Pediatric Inpatient Room Design: Insights from Studies using VR, Eye-Tracking and Biofeedback

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Collaborators
1

Acute Care Pediatric Patient Room Environments

Involving Children in Design Research
The Role of Design in Pediatric Healthcare Experience

- Pediatric healthcare facilities play a key role in creating supportive environments conducive to child development and recovery.

- The diverse nature of pediatric care requires careful consideration of unique developmental and healing needs.

- There is an ongoing need for interdisciplinary approaches that integrate child participation in the design process, aiming for environments that are responsive to the varied requirements of this demographic.
Motivation

- Child engagement in design preference studies is limited.
- Data on room layout impacts on patient experience is scarce.
- Design insights for distinct pediatric age groups are needed.
- Innovative methods (biosensors, eye tracking) to understand emotional responses are in initial stages.
- Participatory Design practices in healthcare are not widespread.
- Valid emotional response data from children in healthcare settings is lacking.

Ulrich's Theory of Supportive Design

Study Design

Study 1
- VR and Eye Tracking using Patient Room Photos
  - Study conducted between April - Sept 2023
  - n=44
  - 8-11 years = 11
  - 12-17 years = 12
  - Parents = 21

Study 2
- VR, Eye Tracking and EMG using fully immersive Patient Rooms
  - Study conducted between May- Sept 2023
  - n=28
  - 8-11 years = 8
  - 12-17 years = 8
  - Parents = 12

Presentation focus

Synthesis of Findings

Recommendations
STUDY 1
Comfort and Care Perceptions of Children and Parents using Photographic Stimuli of Patient Rooms in Virtual Reality with Eye-Tracking
Experiment Setup at XR Lab, UC Berkeley

A) Lab setup showing the participant on a swivel chair with desktop and VR equipment. B) View from the participant's perspective within the VR experience. C. Child participant during the experimental procedure.
Demographic Characteristics

Younger Child  
n=11  
8-11 YEARS

Older Child  
n=12  
12-17 YEARS

Parent  
n=22
Process: Typical session in VR

Headset Setup | Calibration | 'Start' First Set of Photos | Break | 'Start' Second Set of Photos | Exit Survey | Remove headset and 'Start' Interview | End
---|---|---|---|---|---|---|---
0 min | 2 min | 5 mins | 13 mins | 15 mins | 23 mins | 25 mins | 30 mins

Eye tracking calibration
Subjects interact with the initial set of 16 photos presented in a randomized order, with each photo displayed for 20 seconds. Following each photo, subjects offer feedback by rating the room's comfort, care, and preference using a 3-point Likert scale (Like, Neutral, Dislike).

Subjects decide whether they wish to continue on to the next set of photos or conclude the session.

Subjects interact with the next set of 16 photos presented in a randomized order, with each photo displayed for 20 seconds. Following each photo, subjects offer feedback by rating the room's comfort, care, and preference using a 3-point Likert scale (Like, Neutral, Dislike).

Subjects complete an exit survey focused on the VR experience, responding to three questions related to comfort, engagement, and overall experience.

Subjects engage in a qualitative phase involving semi-structured interviews. Providing feedback on room features, expressing what they liked, disliked, and any additional insights.
Photographic Stimuli: 32 Photographs
Workflow

46 Design Element Tags Generated from Literature Review

Two Researchers Independently Tag 32 Photographs with 46 Design Element Tags

Researchers Achieve 100% Consensus on Tags

8 Design Categories Identified to Organize the 46 Individual Design Tags from Literature

Unweighted Sum of Tagged Elements Calculated for Each Design Category

Ratings of Comfort, Care, and Likability for 32 Photographs by 44 Participants Using a 3-Point Likert Scale

K-Means Clustering of Photos

K-Means Clustering Results: C1 (High Ratings), C2 ( Moderate Ratings), C3 (Low Ratings)

Qualitative Feedback on features they liked and disliked

Gaze and Fixation Heatmaps

Eye-Tracking Data: Gaze and Fixation Duration

Thematic Analysis

Ranking Design Categories by Group

Linear Regression

Methodology/Process
Data/Measures
Statistical Analysis and Tests
Results/Findings
Outcome
Correlation

Mann-Whitney U Tests with Bonferroni Correction

Kruskal-Wallis Test

Spearman Correlations

Design Implications for Pediatric Patient Rooms: Age-Specific Preferences, Leveraging Visual Engagement Patterns, and Prioritizing Influential Design Features to Enhance Comfort, Care, and Preference

Group Differences: Perceived Comfort, Care, and Likability Ratings, Gaze and Fixation Duration, Relationship Between Likert Scale Ratings and Eye-Tracking Data

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Photo Tagging: Photographic Stimuli
Photo Tagging: Photographic Stimuli
Photo Clustering: K-means

- Cluster 1 (C1): High comfort, care, and likeability
- Cluster 2 (C2): Medium levels of comfort, care, and likeability
- Cluster 3 (C3): Lower levels of comfort, care, and likeability
Perception of Comfort, Care and Likeability Ratings

**Comfort Ratings**
- Younger: Median ≈ 0.442, IQR ≈ 0.396
- Older: Median ≈ 0.436, IQR ≈ 0.227
- Parents: Median ≈ 0.429, IQR ≈ 0.441
- Significant group differences (p = 0.0085).

**Care Ratings**
- Older: Median ≈ 0.680, IQR ≈ 0.188
- Younger: Median ≈ 0.636, IQR ≈ 0.298
- Parents: Median ≈ 0.631, IQR ≈ 0.250
- Consistent care expected by older children (p < 0.0001).

**Likeability Ratings**
- Younger: Median ≈ 0.455, IQR ≈ 0.298
- Older: Median ≈ 0.417, IQR ≈ 0.177
- Parents: Median ≈ 0.286, IQR ≈ 0.548
- Parents rate lower likeability (p < 0.00001).

Do Younger Children, Older Children, and Parents perceive comfort, care and likeability differently of pediatric patient rooms and room design elements?
Perceptions and Eye-Tracking Analysis

**Perception:**
- **Comfort:** Parents < Younger Children \((p = 0.0047)\).
- **Care:** Older Children > Parents & Younger \((p = 0.0005)\).
- **Likeability:** Parents & Older < Younger Children \((p < 1e^{-8})\).

**Eye-Tracking:**
- **Older Children:** Shorter gazes (quick assessment).
- **Parents:** Longer fixations (detailed evaluation).

**Correlations:**
- **Comfort vs. Likeability:** Strongly positive \((\rho = 0.809)\).
- **Comfort vs. Gaze Duration:** Inversely related \((\rho = -0.089)\).

What is the correlation between the perception ratings and eye-tracking among the demographics?
What design elements are most effective in providing positive distractions for pediatric patients, as measured by eye-tracking data in a VR environment?
Demographic Design Preferences

- **Younger Children**: 'View' and 'People'; less focus on 'Window Size.'
- **Older Children**: Value 'Personal Space' (e.g., 'Window Size'); less on 'Clinical Elements.'
- **Parents**: Value 'View' and 'Color'; 'Window Size' less critical.

**Common Trends**: 'Views' and 'Positive Distractions' valued across all.

**Subtle Differences**: 'People' and 'View' show nuanced perceptual variations ($p \approx 0.07$).

**Design Implications**: These insights underline the necessity for age-adapted room designs in pediatric healthcare settings.

How does the systematic categorization of pediatric patient room design elements through photo tagging inform our understanding of design preferences among the demographics?
Study 1: Key Takeaways

Age-Specific Design:
- Younger Children: Interactive elements cater to developmental exploration needs.
- Older Children: Autonomy and privacy features reflect maturity and spatial awareness.
- Parents: Calm, engaging elements with family-inclusive design enhance emotional well-being.

Visual & Social Elements: Artwork and communal spaces transform patient experience, functional balance is important.

Methodological Advances: VR and eye-tracking reveal distinct cognitive engagement patterns across age groups.

Design Strategy Recommendations:
- Incorporate flexibility for control and exploration.
- Enhance social spaces for family support and patient autonomy.
- Use positive distractions and personalized items for comfort.
- Apply color and visual strategies for therapeutic environments.
STUDY 2
Exploring Pediatric Inpatient Room Design: A Neuroarchitecture and Affect Study with VR and Biofeedback
Experiment Setup at XR Lab, UC Berkeley
Process: Typical session in VR

- Headset Setup and Calibration: 0 min, 2 mins
- VR Practice Room: 8 mins
- VR Experience: 10 mins
- Randomize Inboard/Outboard Layout
- Randomize Order of 6 Rooms: 21 mins
- VR Superroom Experience: 23 mins
- Interview: 28 mins
- Break: 58 mins
- Second Layout Session Start: 60 mins
- Qualitative data collection: interview subjects for their preferred layout

Eye tracking and fEMG calibration: 20 mins for the second layout
Explore 6 room design alternatives in a randomized order
Explore the Super Room with all design features
 qualitative data collection: interview subjects for their feedback on rooms
10-min break
Demographic Characteristics

- Younger Child (8)
  8-11 YEARS
  n=8

- Older Child (8)
  12-17 YEARS
  n=8

- Parent (12)
  n=12

Total: n=28
Applying Ulrich’s Supportive Design Theory

Positive Distractions

Window Size
- Small Window
- Large Window
- Panoramic Window
- Art

Wall & Ceiling Art

Privacy & Safety

Corridor wall
- Nurse View Window
- Open Corridor

Furniture
- Social Support
- Super Room

Social Support
Outboard Layout

Family Zone: 6.67 m²
Patient Zone: 12.29 m²
Staff Zone: 8.70 m²
Total ~27.5m²

Inboard Layout

Family Zone: 8.57 m²
Patient Zone: 8.93 m²
Staff Zone: 8.52 m²
Total ~26m²

Credit: Shepley Bulfinch Architects, Boston for room layouts and 3D models
Outboard Layout: Ulrich's Theory in Application
Inboard Layout: Ulrich's Theory in Application
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Comparison of Layout preferences between Groups

Do layout preferences (inboard vs. outboard) differ significantly among Younger Children, Older Children, and Parents?

- Numerically, more participants preferred the Inboard over the Outboard layout across all groups.
- Statistical tests were not significant due to small sample size.
- Observed trend could inform practical design considerations.
- We explored this further in the room-level analysis.
How do preferences for specific room design features vary within the Outboard layouts?

*This was indicated by subjects during verbal interviews using scores from 0 (least preferred) to 5 (most preferred)

Significant variance in 'Panoramic Window' (Outboard) preferences (Kruskal-Wallis).
Inboard Layout Rooms Ranking

How do preferences for specific room design features vary within the Inboard layouts?

*This was indicated by subjects during verbal interviews using scores from 0 (least preferred) to 5 (most preferred)

High Ranking
- Younger Children
  - Panoramic Window
  - Social Support
  - Art

- Older Children
  - Panoramic Window
  - Social Support
  - Large Window

- Parents
  - Panoramic Window
  - Social Support
  - Art

Low Ranking
- Small Window
- Nurse Window

Significant variance in 'Panoramic Window' (Outboard) preferences (Kruskal-Wallis).
Rooms with Significant Differences between Groups

Outboard Layout

- **Panoramic Window** room stood out, being the favorite across different groups (significant at $p = 0.0109$)

- **Art** was nearly significant ($p = 0.0624$), hinting at potential differences that require further exploration.

Inboard Layout

- **Art** significantly affected preferences ($p = 0.0152$)

- **Large Window** also showed a statistically significant difference ($p = 0.0364$), signaling the value of natural light and views.
Gaze and Fixation Metrics of ‘Objects of Interest’ by Group

- 'Wall Art' and 'Wood' capture attention across all ages, underscoring their importance in pediatric spaces.

- **Younger children** fixate on 'Wall Art' and 'Bright Colors'.

- **Older Children and Parents** on 'Ceiling Art' and 'Windows', indicating an interest in aesthetics and the external environment.

- **Parents** uniquely focus on practical features like 'Furniture' (p = 0.039), showing a concern for comfort and practicality.
Electromyography (EMG) Sensors

- In positive events we expect to see higher **zygomaticus** activation

- In negative events we expect to see higher **corrugator** and **frontalis** activation

- Lower **heart rate** is expected in the events that are less stressful

*An event presented here is the experience of a room

What are the patterns that emerge from physiological data in response to different room designs among Younger Children, Older Children, and Parents?
Physiological Sensor Data by Room, Group and Layout

Outboard Layout
- Art room uniformly positive response
- Glass Corridor had diverse reactions
- Small Window had negative emotions

Inboard Layout
- Art room had strong positive response particularly from parents
- Smaller Windows had noticeable negative response from Older Child

"Small window did not feel comfortable."
“The larger the windows the better”

“I really liked the room with the Nurse View Window as I feel cared for and that I am not shut out from what is happening outside the room”
– Older Child Subject
How do design elements within outboard and inboard layouts affect emotional responses (arousal and valence) across different demographic groups?
Arousal and Valence plots - Outboard layout
Arousal and Valence plots - Inboard layout
Study 2: Key Takeaways

Supportive Design: Inboard layout preferred across demographics, reinforcing Ulrich’s supportive design principles. Larger windows and communal areas enhance therapeutic effects by promoting safety, accessibility, and comfort.

Developmental Design Preferences:
- **Younger Children:** Drawn to vibrant artwork and interactive features, highlighting the need for sensory-rich environments.
- **Older Children:** Favor spaces for social interaction and personal space, reflecting their evolving autonomy.
- **Parents:** Focus on expansive windows and natural views to create calming, stress-reducing environments.

Integrative Design Insights:
- **Holistic Approach:** Advocates for designs that blend supportive design with neuroarchitecture to cater to psychological, emotional, and developmental well-being.
- **Adaptive Strategies:** Emphasizes the need for flexible and customizable environments that can adapt to diverse needs and preferences of pediatric healthcare users.

Photo Credit: https://www.onceuponaroom.org/houston
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Haripriya Sathyanarayan, PhD candidate, UC Berkeley

Design Implications
Summary of Findings

A.

B.

Positive
- Toy
- Wall Pattern
- Couch Pattern
- Curtain Pattern
- Wall Art
- Green View
- Cushions
- Couch

Negative
- Patient Chair
- Color
- Adult
- Child
- Monitoring System
- Headwall System
- Sink

Positive
- Couch
- Extra Chair
- Extra Table
- Privacy Curtain
- TV
- Plant
- Urban View

Negative
- Adult
- Child
- Monitoring System
- Headwall System
- Wall Art
- Toy
- Couch Pattern
- Color
Summary of Findings

Flexible Design: Adapt rooms to accommodate diverse needs.

Privacy Balance: Maintain privacy while ensuring necessary visibility in room layouts.

Harmonious Design: Integrate patient feedback to enhance room design cohesion.

Multifunctional Spaces: Equip rooms with versatile elements to serve various functions.

Personalization: Facilitate customization options to increase patient comfort.

Parent Well-being: Incorporate relaxing features in outboard layouts to support parents.
Limitations and Future Work

**Sample Size Constraints:** Limited sample size may restrict the generalizability of findings.

**Recruitment Challenges:** Couldn’t recruit younger children (<8 years) due to headsets fit challenges.

**Missing Staff Perspectives:** Exclusion of staff viewpoints could result in an incomplete understanding of design impacts.

**Sensory Focus:** Emphasis primarily on visual elements; neglects other sensory and dynamic factors like sound, smell, and movement.

**Patient-Staff Interaction Data:** Lack of data on how room design influences patient-staff interactions.

**Next Steps:** Collaborating with UCSF Benioff Children’s Hospital on the design of their new inpatient tower block

**Publications**
- Study 1: Paper ready for submission
- Study 2: Paper under peer review
Younger Child (8-11 years)

- Like: Interactive elements, such as toys, presence of comforting objects like blankets, and being in brightly colored spaces, and views of nature.
- Dislike: Cluttered environments, visible medical equipment, and views of buildings, which made them feel uncomfortable.
- Implication: Design should foster playful exploration and sensory stimulation, with environments that balance fun and functionality with child-friendly aesthetics.

Older Child (12-17 years)

- Like: Having their own personal space with privacy features that respect their growing independence, and mature aesthetics.
- Dislike: Being in spaces that feel too institutional or where privacy is compromised by design, and overly simplistic themes.
- Implication: Room setups should offer a balance between privacy and sociability, featuring adaptable elements that allow for personalization and self-expression.

Parent

- Like: Homely environments with concealed medical equipment that can support the emotional and psychological well-being of their children.
- Dislike: Sterile environments, clinical views, as well as spaces that lack personal touches or feel cluttered.
- Implication: Design should prioritize functional yet comforting spaces, that enable parents to be active participants in the care process, with cozy elements that promote a sense of normalcy and social support.
Thank you!

Contact

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