article or conference paper. Conference posters and conference abstracts will not be included.
6. Population: Adult stroke survivors, their family/carers, and/or staff who care for adult stroke survivors. Research reporting on mixed populations will only be included if one or more of the populations listed above make up the vast majority of the sample (>60%) or their results are reported separately so that they can be extracted from the mixed population.
7. Intervention/phenomenon of interest: Research reporting on the physical environment of acute or sub-acute inpatient rehabilitation hospital settings where the physical environment is described in sufficient detail. For example, research that reports only on the location of certain activities (e.g., time spent in the dining room) or the position of a rehab ward in relation to an acute ward would not be included, but research that reports the dimensions, features, and etc. of said locations or wards (i.e., 'dining room was 10m2, with south facing windows and positioned adjacent to a courtyard and the nurses station') will be included. For the purposes of this review, the physical environment is defined as comprising the following (this definition of the physical environment is adapted from Harris et al. (2002) [14] – studies that provide *details* about any of the following will be included: a. ambient features (e.g., noise, air quality, odours, light, temperature); b. architectural and landscape features (e.g., position and layout of the building, relationship between the building and its surroundings, dimensions of a room, placement of doors and windows, views and outdoor areas); c. interior design features (e.g., furniture, artwork, signage, colours, equipment and technology); and d. maintenance and housekeeping (e.g., cleanliness, repair and upkeep of architectural and interior features). Both of the following types of studies will be included: 1) research where the intent is to describe or investigate any aspect of a physical environment of inpatient rehabilitation settings, and 2) research where findings concerning the physical environment of inpatient rehabilitation settings are reported (even if this was not the original intent of the research). Research conducted in a virtual setting (e.g. using Virtual Reality) will be included as long as the virtual environment meets all of the criteria outlined above.
8. Outcome: Research reporting on the outcomes, experiences, or perspectives of any of the populations specified above will be included.

3.3. Screening

Figure 2 provides a flowchart illustrating the 4-step process used for screening and assessing the retrieved literature. Each step will be conducted by two researchers independently who will discuss any disagreement until consensus is reached before proceeding to the next step (inter-rater reliability process) [13]. Covidence will be used to manage the screening and inter-rater process [15].

1. All duplicates eliminated
2. Title and abstracts screened for topic relevance
3. Full text articles of all included abstracts will be retrieved and read in full to confirm topic relevance
4. Quality of eligible articles will be assessed using a mixed studies review scoring system [16]

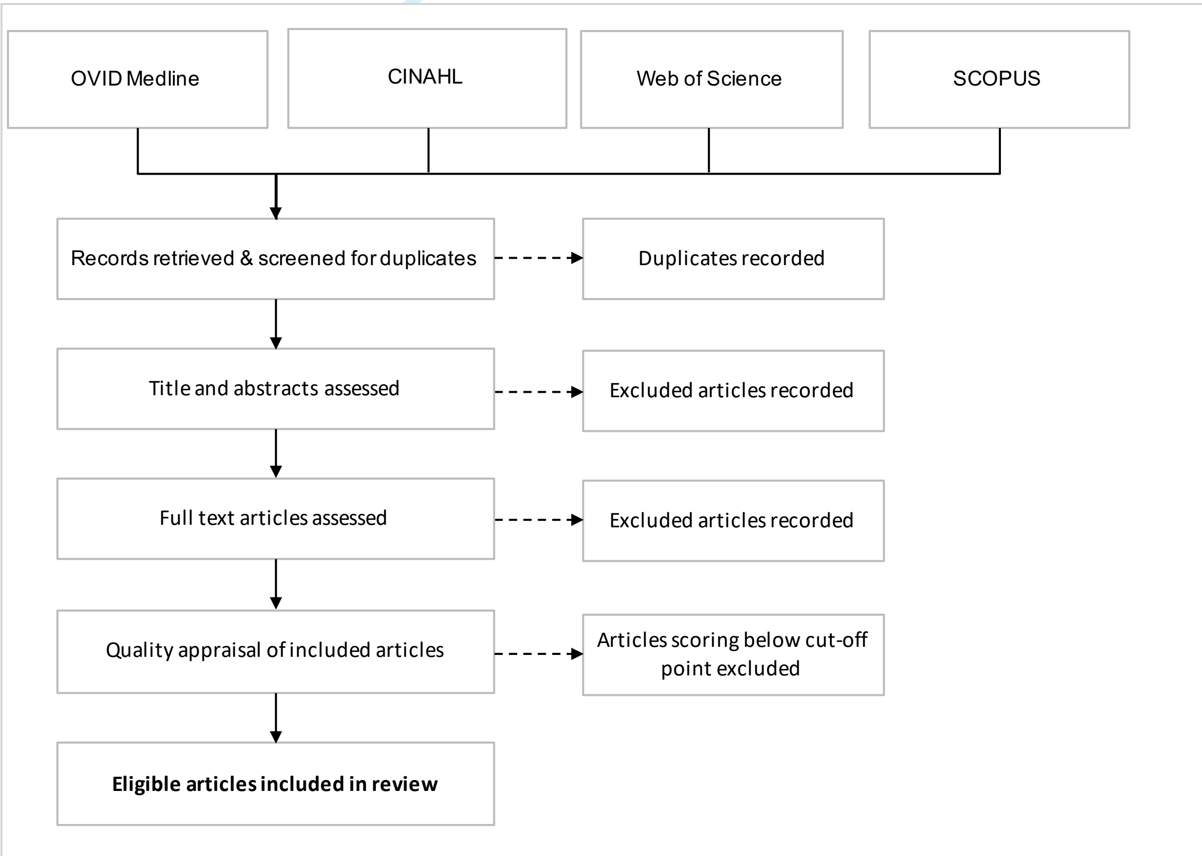

Figure 2 Flowchart of literature search and assessment process

3.4. Quality appraisal

The quality of articles will be assessed using the Mixed Methods Appraisal Tool (MMAT) [16]. This framework provides a system for appraising mixed studies reviews, which are reviews that include qualitative, quantitative and mixed-method research. The level of evidence of the included studies will be assessed following recommendations from Marquardt and Motzek (2013) [17], adapted from Stichler (2010) [18].

3.5. Data extraction and synthesis

A purpose-designed data extraction form will be used to retrieve all data relevant to answering the research questions (see Appendix 1). The form will include variables describing study characteristics in order to descriptively summarize the included studies.

The following variables will be collected:

First author, Year of publication, Country where research conducted, Study focus, Research design and methodology, Sample size, Participant characteristics, Setting characteristics, Type of outcome, Impact of physical environment, Aspects of physical environment.

References

1. Shepley, M.M., et al., *The impact of daylight and views on ICU patients and staff.* HERD: Health Environments Research & Design Journal, 2012. **5**(2): p. 46-60.
2. Connellan, K., et al., *Stressed spaces: mental health and architecture.* HERD: Health Environments Research & Design Journal, 2013. **6**(4): p. 127-168.
3. Papoulias, C., et al., *The psychiatric ward as a therapeutic space: systematic review.* The British Journal of Psychiatry, 2014. **205**(3): p. 171-176.
4. Hamilton, D.K. and J. Stichler, *Evidence-based design: What is it.* Health Environments Research & Design Journal, 2008. **1**(2): p. 3-4.
5. Sadler, B.L., et al., *Fable hospital 2.0: the business case for building better health care facilities.* Hastings Center Report, 2011. **41**(1): p. 13-23.
6. Hamilton, D.K. and M.M. Shepley, *Design for critical care: An evidence-based approach*. 2010: Routledge.
7. Siddiqui, Z.K., et al., *Changes in patient satisfaction related to hospital renovation: experience with a new clinical building.* Journal of hospital medicine, 2015. **10**(3): p. 165-171.
8. Australian Health Services Research Institute, U.o.W., *The AROC Annual Report: The state of rehabilitation in Australia in 2016.* 2017.
9. Muenchberger, H. and M. Shepley, *Buildings That Heal - Contributions from neuroscience in designing the built environment.* The Australian Hospital Health Care Bulletin, 2015.
10. Moher, D., et al., *Preferred reporting items for systematic reviews and meta-analyses: the PRISMA statement.* PLoS med, 2009. **6**(7): p. e1000097.
11. Lizarondo, L., et al., *Chapter 8: Mixed methods systematic reviews*, in *JBI Manual for Evidence Synthesis*, E. Aromataris and Z. Munn, Editors. 2020, JBI.
12. Elo, S. and H. Kyngäs, *The qualitative content analysis process.* Journal of advanced nursing, 2008. **62**(1): p. 107-115.
13. Pope, C., S. Ziebland, and N. Mays, *Qualitative research in health care: analysing qualitative data.* BMJ: British Medical Journal, 2000. **320**(7227): p. 114.
14. Harris, P.B., et al., *A Place to Heal: Environmental Sources of Satisfaction Among Hospital Patients 1.* Journal of Applied Social Psychology, 2002. **32**(6): p. 1276-1299.
15. Covidence systematic review software, *Veritas Health Innovation, Melbourne, Australia. Available at www.covidence.org*.
16. Hong, Q., et al., *Mixed Methods Appraisal Tool (MMAT), version 2018. Registration of Copyright (#1148552)*. 2018, Industry Canada: Canadian Intellectual Property Office.
17. Marquardt, G. and T. Motzek, *How to rate the quality of a research paper: introducing a helpful algorithm for architects and designers.* HERD: Health Environments Research & Design Journal, 2013. **6**(2): p. 119-127.
18. Stichler, J.F., *Weighing the evidence*. 2010, SAGE Publications Sage CA: Los Angeles, CA.

Appendix 1 Sample data extraction form

First author (year), country [ref]	**Study focus**	**Research design and methodology**	**Sample size (n)**	**Participants characteristics**	**Setting characteristics**	**Primary outcomes**	**Secondary outcomes**

Supplementary material 3

OVID Medline Boolean search strategy

Database: Ovid MEDLINE(R) ALL <1946 to July 29, 2019>
Search Strategy:
----
1 (("environment* factor*" or "physical environment*" or "built environment*" or facility or facilities or architecture* or "evidence-based design" or garden* or "outdoor setting*" or "outdoor environment*" or "facilit* design*" or "hospital design" or "interior design") not "nursing facilit*").m_titl. (53548)
2 ((stroke or neurologic* or "brain injur*" or "brain recovery" or "stroke rehabilitation" or "neurologic* rehabilitation" or "brain injur* rehabilitation" or "stroke recovery" or "neurologic* recovery" or "brain injur* recovery") not gene* not robot* not pharmacol* not non-pharmacol* not delirium not ulcer* not pollution not syndrome* not wildlife not dementia not sepsis not pneumonia not "spinal cord injur*" not mouse* not rat* not "animal model*" not ventilat* not transfer not multidrug* not drug* not malnutrition* not cardi* not kidney not fracture* not thrombolys* not "aged care" not "nursing home" not Parkinson* not fibrillat* not tomograph* not ecology* not incontinen* not continen* not urin* not ultrasound not geograph* not treadmill not "muscle architecture" not "sleep architecture" not "clot architecture" not "pagodian architecture" not "brain architecture" not influenza not payment not "systematic review" not "meta-synthesis" not "meta-analysis" not "methicillin*").m_titl. (133295)
3 1 and 2 (123)
4 limit 3 to (english language and yr="2000 - 2020") (90)

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Supplementary material 4

Levels of evidence

Level	Criteria
Level 1	Systematic reviews, meta-analyses of qualitative studies, and meta-syntheses of multiple qualitative studies leading to an integrative interpretation.
Level 2	Well-designed experimental (randomized), quasi-experimental (nonrandomized), and multiple-case studies. Integrative or systematic reviews of observational or qualitative studies.
Level 3	Well-designed observational and qualitative studies, and poorly designed experimental, quasi-experimental, and multiple-case studies.
Level 4	Poorly designed observational and qualitative studies, and professional standards or guidelines with studies to support recommendations.
Level 5	Opinions of recognized experts, single case studies.
Level 6	Recommendations from manufacturers or consultants who may have a financial interest or bias.

Adapted from Marquardt & Motzek (58) and Stichler (20)

Articles authored by reviewers were appraised by non-authors

Following the eligibility criteria for this review (see Table 1), systematic reviews with no meta-analysis or integrative component were not included, nor were non-peer reviewed articles, such as professional standards and guidelines, nor were any of the article types at Levels 5 and 6.

Supplementary material 5

Standardised form for data extraction.

Variable	Description
Author	First author of article
Year	Year article published
Title	Title of article
Aim	Aim as stated in the article
Study type	Qualitative | Quantitative randomized controlled trials | Quantitative nonrandomized | Quantitative descriptive | Mixed methods
Study design	Study design as stated in the article
Year data collected	
Participant type	Patients (acute, rehab, all stroke, or mixed population, etc.), or staff, or family/visitors. Include eligibility criteria if provided.
Mixed population	Are other patient/carer/staff types included besides stroke? Y/N
Stroke data extracted	If Y to 'mixed population', can the stroke-specific data be extracted? Y/N
Participant number	Number of participants
Participant age	Mean age
Time since stroke	Only relevant for patient participants
Other participant characteristics	
Country	Country or countries where the study was completed
Setting	Setting in which the study was completed, i.e., acute hospital, rehab hospital, etc. Include definition of this setting if provided in the paper.
Intervention/Exposure	Was an intervention conducted by the researchers? Or did they expose the participants to different environments? Y/N
Observational pre/post	Was this an observational study of an environment pre/post a move? Y/N
Details of physical environment	Include the details of the physical environment of the setting of this study.

Variable	Description
Aspect of physical environment	What aspect of the physical environment was of interest in this study? A particular room/location? Access to nature? Particular design or architectural feature? Or whole environment considered?
Floorplans provided?	Y/N
Photographs provided?	Y/N
Outcomes measured	Which outcomes were measured in this study
Method of data collection	How the data were collected
Method of data analysis	How the data were analysed
Findings	Ensure that the summary you provide for this variable refers to both the physical environment and the outcomes as they were measured in this study.
Conclusions	Our conclusions might not be the same as the conclusions in the paper - we need to think about the conclusions that we can draw from their results about the relationship between physical environment and patient/staff outcomes.
Comments	

Supplementary material 6

Summaries of the results of the included articles

Aspect of built environment	First author, year	Results summary
Enriched environment	Janssen, 2014	Participants in the enrichment group were 1.7 (95% CI 1.1 to 2.5, $p = 0.02$) times more likely to be engaged in cognitive activity, 1.2 (95% CI 1.0 to 1.5, $p = 0.04$) times more likely to be engaged in social activity, 0.7 (95% CI 0.6 to 0.9, $p < 0.001$) times as likely to be inactive and alone and 0.5 (95% CI 0.4 to 0.7, $p < 0.001$) times as likely to be asleep compared to the usual care group. Physical activity was not different between groups.
	Khan, 2016	At discharge, stroke participants in enrichment group had improved mood (DASS total mean difference = –24.1, CI = –40.1, –7.2, $p = 0.006$) and functional independence for self-care (FIM self-care mean difference = 3.5, CI = 0.4, 6.6, $p = 0.028$) and mobility (FIM mobility mean difference = 2.0, CI = 0.3, 3.8, $p = 0.024$) compared to the control group. At 3-months follow-up, stroke participants in enrichment group showed improvement in “overall health” section of EQ-5D (total mean difference = 11.4, CI = 0.1, 22.7, $p = 0.047$) compared to control group.
	Robertson, 2020	Neither standard care nor enriched environment participants met daily requirements for energy (70.7% ± SD 16.8 vs. 70.7% ± SD 17.3, $p = 0.94$) or protein intake (73.2% ± SD 18.6 vs. 69.8% ± SD 17.3, $p = 0.70$). Mean body weight dropped for both groups; standard care 0.92 kg ± SD 2.47 vs. enriched 0.64 kg ± SD 3.12 ($p = 0.53$) and malnutrition increased; standard care 3.3% - 26.6% vs. enriched 6.6% - 13.3% ($p = 0.07$). Predictors of malnutrition on discharge in logistic regression models were length of stay ($p < 0.01$) and protein ($p < 0.01$) or energy intake ($p = 0.02$).
	Rosbergen, 2017a	Staff felt that the activity area helped to increase activity, empowerment, and psychological well-being for patients. Activity area led to increased workload for some nurses (esp. with higher acuity patients) but others experienced reduced workload because patient kept occupied (esp. if other staff cooperated). The activity area was not purpose-built, which was challenging; staff converted therapy area to dining area daily.
	Rosbergen, 2017b	Participants in the enrichment group a spent a greater proportion of their day in physical (33% vs. 22%, $p < 0.001$), social (40% vs. 29%, $p = 0.003$) and cognitive activity (59% vs. 45%, $p < 0.001$) compared to usual care group. Changes were sustained six months post-implementation. Participants with an activity area experienced fewer adverse events (0.4 ± 0.7 vs.1.3 ± 1.6, $p = 0.001$), but no differences in serious adverse events (0.5 ± 1.6 vs.1.0 ± 2.0, $p = 0.309$).
	Rosbergen, 2019	Participants in enrichment group had higher activity levels during scheduled communal activity ($p < 0.001$), weekday non-scheduled activity ($p = 0.007$) and weekends ($p = 0.018$) compared to control group, but no difference between groups on weekdays after 5 p.m. ($p = 0.324$). Participants in enrichment group spent more time on upper limb ($p < 0.001$), communal

		socializing ($p < 0.001$), listening ($p = 0.007$) and iPad activities ($p = 0.002$) compared to control group. There was no difference in staff assistance during activities ($p = 0.055$).
	White, 2014	Staff felt that the activity area promoted patient activity, participation, and moral. Some nurses felt obliged to facilitate patients' use of activity area, other nurses were unsure how to facilitate use or did not consider this their responsibility. Some nurses felt too busy to facilitate, others experienced reduced workload because activity area kept patient occupied. Suggested having dedicated staff to facilitate use of activity area.
	White, 2015	Patients felt that the activity area helped to increase their physical and social activity and reduce boredom. Activity area may have been used more by internally motivated patients. Access to activity area was difficult for those with mobility restrictions, and patients hesitant to ask for help.
Bedroom design	Arbel, 2019	The AHR was rated more positively on all aspects compared to the standard room, and participants in the AHR reported more positive feelings and fewer negative feelings. More participants in the AHR reported a satisfactory overall experience compared to participants in standard rooms (100% [$n = 10$] vs 46.7% [$n = 7$], $p = 0.016$) and more reported a satisfactory experience of waking-up from sleep (90% [$n = 9$] vs 53.3% [$n = 8$], $p = 0.046$). Most felt that the orientation screen helped them to feel oriented (80% [$n = 8$]) and that the nature screen positively impacted their mood (70% [$n = 7$]).
	Daemen, 2014a	All participants rated the AHR positively for impact on clinical outcomes and workflow (score of 5 or over on a 7-point Likert scale). Participants felt that the AHR would promote patient/staff relationship, be patient-centered, help patients wake-up naturally, give more structure to the day, give stimulation at the right times and so be beneficial for both healing and workflow. Participants noted that patients would also be impacted by stimuli outside the AHR (e.g. sounds in hallway).
	Perovic, 2017	There was no significant difference in depression or anxiety (HADS) between participants in the bedrooms pre-refurbishment (many beds per room, poor light, poor aesthetics, old; mean HADS score = 9.14) and those in the bedroom post-refurbishment (fewer beds per room, more colour and light, new; mean HADS score = 7.18).
Therapy spaces	Skubik-Peplaski, 2015	Participants felt that they choose to treat in whichever space they are used to going to (habit), that the environment influenced their intervention choices ("see it use it"), and that they felt safer and so more confident treating in a gym environment versus an environment that was more isolated and was not purpose built for therapy.
Whole of built environment	Anaker, 2017	Participants were more inactive and alone post-move and spent more time in their bedrooms compared to pre-move (inactive for 25.3% of day pre-move, 54.1% post-move; alone 49.6% vs. 82.8%; in bedroom 54.8% vs. 83.1%). Authors suggest that the following factors contributed to the decreased activity and increased time alone and time in bedroom: increase in single-bed rooms post-move, more therapy in the bedroom, doors to bedrooms were always kept shut, lounge difficult to locate, and built environment hard to navigate.
	Anaker 2018	Participants in the ward with a combination of single- and multi-bedrooms were more active than participants in the wards with mostly single-bed rooms (31.6% of the day inactive vs 54.1% and 54.4%), but multi-bed rooms appeared to have less privacy and more noise. In all wards, participants spent very little time in the lounge and therapy areas (between 0.2% and 8.6% of the day),

	possibly because these rooms were difficult to locate or because they were not attractive spaces. Overall, three main aspects of the built environment appeared to have an impact on patients' activities and care: (1) Ease of navigation; (2) Responsiveness, flexibility and variety; and (3) Privacy and respect for personal integrity.
Anaker, 2019	Interviews with participants revealed two themes: 1) there is incongruence between community and privacy in the environment (single rooms promote privacy and control but also loneliness, and there is a lack of communal areas); 2) Connectedness with the outside world provides distraction and a sense of normality (nature and outdoors facilitate well-being and view of outdoor activities evoke memories and bring positive distraction).
Anaker, 2020	Staff rarely worked in teams of two or more while with patients, but when they do it is usually in the bedroom, indicating a need for large bedrooms with access to privacy. None of the included stroke units had a co-location for all the members of the multi-professional team. Three main categories were common across the stroke units: the units all contained a central hub; places were divided by profession and did not facilitate teamwork; the power imbalance between different staff groups and between staff and patients appears to be accentuated by the environment (e.g., meeting rooms being too small to accommodate all staff).
Daemen, 2014b	Authors state that patients' experiences and recovery could be improved if the following environmental needs are met: dosing stimulus load, having social support, having access to both single and multiple patient rooms, balancing a clinical and personal environment, providing structure to the day, undisturbed sleep, access to information.
Kevdzija, 2018	Staff and patients identified the following issues in the built environment that are barriers to patients' independent mobility: wayfinding problems, insufficient dimensions of spaces (corridors), physical obstacles, uneven floor surfaces and large distances between patient rooms and therapy rooms. Patients in the earlier stages of rehabilitation, especially those using a wheelchair, appeared to experience more barriers related to the built environment.
Lampinen, 2003	Participants described 3 main aspects of the built environment that impact their performance of everyday tasks: 1) Everything seems unfamiliar, familiar characteristics become unrecognizable, perceptions and sensations changed; 2) Interacting with the physical world can be difficult, objects can be obstacles and seem to have a mind of their own; and 3) Experiences of adaptation to the new problematic world, striving for mastery over things in the environment which used to be easy.
Lipson-Smith, 2019	Participants identified 4 fundamentally important things that the built environment must achieve for stroke rehabilitation: 1) maximise efficiency (by minimising time, cost and maximising responsiveness of the space), 2) maximise clinical outcomes (by maximising patient activity, sleep and rest), 3) maximise emotional well-being for all users, and 4) maximise safety for all users. Participants also identified 14 means by which these 4 things could be achieved: Maximise adaptability, versatility, adequate technology, multipurpose circulation spaces, outdoor and green space, personal control over space, integration with community, aesthetics, indoor environmental quality, legibility, accessibility, and sight lines, adhere to safety guidelines and minimize manual handling.
O'Halloran, 2011	The medical chart (visible in the patient bedroom) was observed to facilitate communication between patients and healthcare providers. All the other observed physical environmental factors appeared to create barriers to communication, including background noise, lack of physical aids, small print on food menus, and lack of written information to aid recall.

O'Halloran, 2012	The physical environment predominantly acted as a barrier to communication between patients and health care providers via e.g., high levels of background noise, visual distractions. Assistive communication devices were absent or frequently inaccessible. The lack of single-bed rooms made it more difficult to have conversations with patients.
Shannon, 2019	Higher proportion of single-bed rooms post-move. Overall, there was no difference in time spent in social activity between the two wards, but there was more in-bed social activity in the pre-move ward than in the post-move ward (33% of time vs 8%, p = 0.03). Participants were more physically active in their bedrooms post-move compared to pre-move (47% of time vs 2%, p = 0.001).
Turner, 2012	Participants identified that the rehabilitation environment contributed to their feelings of disempowerment, lack of control, and feeling of being in a time capsule, all of which they felt contributed to their post-stroke depression.

Abbreviations: AHR = Adaptable Healing Room; DASS = Depression Anxiety, Stress Scales; CI = Confidence Interval; FIM = Functional Independence Measure; EQ-5D = Euro-Quality of Life-5D questionnaire.

Supplementary material 7

Details of the results of methodological appraisal using the Mixed Methods Appraisal Tool (21).

Quality appraisal ratings of each study

First author, year	Criteria from the Mixed Methods Appraisal Tool																								
	1.1	1.2	1.3	1.4	1.5	2.1	2.2	2.3	2.4	2.5	3.1	3.2	3.3	3.4	3.5	4.1	4.2	4.3	4.4	4.5	5.1	5.2	5.3	5.4	5.5
Anaker, 2017	1	0	1	1	1											1	1	1	1	1	0	1	1	1	1
Anaker, 2018	1	0	1	1	1											1	1	1	1	1	1	1	1	1	1
Anaker, 2019	1	1	1	0	1																				
Anaker, 2020	1	1	1	1	1											0	0	1	0	1	1	1	1	1	0
Arbel, 2019	1	0	0	0	1						0	0	0	0	0						1	1	1	1	0
Daemen, 2014a	1	1	0	1	1											0	0	1	0	0	1	0	0	0	0
Daemen, 2014b	1	1	0	0	0																				
Janssen, 2014											0	1	0	1	1										
Kevdzija, 2018	1	1	1	1	1																				
Khan, 2016						1	1	1	1	1															
Lampinen, 2003	1	1	1	1	1																				
Lipson-Smith, 2019	1	1	1	1	1																				
O'Halloran, 2011	1	1	0	1	1																				
O'Halloran, 2012	1	1	1	1	1																				
Perovic, 2017											0	1	1	1	1										
Robertson, 2020											0	1	1	1	1										
Rosbergen, 2017a	1	1	1	1	1																				
Rosbergen, 2017b											0	1	1	1	1										
Rosbergen, 2019											0	1	1	1	1										
Shannon, 2019											0	1	1	0	1										
Skubik-Peplaski, 2015	1	1	1	1	1																				
Turner, 2012	1	1	0	0	0																				
White, 2014	1	1	1	1	1																				
White, 2015	1	1	1	1	1																				

1 = a score of 'yes'; 0 = a score of 'no' or 'can't tell'

Mixed methods studies were given the score of their lowest scoring criterion, as recommended by MMAT

Criteria within the Mixed Methods Appraisal Tool

Category of study designs	Methodological quality criteria
1. Qualitative	1.1. Is the qualitative approach appropriate to answer the research question?
	1.2. Are the qualitative data collection methods adequate to address the research question?
	1.3. Are the findings adequately derived from the data?
	1.4. Is the interpretation of results sufficiently substantiated by data?
	1.5. Is there coherence between qualitative data sources, collection, analysis and interpretation?
2. Quantitative randomized controlled trials	2.1. Is randomization appropriately performed?
	2.2. Are the groups comparable at baseline?
	2.3. Are there complete outcome data?
	2.4. Are outcome assessors blinded to the intervention provided?
	2.5 Did the participants adhere to the assigned intervention?
3. Quantitative nonrandomized	3.1. Are the participants representative of the target population?
	3.2. Are measurements appropriate regarding both the outcome and intervention (or exposure)?
	3.3. Are there complete outcome data?
	3.4. Are the confounders accounted for in the design and analysis?
	3.5. During the study period, is the intervention administered (or exposure occurred) as intended?
4. Quantitative descriptive	4.1. Is the sampling strategy relevant to address the research question?
	4.2. Is the sample representative of the target population?
	4.3. Are the measurements appropriate?
	4.4. Is the risk of nonresponse bias low?
	4.5. Is the statistical analysis appropriate to answer the research question?
5. Mixed methods	5.1. Is there an adequate rationale for using a mixed methods design to address the research question?
	5.2. Are the different components of the study effectively integrated to answer the research question?
	5.3. Are the outputs of the integration of qualitative and quantitative components adequately interpreted?
	5.4. Are divergences and inconsistencies between quantitative and qualitative results adequately addressed?
	5.5. Do the different components of the study adhere to the quality criteria of each tradition of the methods involved?

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	5
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	6
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	7
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	6
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supp material 3
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	6
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	8
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Supp material 5
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Fig 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Table 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Supp material 7
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	Supp material 6
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	14-19
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	20-21
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	23
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	23
FUNDING			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	24

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