



Built Environments as a catalyst towards recovery: Influence of Design Behavior Codes (DBC)[®] based Rehabilitation setup on Human Behavior

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ABSTRACT: Adherence to cardiac rehabilitation (CR) programs is essential for long-term cardiovascular outcomes yet remains suboptimal. Emerging evidence suggests that environmental design may influence patient behaviour, stress regulation, and engagement in health programs(1,5,6,34,37,45). This study investigates how spatial designs through DBCs influence human behavior within rehabilitation environments. The research examined 10 patients with cardiovascular disease who underwent rehabilitation in the Cardiac Rehabilitation Centre(DBC-led spatial designs) at a tertiary care hospital and participated in a post-program environmental perception survey using a mixed-methods approach combining quantitative surveys and qualitative feedback. The Quantitative survey evaluated the perceived influence of lighting, materials, and tactile comfort, acoustics, colour, biophilic elements, safety, spatial layout, and pacing (DBC Codes) using the Cardiac Rehabilitation Environment Behaviour Index (CREBI) Questionnaire. The responses were analysed and interpreted alongside observed program outcomes such as stress reduction using the Perceived Stress Scale (PSS) and stabilization of physiological vital parameters.

Descriptive analysis from the CREBI questionnaire revealed significant increased score (68/70) and positive behavioural experiences by the patients who completed rehab at the outpatient cardiac rehab centre, which was spatially designed using DBC codes as compared to inpatient(47/70) and home-based settings(33/70). Also, there was a negative association seen between the CREBI scores and the Perceived Stress Scale (PSS) in the patients who completed rehab at the outpatient cardiac rehab centre (PSS reduced from 22 to 18.1). The positive behavioural outcomes included increased social interaction, calmness, and comfort, and decreased anxiety, fatigue, impulsiveness, and irritability.

The qualitative feedback was positive and supported these findings, revealing that participants attributed emotional ease and social engagement to biophilic and human-centred design elements. Patients consistently reported that the outpatient cardiac rehabilitation centre's environment supported greater motivation, reduced stress, and improved adherence compared to home and inpatient settings. Environmental features were associated with improved emotional comfort, reduced cognitive load, and enhanced physiological stability during rehabilitation sessions(22,24,28,44).

The study concludes that architecture and spatial designs play a fundamental role in shaping psychological, physiological, and behavioural experiences and proposes evidence-based guidelines for designing emotionally supportive and behaviourally conducive spaces(1,5,6,34). This can be done through implementing Design Behaviour Codes (DBC)[®], which is vital for architects, planners, and educational institutions, hospitals, aiming to create environments that promote well-being and positive user experience. Integrating evidence-based environmental/Spatial Design principles into rehabilitation settings may enhance patient engagement and clinical outcomes.

KEYWORDS: Rehabilitation, Environmental design, spatial Design; Human Behaviour; Architectural design, built environment; psychology, cognitive behaviour, behavioural neuroscience

I. INTRODUCTION:

1. Architecture has long been recognised as a determinant of human behaviour, yet its effects have remained largely implicit and difficult to audit. Advances in neuroscience and environmental psychology now demonstrate that spatial variables such as sensory load, predictability, movement pacing, and enclosure directly influence stress responses, impulse control, and decision



quality(1,3,5,22,24,45). Design Behaviour Codes (DBC) formalise this evidence into enforceable spatial conditions that regulate behavioural probability rather than individual choice. By shaping the neurobiological context in which decisions occur, DBCs position architecture as an upstream determinant of behavioural health and decision stability(7,8,10,11,12).

2. Design Behaviour Codes (DBC): Methodological Framework: Design Behaviour Codes (DBC) represent a structured framework that translates evidence from neuroscience, cognitive psychology, behavioural economics, and environmental psychology into auditable architectural conditions(7–12,45). Unlike traditional architectural guidelines that rely on aesthetics or symbolic intent, DBCs codify spatial parameters that systematically influence cognition, emotion, physiology, and decision-making. This paper presents a condensed synthesis of the DBC methodology, its grounding in two-brain logic, and its effects on impulsivity, stress physiology, autonomic regulation, hormonal balance, and neurotransmitter systems. The paper further outlines measurable neurobiological and behavioural outcomes, positioning DBCs as a preventive, non-invasive behavioural infrastructure embedded within the built environment.

DBC are a systematic set of spatial rules derived from cognitive science, behavioural economics, environmental psychology, and applied physical principles. Each DBC specifies a minimum architectural condition, such as circulation continuity, graded thresholds, spatial depth, rhythm, or sensory modulation, that has a predictable influence on cognition and behaviour.

DBC are not aesthetic prescriptions or behavioural nudges. They define non-negotiable spatial expressions and guardrails that remain valid across cultures, climates, and architectural styles, ensuring global adaptability. Their structure mirrors established regulatory codes in safety and accessibility: they regulate conditions rather than outcomes and bias the behavioural probability space without determinism.

Audibility is achieved through applied physics. Spatial continuity, gradients, proportions, acoustic damping, and lighting transitions are measurable, making DBCs verifiable design standards rather than interpretive guidelines(6,34,45).

3. Two-Brain Logic and Spatial Cognition

The DBC framework is grounded in dual-process theories of cognition, which describe decision-making as an interaction between a fast, intuitive,

reactive system and a slower, deliberative, reflective system(7,8,9). The fast system prioritises speed and emotional salience, while the slow system supports planning, inhibition, and long-term evaluation.

Contemporary built environments characterised by speed, density, and sensory overload disproportionately activate the fast system, increasing impulsivity and stress(22,24,28,30). DBCs counter this bias by embedding architectural pacing, graded transitions, and spatial coherence that preserve engagement of the slower system without requiring conscious effort. Thus, Two-Brain Logic is operationalised spatially rather than cognitively, transforming architecture into a stabilising cognitive infrastructure.

4. Pathways Through Which DBCs Influence Human Behaviour

DBC influence behaviour through multiple converging pathways:

4.1 Sensory Load Regulation

Excessive visual, auditory, or tactile stimulation increases sympathetic activation and cortisol release, whereas moderated sensory environments support parasympathetic tone and cognitive clarity(22,24,28,31). DBCs regulate lighting gradients, acoustics, textures, and visual coherence to stabilise arousal.

4.2 Spatial Predictability and Cognitive Mapping

Legible layouts and consistent spatial cues reduce cognitive load and uncertainty, maintaining hippocampal–prefrontal engagement and impulse control(18,19).

4.3 Autonomic Nervous System Modulation

Gradual transitions, adequate personal space, and low-threat cues enhance vagal tone and reduce sympathetic dominance, improving emotional regulation and reflective decision-making(15,20,21).

4.4 Stress and Hormonal Regulation

Calm, coherent spaces reduce unnecessary activation of the HPA axis and cortisol release, while chaotic environments amplify stress responses(22,23,29).

4.5 Impulsivity and Decision Bias

By embedding pauses, buffer zones, and effort–reward separation, DBCs strengthen prefrontal inhibitory control and reduce present bias and risk-taking(10,25,26).

5. Neurobiological Basis: Impulsivity, Cortisol, and the HPA Axis

Impulsivity is associated with heightened amygdala reactivity and reduced prefrontal inhibition, leading to activation of the hypothalamic–pituitary–adrenal



(HPA) axis and cortisol release. Sensory overload and urgency cues accelerate this cascade by suppressing hippocampal contextual modulation and disinhibiting hypothalamic stress signalling(22,24,28,29).

Cortisol feeds back to impair prefrontal function and enhance limbic salience, creating a self-reinforcing loop of impulsivity and stress. DBCs intervene upstream by reducing amygdala activation at the sensory and spatial levels, preserving hippocampal modulation, and slowing autonomic escalation before cortisol release.

6. Autonomic, Hormonal, and Neurotransmitter Effects

Impulsive states are marked by sympathetic dominance, reduced heart rate variability (HRV), and diminished parasympathetic recovery, all of which bias behaviour toward speed and reactivity(20,21). Chronic impulsivity is associated with dysregulated cortisol, adrenaline, noradrenaline, disrupted melatonin rhythms, and impaired metabolic regulation.

At the neurotransmitter level, impulsivity involves increased dopaminergic volatility, reduced serotonergic inhibition, elevated noradrenergic urgency, and weakened GABAergic control. By stabilising sensory input, pacing movement, and enforcing predictability, DBCs indirectly normalise these neurochemical systems, shifting behaviour from reactive to adaptive(26,28).

7. Measurement of Neurobiological and Behavioural Outcomes

Established neurobiological measurement tools enable objective evaluation (33,44,58).

The effects of DBCs are empirically measurable using established tools:

- **Central neurobiology:** fMRI, EEG, PET
- **Autonomic regulation:** HRV, skin conductance, respiratory variability
- **Hormonal markers:** salivary and hair cortisol, catecholamines
- **Behavioural outcomes:** impulsivity scales, delay discounting, executive function tests
- **Spatial metrics:** space syntax, visibility analysis, dwell time, and movement entropy

This integrated measurement framework enables rigorous evaluation of DBC-aligned environments.

BACKGROUND:

Adherence to rehabilitation programs is a critical determinant of long-term outcomes in

chronic disease management, particularly in cardiac rehabilitation, where sustained participation, stress regulation, and behavioural compliance directly influence morbidity and mortality. While clinical protocols focus on exercise prescription, pharmacotherapy, and counselling, the role of the built environment in shaping patient behaviour and physiological response remains underexplored within mainstream rehabilitation research.

Emerging evidence from environmental psychology, neuroscience, and behavioural science indicates that architectural environments exert measurable effects on emotional regulation, cognitive load, and physiological stability. Neurocognitive studies have demonstrated that spatial geometries, such as curvature, enclosure, symmetry, and spatial volume, activate neural pathways associated with calmness, arousal, or stress reduction, independent of symbolic or decorative elements(41,42,45). These findings suggest that architectural form itself can function as a behavioural and emotional modulator within healthcare settings.

Beyond perceptual effects, research indicates that environmental stimuli within built spaces influence physiological and biochemical processes relevant to rehabilitation. Studies have shown that architectural perception can alter neural activity, hormonal response, and stress-related gene expression, reinforcing the understanding that space is processed somatically as well as cognitively(44,48). In rehabilitation contexts, where patients often experience anxiety, fatigue, and reduced motivation, such environmental influences may impact treatment tolerance, emotional resilience, and engagement with therapy.

Aesthetic quality and sensory coherence have also been linked to emotional comfort, perceived safety, and social interaction, factors that are particularly relevant in outpatient rehabilitation settings reliant on voluntary attendance. Research examining pleasure–arousal–dominance dynamics suggests that spatial environments influence mood states, interpersonal behaviour, and self-efficacy, all of which are known behavioural determinants of rehabilitation adherence(3,49). Similarly, spatial organization, lighting, movement pathways, and visual continuity contribute to cognitive mapping, orientation, and pacing, potentially reducing cognitive load and enhancing perceived control during rehabilitation sessions(18,19,50).

Advances in neuroarchitecture and emotional architecture have enabled objective assessment of these effects using tools such as EEG monitoring, mood-state profiling, and physiological



signal mapping(57,58). However, despite increasing empirical support for the influence of space on health-related behaviour, architectural considerations remain largely absent from clinical rehabilitation frameworks and outcome-based healthcare design models.

RATIONALE:

Although existing literature establishes associations between built environment characteristics and emotional or physiological responses, most studies remain descriptive, context-specific, and lack standardized mechanisms for clinical translation(6,34,45). There is a notable absence of structured frameworks that encode behavioural evidence into replicable design strategies applicable across rehabilitation settings. Consequently, architectural design is rarely leveraged as a deliberate, evidence-based behavioural intervention within healthcare systems.

Design Behaviour Codes (DBC) offer a systematic approach to address this gap by translating behavioural and neuropsychological evidence into defined spatial parameters linked to predictable behavioural and physiological outcomes. By operationalizing design elements such as pacing, sensory modulation, spatial sequencing, and environmental safety, DBCs enable rehabilitation environments to actively support stress regulation, engagement, and behavioural stability(7-12,45).

In high-burden conditions such as cardiovascular disease, where adherence, emotional regulation, and sustained participation are central to clinical success, evaluating DBC-led rehabilitation environments is both timely and necessary(39,40). This study seeks to assess whether spatial design guided by DBCs can function as a non-pharmacological adjunct to rehabilitation care, contributing measurable improvements in patient behaviour, stress perception, and physiological stability. Generating such evidence is essential for informing patient-centred, behaviourally informed healthcare architecture and advancing rehabilitation design from an intuitive practice to an outcome-driven clinical strategy.

NEED FOR THE STUDY:

Despite growing evidence that the built environment influences emotional, behavioural, and physiological responses, rehabilitation design lacks standardized, evidence-based frameworks that translate behavioural science into actionable architectural practice. Existing studies predominantly describe associations without offering structured tools for implementation or

evaluation in clinical settings. There is a critical need to examine whether Design Behaviour Codes (DBC) can systematically enhance patient engagement, reduce stress, and support physiological stability in rehabilitation environments. This study addresses this gap by evaluating DBC-led rehabilitation design as a behavioural intervention, contributing empirical evidence to inform patient-centred, therapeutically supportive healthcare architecture.

AIM AND OBJECTIVE:The study aims to critically examine how architectural design elements through DBCs influence human behaviour in a rehabilitation setting with a view to establishing codified design strategies that promote positive psychological and physiological responses within built environments.

The objectives of the Study are to:

1. To evaluate how specific architectural stimuli (including lighting, materiality, and spatial transitions) affect human behaviour within an outpatient cardiac rehabilitation centre.
2. To propose evidence-based architectural design behaviour codes (DBC) that support emotional well-being and behavioural comfort in a rehabilitation setting.

II. LITERATURE REVIEW:

Mehrabian A, Russell JA (1974) introduced the Pleasure-Arousal-Dominance (PAD) model, showing that environments reliably evoke emotional states guiding approach-avoidant behaviour (3). Established that spatial stimuli directly influence behaviour. Foundational to environmental and behavioural psychology. **Ulrich RS (2001)** demonstrated that healthcare environmental design influences stress, pain perception, and recovery outcomes (37). Patients exposed to supportive environments showed reduced anxiety and improved satisfaction. Established design as a clinical variable. **Evans GW (2003)** identified strong associations between poor built environments (crowding, noise, housing stress) and psychological distress(1). Environmental stressors cumulatively increased anxiety and mental health burden. Positioned environment as a public mental health determinant. **Bechara A (2005)** demonstrated that emotional dysregulation and stress impair impulse control and decision-making (10). Highlighted neural vulnerability to environmental conditions. Relevant to behaviour regulation in clinical contexts. **Lupien SJ et al. (2007); Porcelli & Delgado (2009)** showed that elevated cortisol impairs memory, attention, and decision-making(24). Stress exposure increased impulsivity



and altered risk behaviour. Reinforced the importance of stress-reducing environments for cognitive stability. **Kellert SR et al. (2008)** established that biophilic design enhances emotional well-being and physiological restoration(35). Natural elements reduced stress and supported cognitive recovery. Positioned nature integration as essential to health-supportive design.

Ulrich RS et al. (2008) conducted a Systematic review confirming that evidence-based healthcare design improves outcomes, including stress reduction and patient satisfaction(6). Findings are consistent across hospital settings. Called for design integration into healthcare planning. **Sternberg EM (2009)** argued that healing spaces modulate stress physiology and emotional recovery. Demonstrated links between environment, immune response, and autonomic regulation(5). Framed architecture as a therapeutic adjunct. **Centre for Health Design (2010)** concluded that the physical environment directly affects health outcomes, safety, and care quality(34). Evidence supported reduced stress and improved staff and patient performance. Reinforced need for measurable design standards. **Zaino A, Abbas M (2020)** provided early evidence that architectural space alters gene expression related to stress. Introduced epigenetic implications of built environments(51). **Kahneman D (2011)** Demonstrated that behaviour is dominated by fast, automatic cognitive processes highly sensitive to environmental cues(7). Highlighted the vulnerability of decision-making to contextual design. Critical for behavioural intervention framing. **Browning WD et al. (2014)** identified 14 biophilic patterns associated with reduced stress, improved mood, and cognitive performance(36). Reported physiological benefits include heart rate reduction. Provided actionable design guidance. **Zaino A, Abbas M (2020)** showed that architectural space can influence stress-related gene expression. Positioned architecture within molecular and physiological health discourse. Suggested non-pharmacological intervention potential. **Abbas M, Zaino A (2020)**, Single-case experimental study demonstrating that spatial manipulation can deliberately induce emotional states(48). Showed measurable emotional shifts post-design intervention. Supported causality between space and emotion. **Shemesh A et al. (2022)**, A neurocognitive study showing curved geometries elicited positive emotional responses compared to rectilinear forms(41). fMRI data demonstrated reduced amygdala activation. Confirmed geometry as an emotional stimulus. **Clark O et al. (2022)** Systematic review confirming architectural stimuli influence mood, stress, heart

rate, and cognition(45). Reported consistent physiological effects across lighting, form, and materials. Supported architecture as a health intervention. **Kakkar G (2022)** concluded that architecture profoundly influences psyche, behaviour, and emotional well-being(52). Called for ethical responsibility in design. Advocated integration of psychological principles into architectural practice. **Dewancker B et al. (2024)** found that urban and roadside architectural forms elicit measurable emotional and cognitive responses(46). Visual form influenced comfort and stress perception. Extended evidence to urban-scale environments. **Abbas S et al. (2024)** demonstrated that perception of architectural space alters neural activity and hormonal response(44). Provided biological evidence for neuroarchitecture. Strengthened clinical relevance of spatial design. **Ogunnaik, Daniel, and Atulegwu (2025)** investigated how architectural design influences human emotion, behaviour, and well-being using a mixed-method approach with 772 student participants from two Nigerian universities(60). It found statistically significant correlations between architectural geometries (e.g., curvilinear forms, balanced proportions) and positive emotional states such as calmness and pleasure (e.g., Pearson's r values up to 0.52, $p < 0.001$), while rectilinear and enclosed forms were associated with anxiety. Natural lighting, warm materiality, and fluid spatial transitions were significantly linked to increased social interaction and comfort. Qualitative thematic analysis showed that biophilic and human-centred design elements promoted emotional ease and engagement. The authors conclude that evidence-based spatial design robustly shapes psychological and behavioural outcomes and recommend design guidelines to enhance well-being.

STUDY DESIGN: Cross-sectional design study using a Survey Questionnaire

STUDY POPULATION AND SIZE: Ten adult patients with cardiovascular disease who completed phase 1 inpatient cardiac rehabilitation in the hospital, then home-based rehabilitation, followed by a structured outpatient program at the cardiac rehabilitation centre (DBC-led spatial designs) within the tertiary care hospital, were included. All participants had prior experience with inpatient rehabilitation and home-based recovery, allowing comparative reflection.

STUDY SETTING: Outpatient cardiac rehabilitation centre (DBC-led spatial designs) within the tertiary care hospital in India.

MATERIALS: 1. The CREBI Survey Questionnaire (Total score=70). The environmental



survey, which focused on the following domains: Lighting (natural and artificial), Materials and tactile comfort, Acoustics, Colour and visual tone, Biophilic elements (plants, natural views, daylight), Safety and spatial layout, Pacing. 2. Perceived Stress scale (PSS) Questionnaire 3. List of 200 DBC©

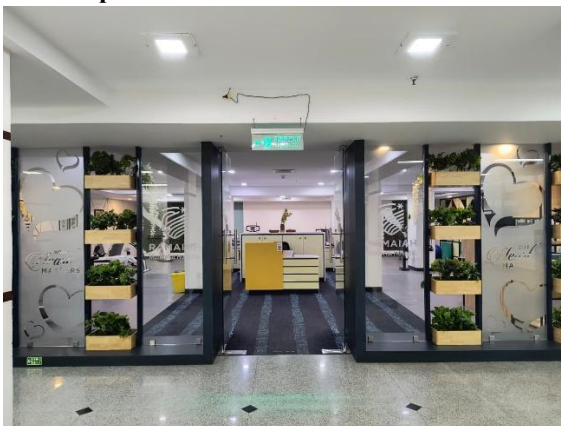
OUTCOMES: CREBI Score, PSS score, physiological vital parameters (heart rate, blood pressure trends during sessions), and Experienced Behaviours.

DATA COLLECTION METHODOLOGY: The 10 patients, after completing their inpatient rehab program and treatment at their home setting, visited the outpatient-based cardiac rehab centre (DBC-led design). Each of them completed a minimum of 6 weeks of a cardiac rehab program. For the quantitative data, the structured questionnaires were administered. At the beginning of the program, the patient had to fill out the PSS questionnaire, and at

the end of the rehab sessions, it was readministered. The patients were asked to complete the CREBI Questionnaire, which also included their experiences from their inpatient and home settings. The CREBI questionnaire items were designed to assess perceptions of architectural space, emotional responses, behavioural tendencies, and overall well-being. The instrument incorporated items from the list of 200 DBC © and from prior studies on architectural psychology and environmental perception to ensure reliability. The patients reflected on how each of the environmental factors in the CREBI influenced their behaviour experience, like motivation, comfort, stress, and adherence, consistent with established DBC frameworks. The physiological parameters, like HR and BP, were tracked throughout the rehab sessions.

Qualitative feedback was also taken from the patients on their behavioural experiences at the outpatient cardiac rehab centre.

IMAGES: Outpatient cardiac rehab centre





DATA ANALYSIS: Descriptive analysis was done for CREBI, PSS, and Heart rate (HR) in terms of the mean value. Qualitative responses in relation to environmental perceptions obtained as feedback were summarized.

RESULTS: The quantitative and qualitative findings are summarized in Table 1.

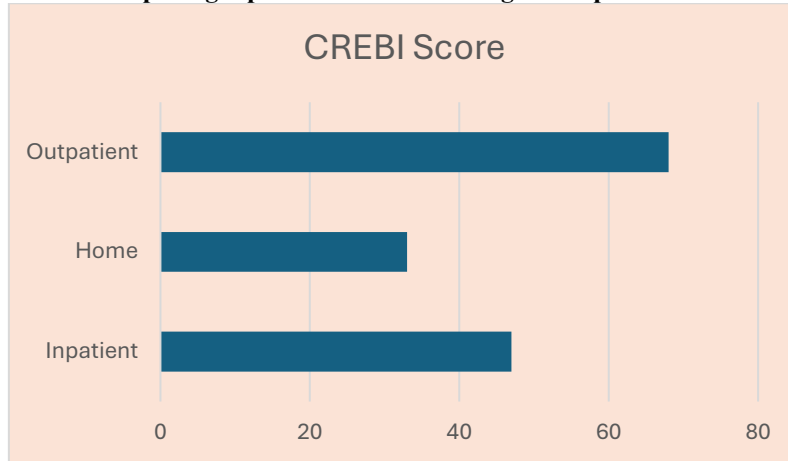
TABLE 1: Effect of Architectural Stimuli on Emotional & Behavioural Response Mapped with DBC®

Stimulus	DBC®	Emotional & Behavioral Response
Lighting	DBC Codes	↑Calmness, ↑alertness, ↓fatigue
Materials and tactile comfort	DBC Codes	↑Comfort, ↓impulse, ↑ mindfulness, ↑attention
Acoustics	DBC Codes	↑Concentration, ↑emotional regulation, ↓irritability
Colour and visual tone	DBC Codes	↓Aggression, ↓ impulsiveness, ↓stress, ↓visual load, and ↑mental well-being
Biophilic elements	DBC Codes	↓Anxiety, ↑confidence, ↑attention, ↑calmness, ↓burnout, ↑productivity, ↑social ease
Safety	DBC Codes	↓Irritability, ↑endurance, ↑emotional resilience
Spatial layout, Pacing	DBC Codes	↓Cognitive load, ↑attention, ↑calmness, ↑trust, ↑comfort, ↓stress, ↑Emotional regulation, ↑social engagement, and ↓ aggression

The table summarizes the various emotional and behavioral responses experienced by the patient using both quantitative and qualitative measures. They were then mapped with the DBC codes and were found to be consistent with the DBC® framework.

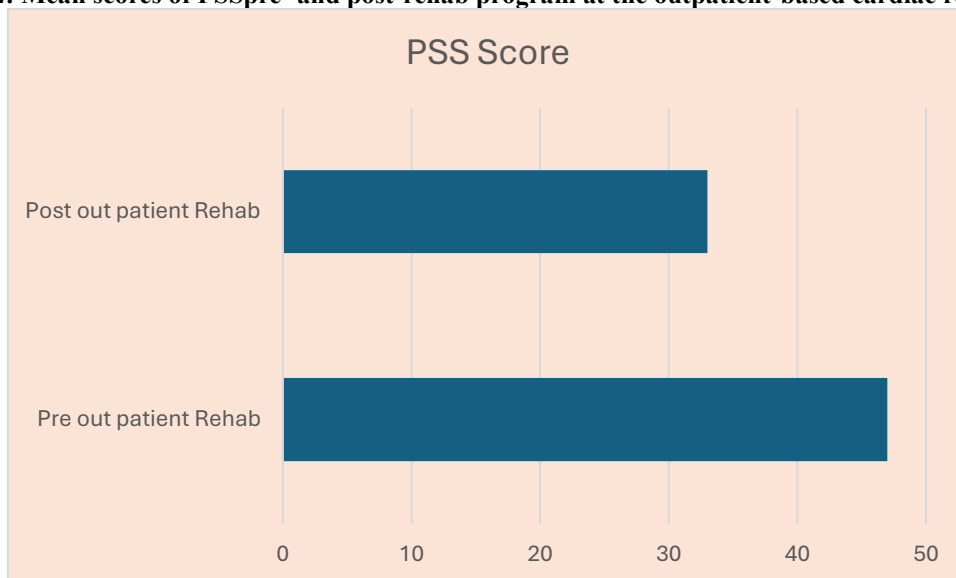


GRAPH 1:
Mean scores on CREBI comparing inpatient Vs home setting Vs outpatient based cardiac rehab center



It is seen from the graph that the mean scores were highest (68/70) in the outpatient cardiac rehab center, as compared to inpatient (47/70) and home setting (33/70).

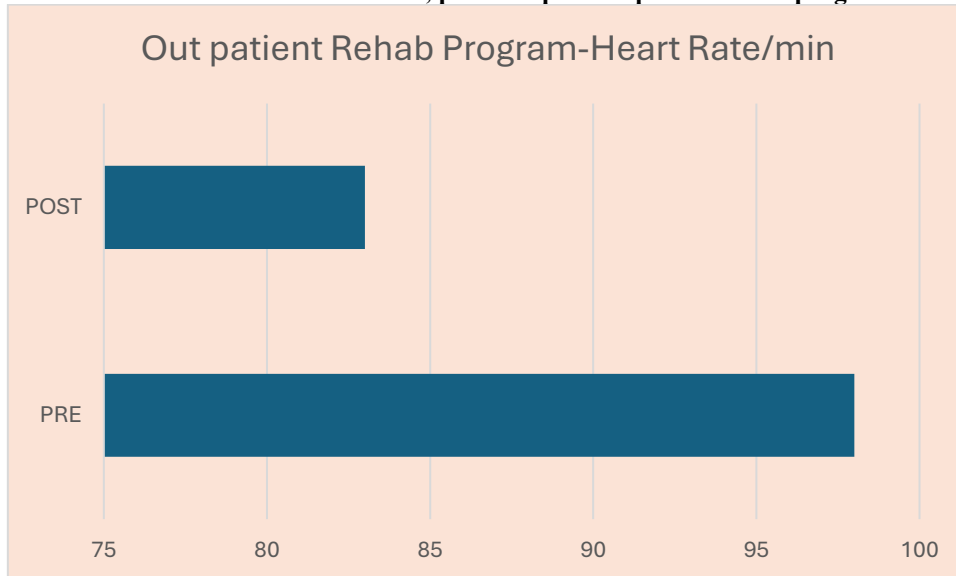
GRAPH 2: Mean scores of PSSpre- and post-rehab program at the outpatient-based cardiac rehab center



The PSS scores decreased from 22 to 18 post-rehabilitation at the outpatient-based cardiac rehabilitation center.



GRAPH 3: Mean values of HR, pre- and post-outpatient rehab program.

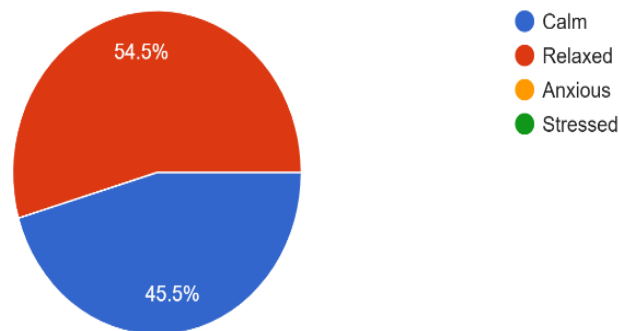


The mean values of HR reduced from 98/ min to 83/ min post-outpatient rehabilitation as compared to pre-outpatient rehab at the outpatient-based cardiac rehabilitation center.

QUALITATIVE FEEDBACK SUMMARY FROM THE PATIENTS AT THE OUTPATIENT CARDIAC REHAB CENTRE:

2. How does the rehabilitation environment make you feel emotionally ?

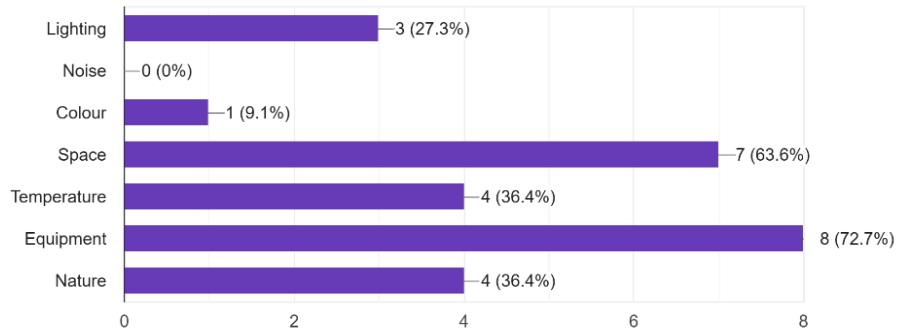
11 responses





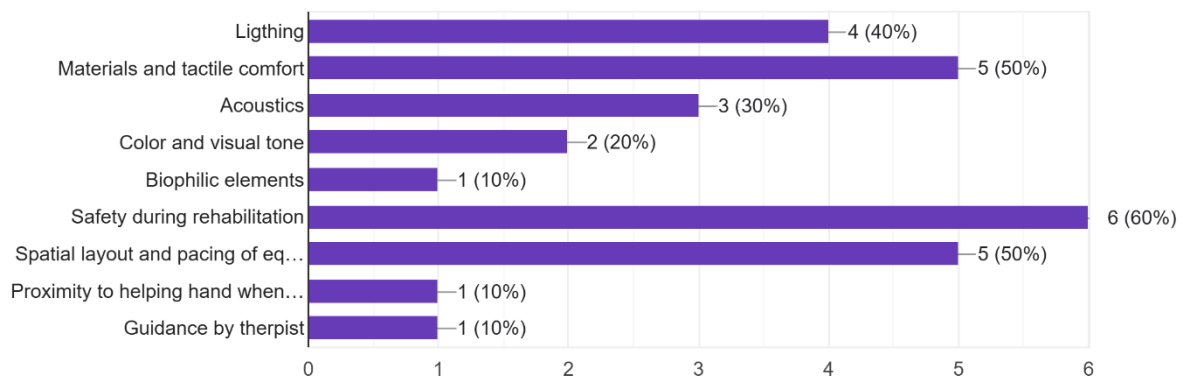
3. Which aspects of the environment influence you the most?

11 responses



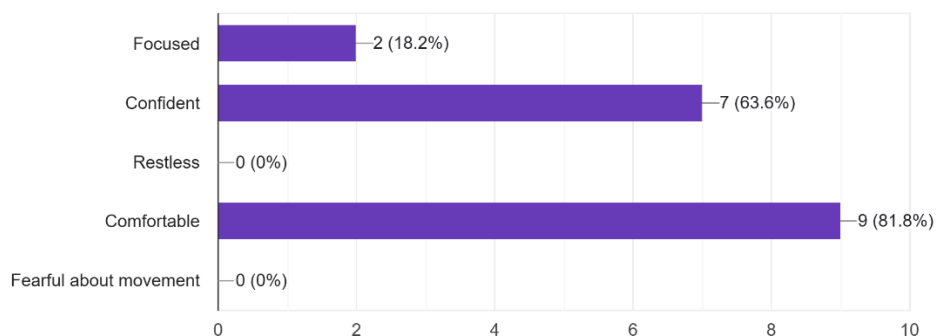
9. What features of the rehabilitation environment help you feel most calm, comfortable, or confident?

10 responses



4. Do you feel the environment influences how you behave during therapy sessions?

11 responses



Most participants reported that a supportive rehabilitation environment, characterized by a



pleasant atmosphere, encouraging therapists, and confidence-building cues, significantly enhanced their motivation and active participation.

Positive interpersonal feedback and environmental features (e.g., mirrors, hospital setting) reinforced self-efficacy, effort, and adherence during exercises.

Most respondents reported that a calm, comfortable environment, particularly appropriate temperature and room comfort, reduced fatigue and enhanced relaxation during and after therapy. Environmental factors such as cooling and spatial comfort supported easier breathing, faster recovery, and overall physical ease, with minimal reports of discomfort.

Participants reported that a pleasant, calm, and low-distraction environment significantly improved focus, alertness, and confidence during exercises. The supportive setting enhanced concentration, particularly for individuals with respiratory conditions, enabling safer and more attentive participation.

III. DISCUSSION:

The present study demonstrates that rehabilitation environments designed using Design Behaviour Codes (DBC) are associated with improved behavioural comfort, reduced perceived stress, and favourable physiological stabilization among cardiac rehabilitation participants. These findings are consistent with a growing body of international research showing that architectural environments directly influence emotional regulation, cognitive load, and behavioural engagement in healthcare settings. Compared with home environments, which often lack structure and supportive cues, and inpatient settings, which may feel restrictive or overstimulating, the outpatient rehab environment functioned as a behavioural scaffold.

The significantly higher CREBI scores observed in the outpatient DBC-led rehabilitation centre compared with inpatient and home settings align with evidence that spatial coherence, sensory regulation, and predictable movement pathways reduce stress and enhance user engagement. Ulrich's foundational healthcare design research demonstrated that supportive environments reduce anxiety and improve recovery outcomes in medical settings. Subsequent systematic reviews confirmed that evidence-based healthcare environments consistently improve patient satisfaction and reduce stress responses across hospital contexts (Ulrich et al., 2008; Centre for Health Design, 2010). Our

results extend this evidence specifically to cardiac rehabilitation adherence contexts.

The observed reduction in Perceived Stress Scale (PSS) scores following outpatient rehabilitation parallels findings that exposure to calming environments lowers physiological stress markers and enhances emotional recovery (Sternberg, 2009). Studies on nature exposure and biophilic environments show measurable reductions in rumination, stress, and sympathetic activation when natural elements are incorporated into built environments (Kaplan & Kaplan, 1989; Bratman et al., 2015). Similarly, Joye and van den Berg (2011) argue that human preference for natural stimuli may be evolutionarily embedded, supporting our participants' qualitative reports that greenery and daylight enhanced comfort and motivation.

Our findings on reduced cognitive load and improved emotional stability also align with dual-process theories of cognition. Kahneman (2011) and Evans & Stanovich (2013) demonstrate that environments rich in sensory overload promote impulsive, stress-driven decision processes(7,8). In contrast, structured and legible environments support reflective cognition and behavioural control(6,34,37). DBC-guided pacing, spatial predictability, and graded transitions may therefore sustain engagement of reflective cognitive systems, reducing anxiety and behavioural fatigue during rehabilitation.

Neuroarchitecture research further supports our findings. Recent neuroimaging studies indicate that curved and coherent spatial geometries evoke more positive emotional responses and reduce amygdala activation compared with harsh or chaotic spatial forms (Bar et al., 2021; Shemesh et al., 2022). Clark et al. (2022) similarly conclude that architectural stimuli influence mood, heart rate, and cognitive performance across diverse contexts(41,42). Such mechanisms may explain the stabilization of heart rate, blood pressure, and exertion measures observed in our participants.

Emerging evidence also links built environments to biological stress regulation(5,16,17). Abbas et al. (2024) and Zaino & Abbas (2020) demonstrate that perception of architectural environments can influence neural and hormonal responses related to stress(44,48). These findings reinforce our observation that patients reported improved emotional regulation and physiological stability within the DBC-designed rehabilitation space.

The behavioural engagement and social interaction improvements noted in our study align with environmental psychology research showing



that aesthetic coherence and sensory comfort foster social ease and psychological safety (Mehrabian & Russell, 1974)(3). Such behavioural outcomes are critical in outpatient programs reliant on voluntary adherence.

The present study supports international evidence that architecture functions not merely as a background setting but as an active behavioural and physiological regulator. By codifying behavioural evidence into measurable spatial standards, DBC-led environments provide a replicable framework capable of improving rehabilitation engagement and potentially enhancing long-term health outcomes.

LIMITATIONS:

The study is limited by a small sample size and reliance on self-reported perceptions. Future studies should incorporate larger samples, different systems, built areas, measurable objective physiological stress markers, and controlled comparisons across environments.

IV. CONCLUSION:

DBC-guided rehabilitation environments significantly improved patient behavioural comfort, reduced perceived stress, and supported physiological stabilization compared with inpatient and home settings. Patients reported motivation, social engagement, and adherence, demonstrating that evidence-based spatial design functions as a therapeutic intervention, strengthening rehabilitation outcomes and supporting integration of behaviour-oriented architectural standards in facilities(6,34,37).

IMPLICATIONS OF THE STUDY:

1. Healthcare Design Practice: Rehabilitation facilities should integrate Design Behaviour Codes (DBC) to create environments that actively support patient recovery and engagement(6,34,37).
2. Clinical Outcomes Improvement: Behaviour-supportive environments can function as non-pharmacological interventions, reduce stress, and improve adherence to rehabilitation programs(39,40).
3. Policy and Infrastructure Planning: Health systems and hospital planners should include behavioural design standards in future rehabilitation and healthcare infrastructure guidelines.
4. Interdisciplinary Collaboration: Stronger collaboration between architects, clinicians, and behavioural scientists is necessary to

develop evidence-based healing environments.

5. Future Research and Standardization: The study supports further large-scale research to standardize behavioural design frameworks and incorporate them into healthcare accreditation and facility design norms(7-12).

V. RECOMMENDATIONS:

1. Lighting: Provide well-distributed natural and soft artificial lighting to reduce stress and visual fatigue. Proper lighting improves emotional comfort and therapy participation(6,34,37,45).

2. Materials and Tactile Comfort: Use warm, tactilely comfortable materials to reduce clinical anxiety and enhance patient comfort. Avoid harsh, cold, and overly reflective finishes.

3. Acoustics: Control environmental noise to maintain calm, focus, and emotional stability during therapy. Reduce echoes and mechanical disturbances in rehabilitation spaces.

4. Colour and Visual Tone: Apply calming colour palettes and soothing visual tones to reduce irritability and stress. Avoid visually overwhelming or high-contrast colour schemes.

5. Foster Biophilic Integration: Incorporate natural elements and outdoor views to reduce perceived stress and improve emotional well-being. Provide access to restorative green environments where possible(35,36,16,17,53).

6. Safety: Ensure clear visibility, supportive movement aids, and unobstructed circulation to promote safe mobility. Environments should enhance both physical and psychological safety(18,19,50).

7. Design for Gradual Spatial Transitions: Provide intuitive layouts and graded movement pathways to reduce cognitive load and support rehabilitation pacing. Smooth transitions between therapy and rest areas sustain participation.

8. Develop Human-Centred Campus Design Policies: Institutions and Organizations should establish design standards that incorporate findings from environmental psychology and neuroarchitecture to promote well-being across all individuals' touchpoints.

9. Conduct Post-Occupancy Evaluations: Regular assessment of users' emotional and behavioural responses to architectural spaces can inform future upgrades and improve functional and psychological performance of built environments

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