



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

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**The Wallace Center**  
for maternal, child & adolescent health

**2021-2022 Helen Wallace  
Dissertation Award**

The Wallace Center in Maternal, Child, and Adolescent Health (MCAH) funded data collection and dissemination of this research

The Roselyn Lindheim Award in Environmental Design and Public Health funded data collection of this research

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**2021 Griffin/McKahan/Zilm (GMZ) Graduate  
Fellowship in Health Facility Planning &  
Design recipient**

AIA-AAH funded data analysis and dissemination of this research

# Collaborators



SHEPLEY  
BULFINCH



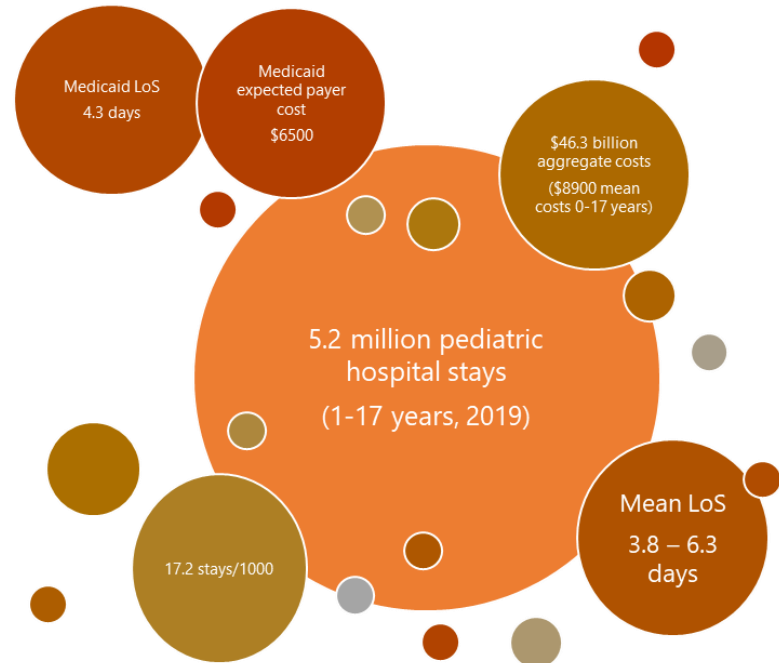
# Acute Care Pediatric Patient Room Environments

## Involving Children in Design Research



# The Role of Design in Pediatric Healthcare Experience

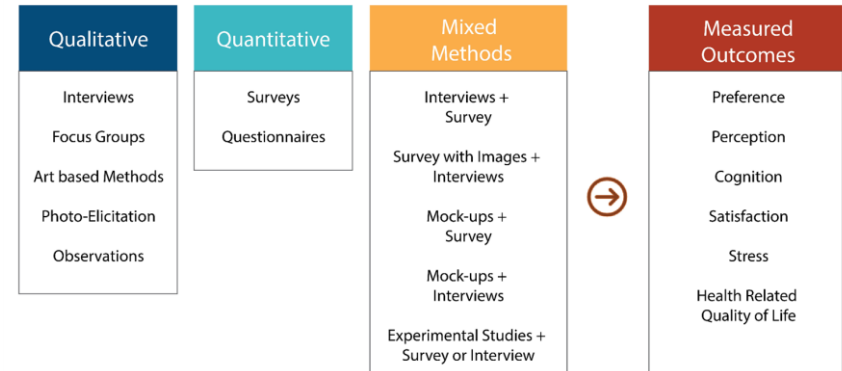
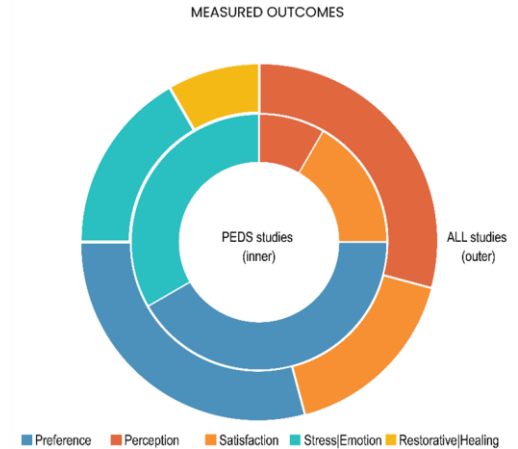
- Pediatric healthcare facilities play a key role in creating **supportive environments** conducive to child development and recovery.
- The diverse nature of pediatric care requires careful consideration of **unique developmental and healing needs**.
- There is an ongoing need for **interdisciplinary approaches that integrate child participation in the design process**, aiming for **environments that are responsive to the varied requirements** of this demographic.



KID Database HCUP AHRQ 2019

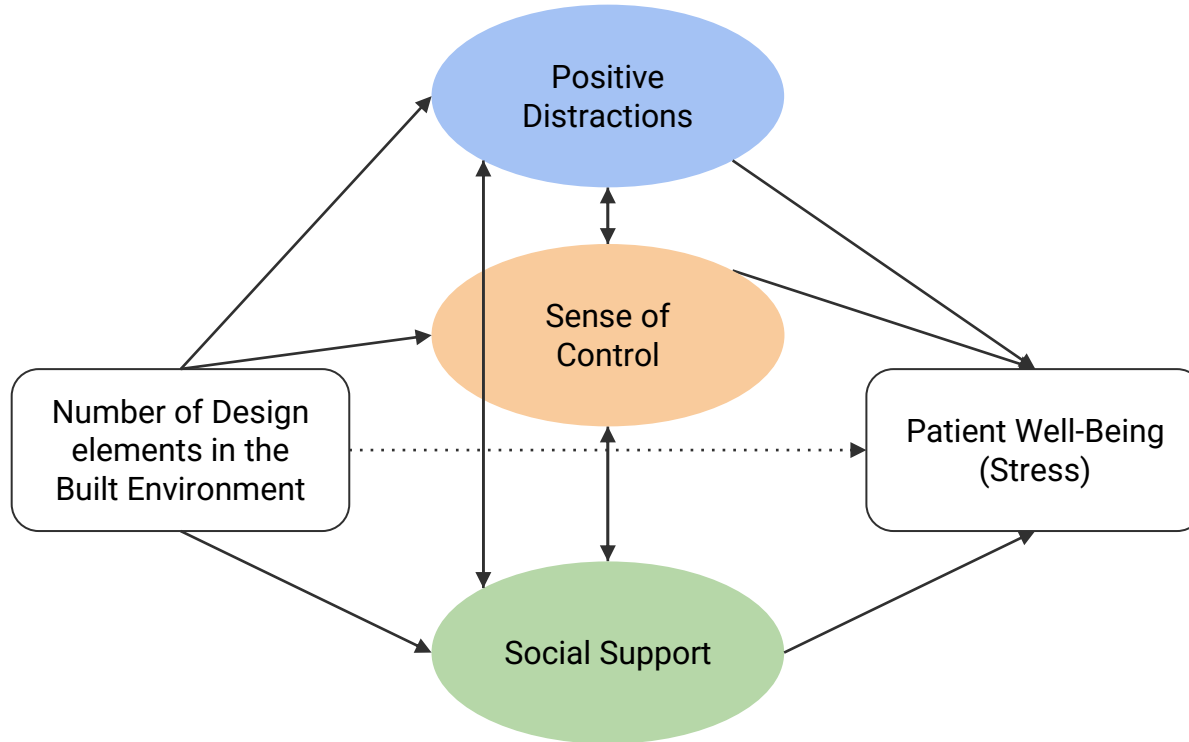
# Motivation

- 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.



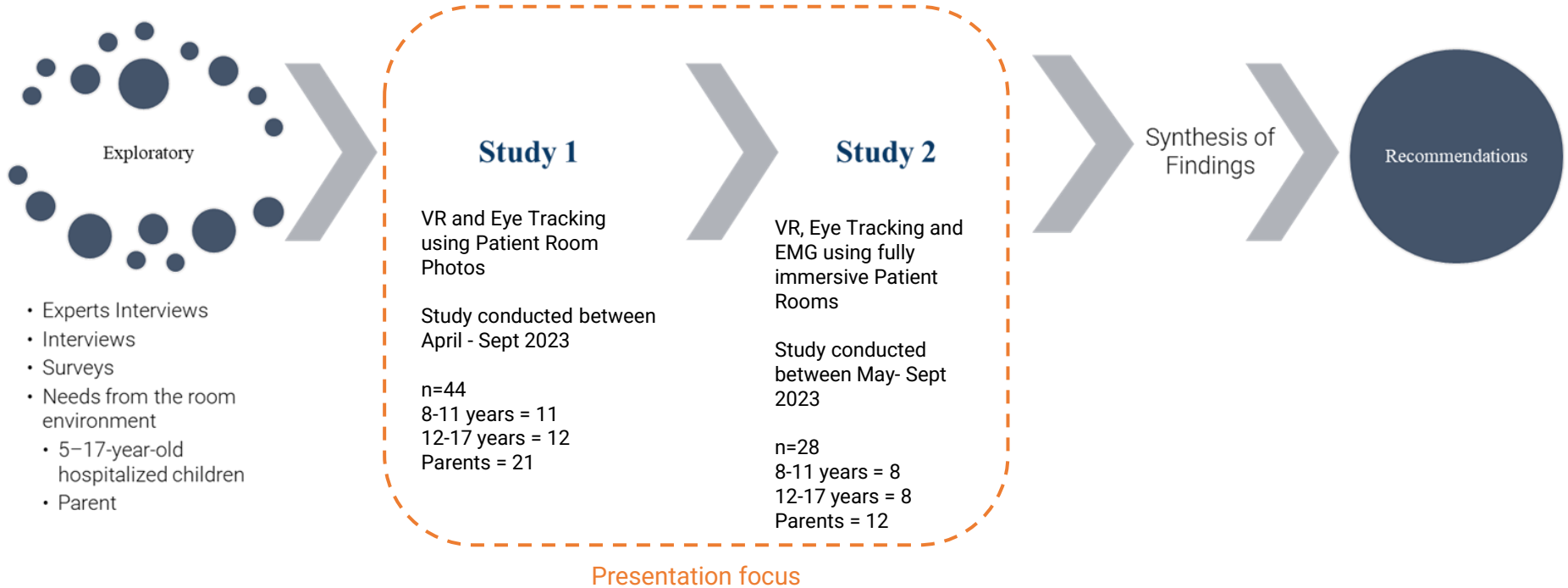
Sathyanarayanan, H., & Caldas, L. (2022). Co-designing with children: Innovating patient engagement and participation in pediatric healthcare design research with immersive technology and affective interaction. *Academy of Architecture for Health Knowledge Community*, 24, 30–47.

# Ulrich's Theory of Supportive Design



Ulrich, R. S. (1991). Effects of interior design on wellness: Theory and recent scientific research. *Journal of Healthcare Interior Design*, 3(1), 97–109.

# Study Design



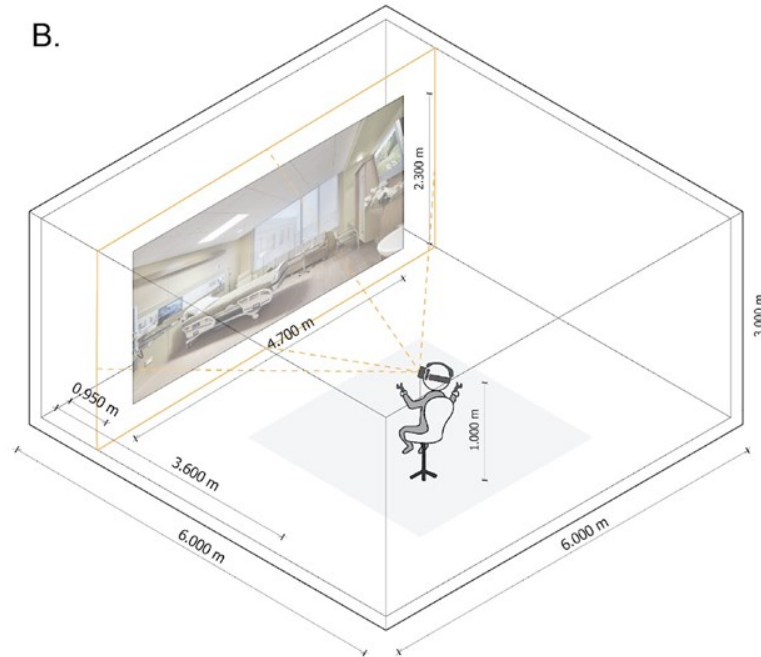
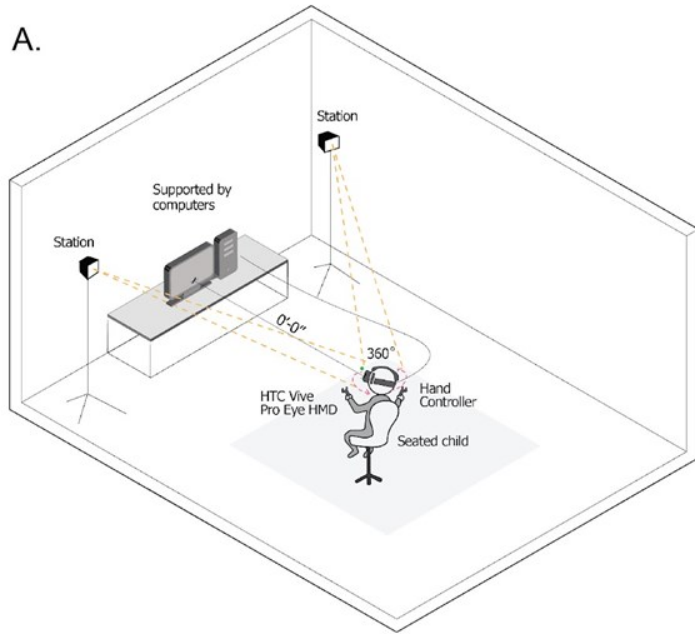


# 2

## **STUDY 1**

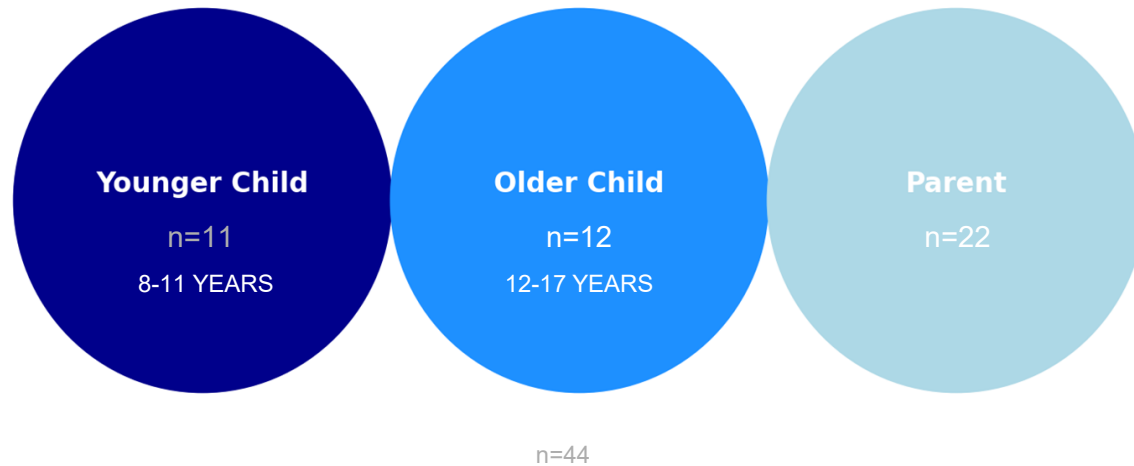
### **Comfort and Care Perceptions of Children and Parents using Photographic Stimuli of Patient Rooms in Virtual Reality with Eye- Tracking**

# Experiment Setup at XR Lab, UC Berkeley

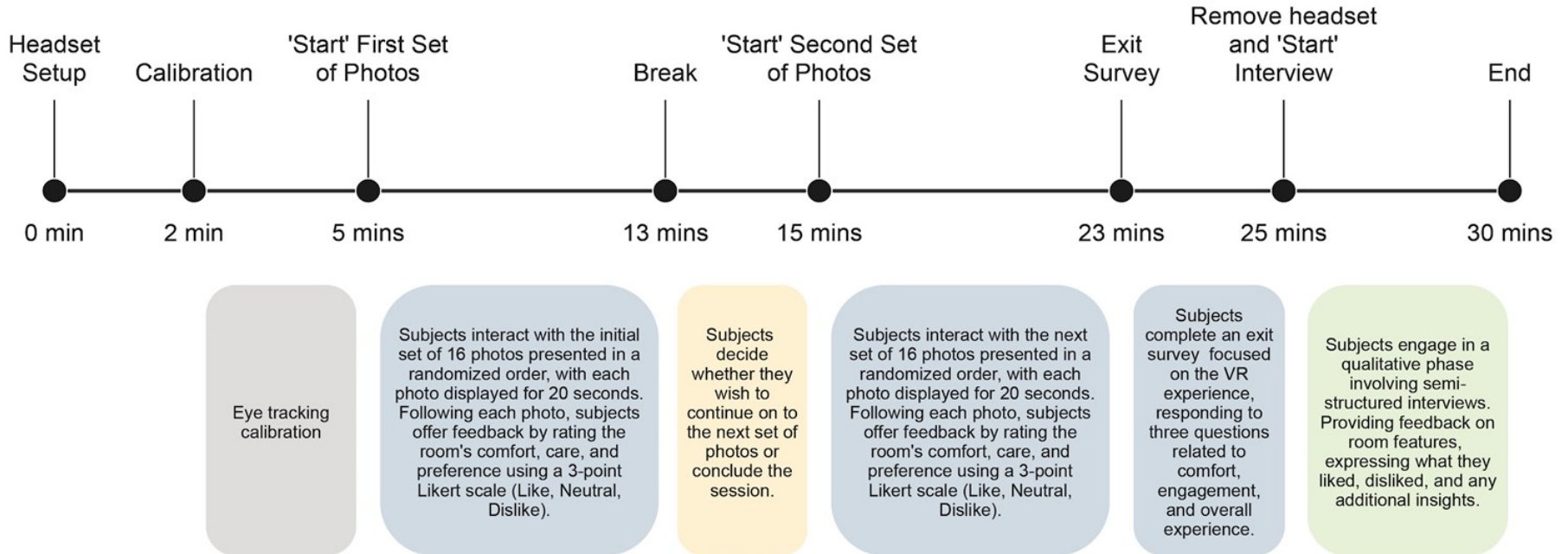


A) Lab setup showing the participant on a swivel chair with desktop and VR equipment. B) View from the participant's perspective within the VR experience. C. Child participant during the experimental procedure.

# Demographic Characteristics



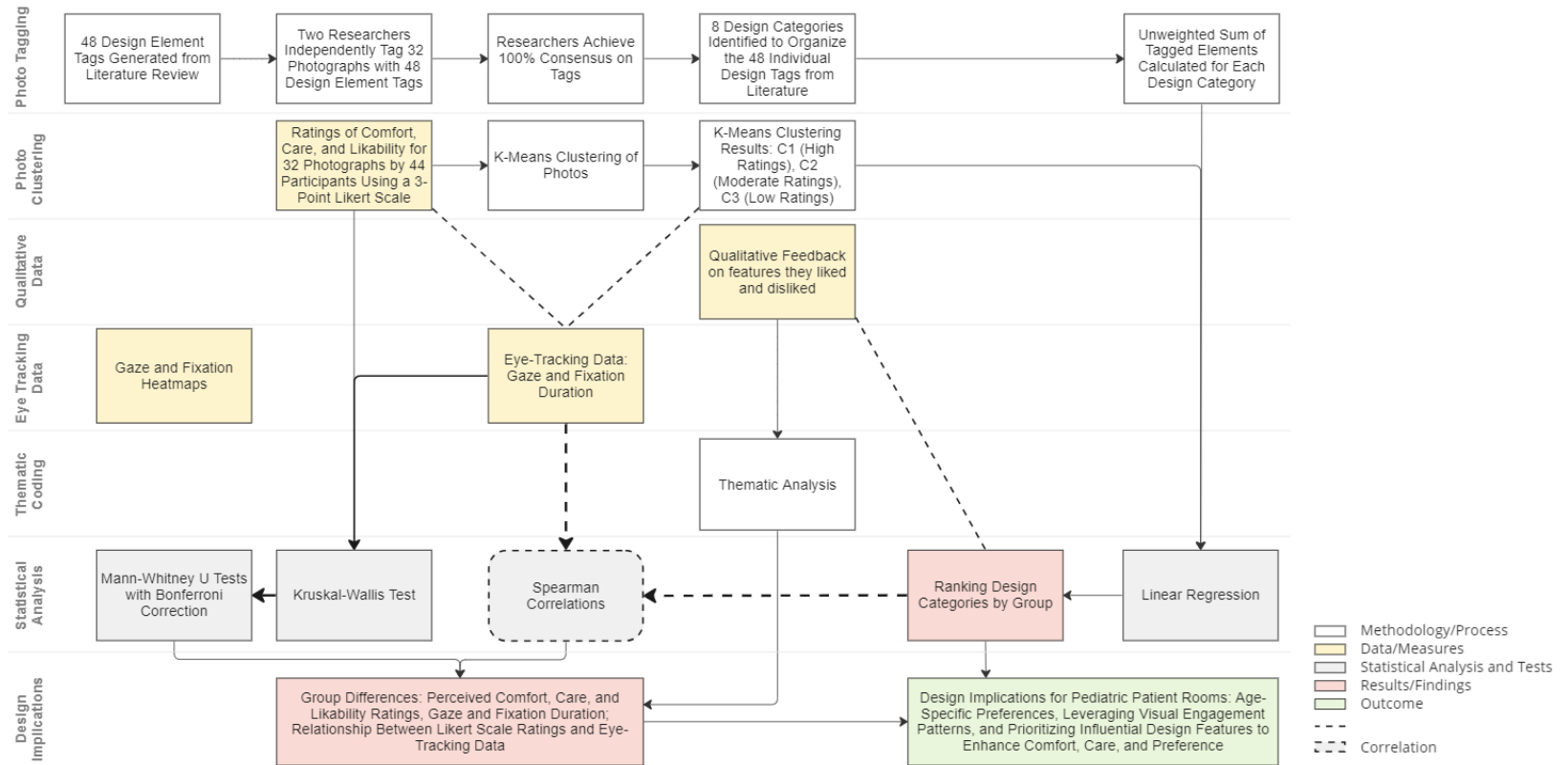
# Process: Typical session in VR



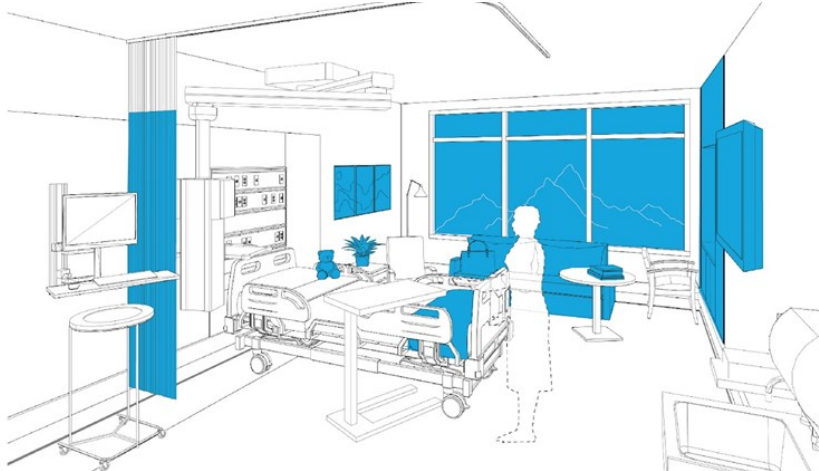
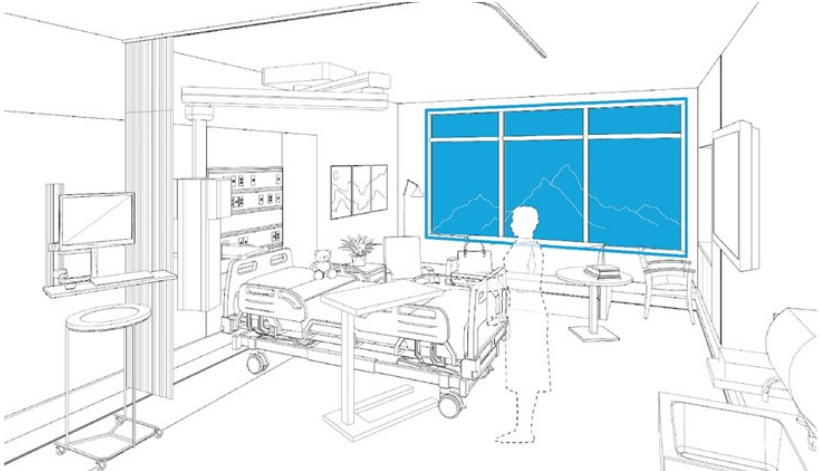
# Photographic Stimuli: 32 Photographs



# Workflow



# Photo Tagging: Photographic Stimuli



WINDOW SIZE



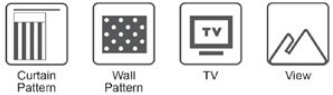
VIEW



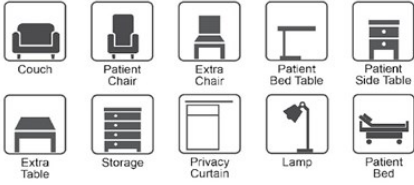
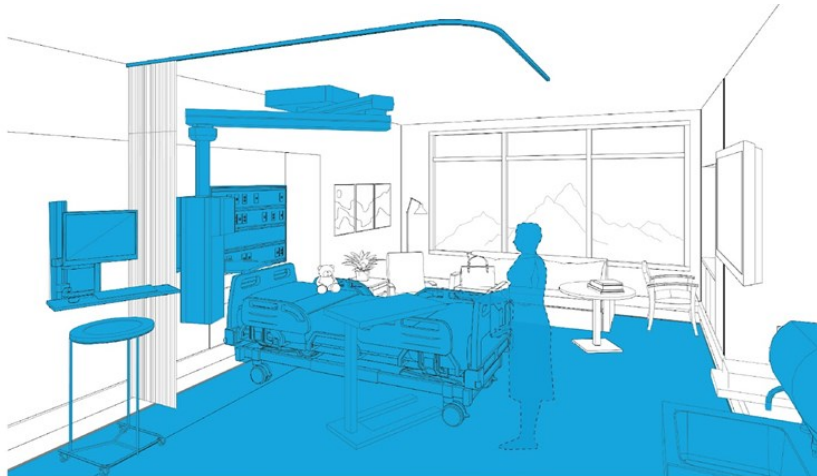
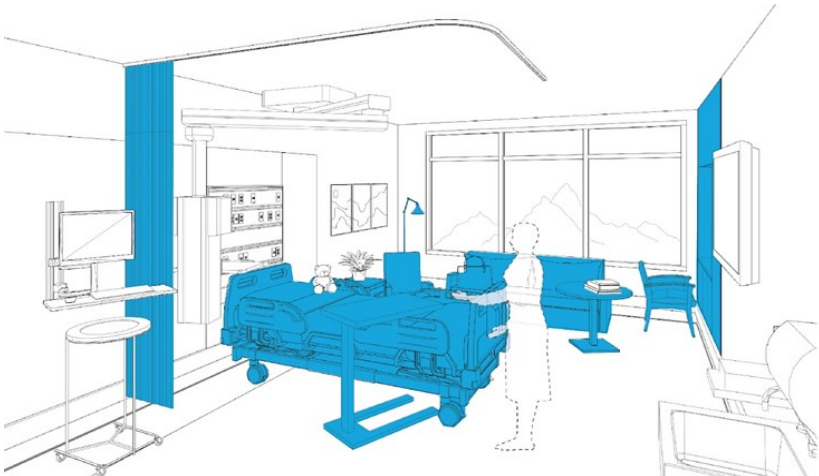
POSITIVE DISTRACTION



ACCOUTERMENTS



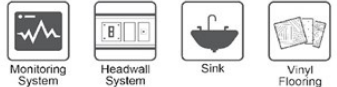
# Photo Tagging: Photographic Stimuli



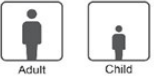
FURNITURE



COLOR



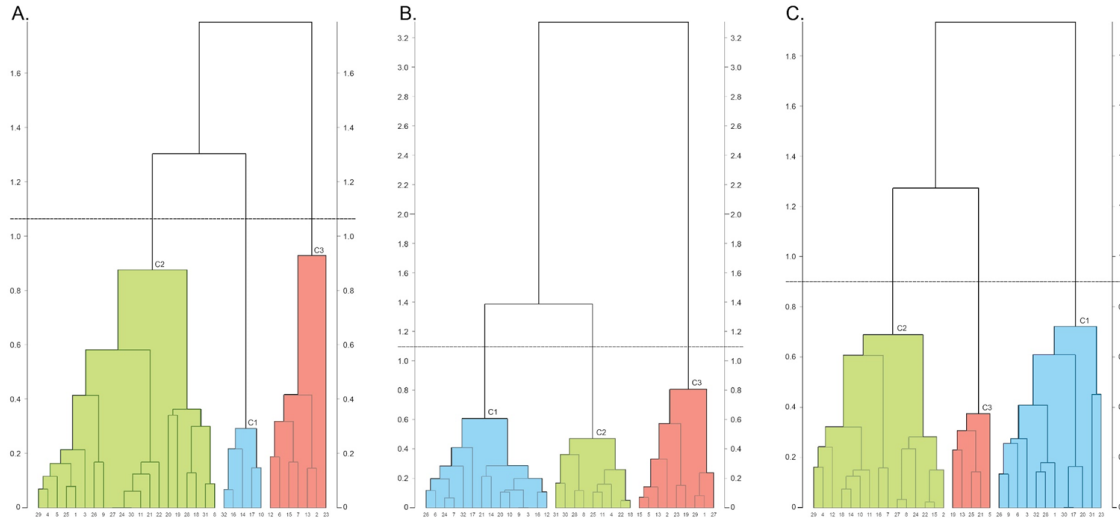
CLINICAL



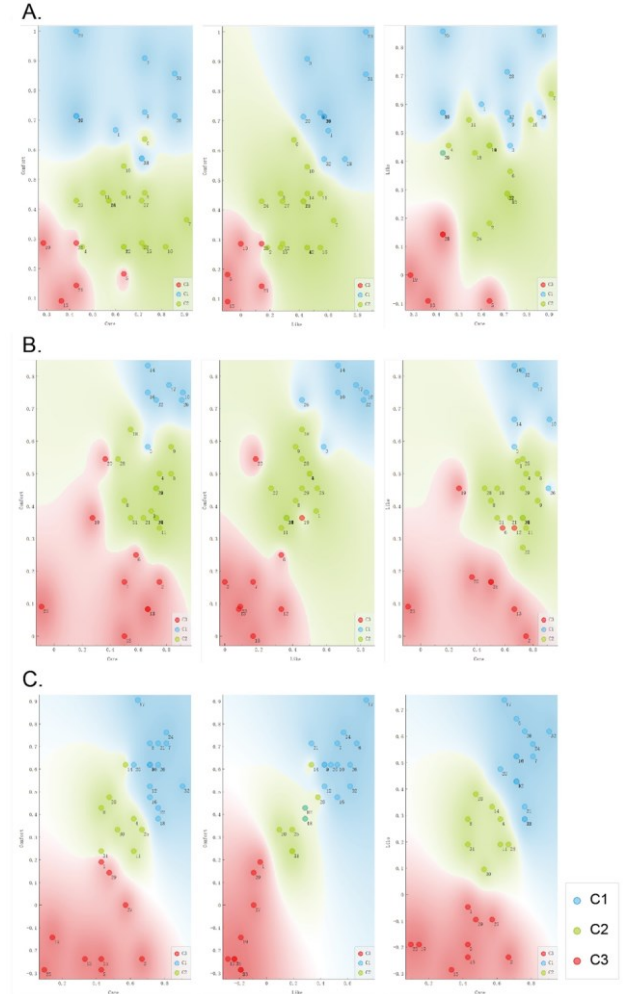
PEOPLE



# 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

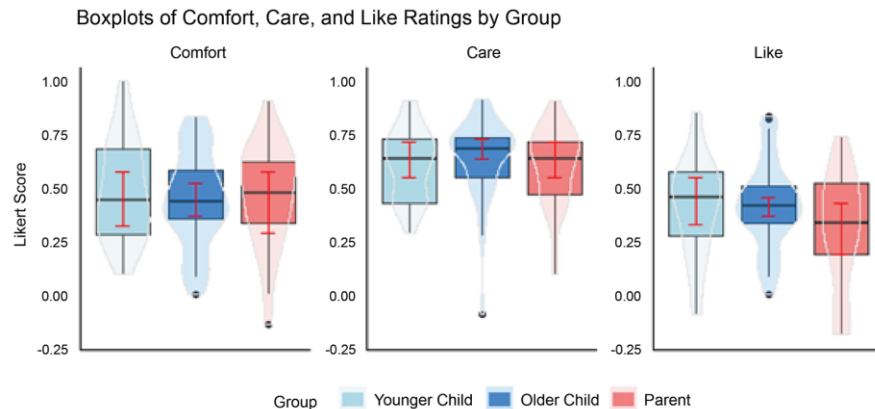
- Younger: Median  $\approx 0.442$ , IQR  $\approx 0.396$
- Older: Median  $\approx 0.436$ , IQR  $\approx 0.227$
- Parents: Median  $\approx 0.429$ , IQR  $\approx 0.441$
- Significant group differences ( $p = 0.0085$ ).

## Care Ratings

- Older: Median  $\approx 0.680$ , IQR  $\approx 0.188$
- Younger: Median  $\approx 0.636$ , IQR  $\approx 0.298$
- Parents: Median  $\approx 0.631$ , IQR  $\approx 0.250$
- Consistent care expected by older children ( $p < 0.0001$ ).

## Likeability Ratings

- Younger: Median  $\approx 0.455$ , IQR  $\approx 0.298$
- Older: Median  $\approx 0.417$ , IQR  $\approx 0.177$
- Parents: Median  $\approx 0.286$ , IQR  $\approx 0.548$
- 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:

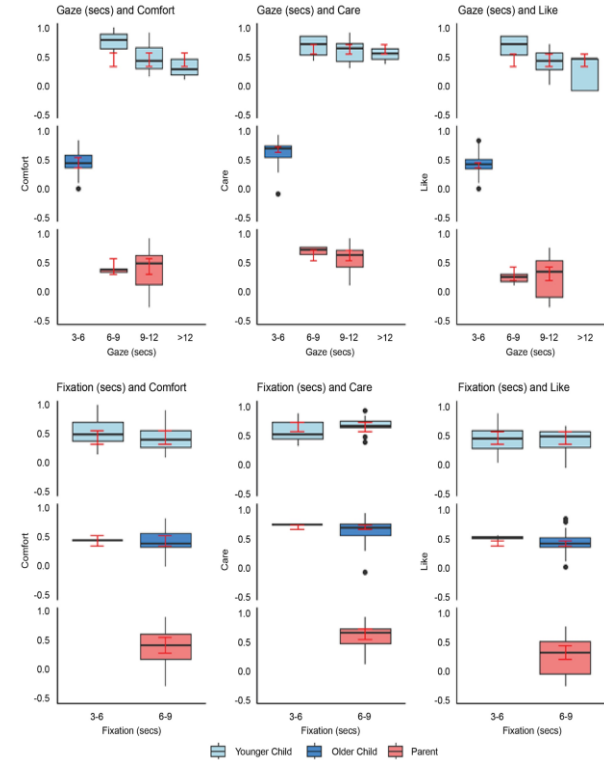
- **Comfort:** Parents < Younger Children ( $p = 0.0047$ ).
- **Care:** Older Children > Parents & Younger ( $p = 0.0005$ ).
- **Likeability:** Parents & Older < Younger Children ( $p < 1e-8$ ).

## 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?

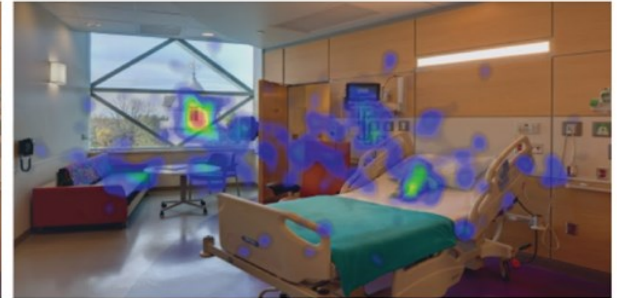
# Eye-Tracking Heatmaps



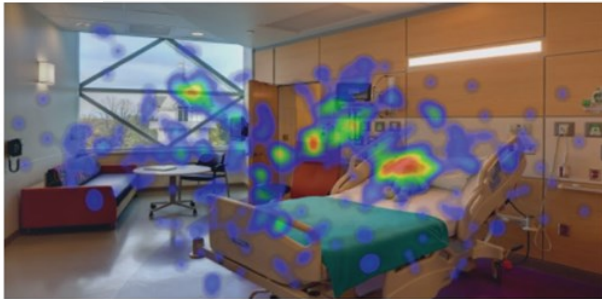
**Gaze:** Younger Child



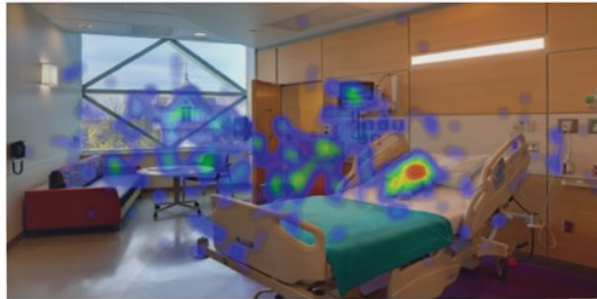
Older Child



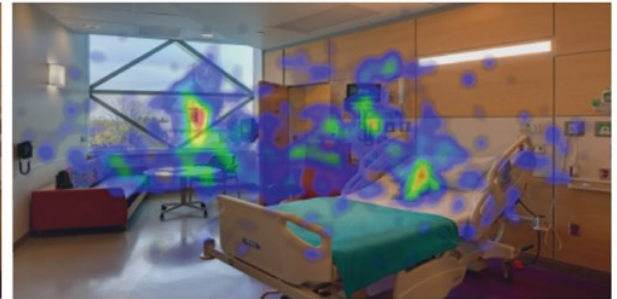
Parents



**Fixation:** Younger Child



Older Child



Parents

**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.



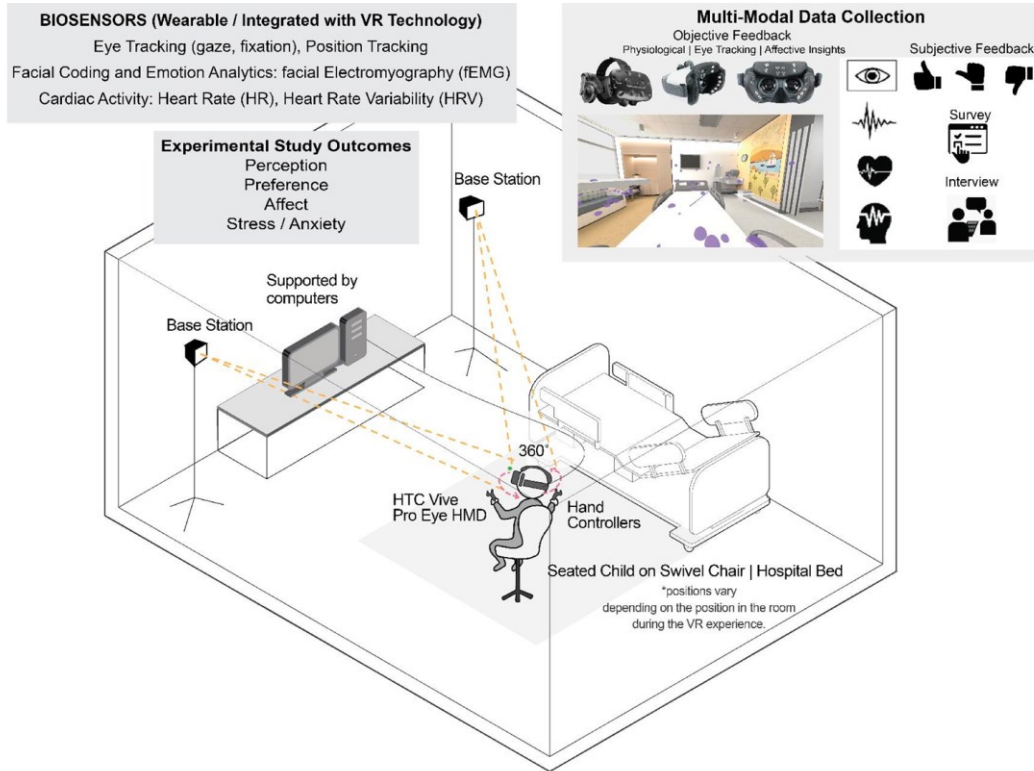
Photo Credit: <https://cdmlight.com/index.php/portfolio-item/university-of-iowa-childrens-hospital/>

# 3

## **STUDY 2**

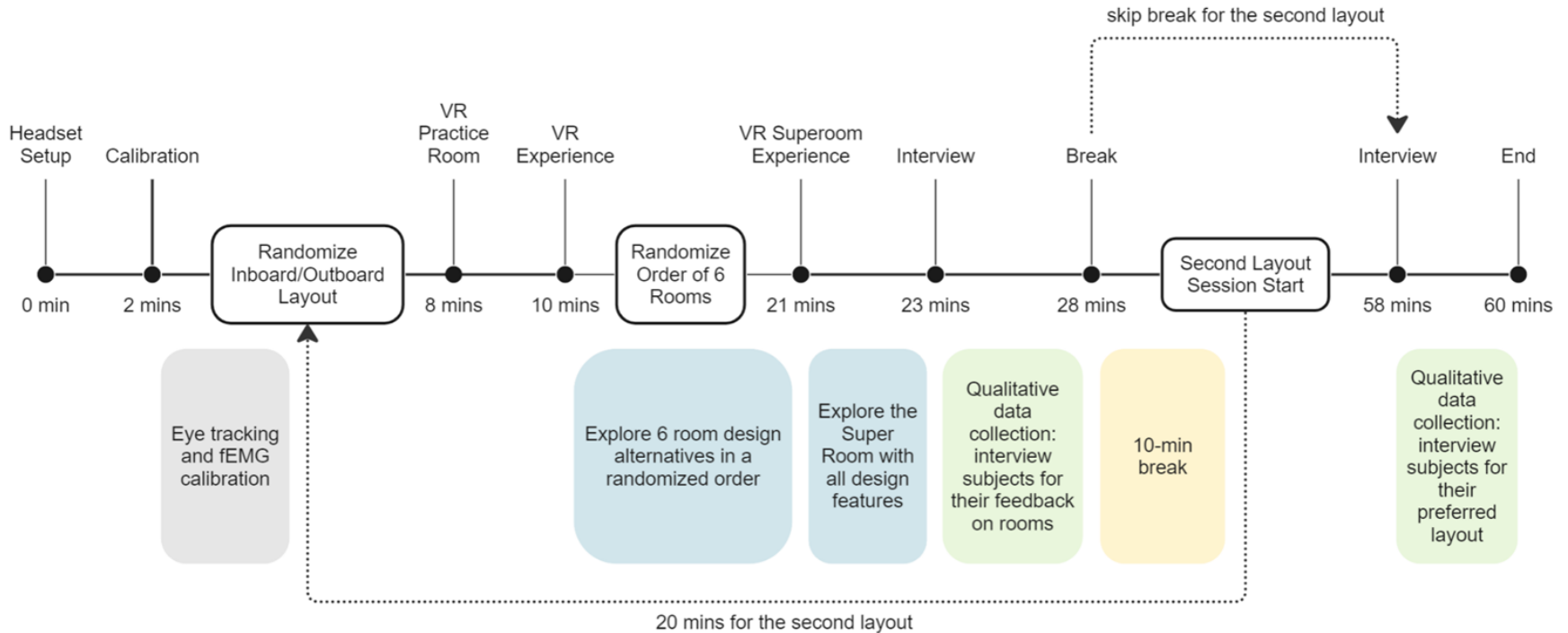
### **Exploring Pediatric Inpatient Room Design: A Neuroarchitecture and Affect Study with VR and Biofeedback**

# Experiment Setup at XR Lab, UC Berkeley

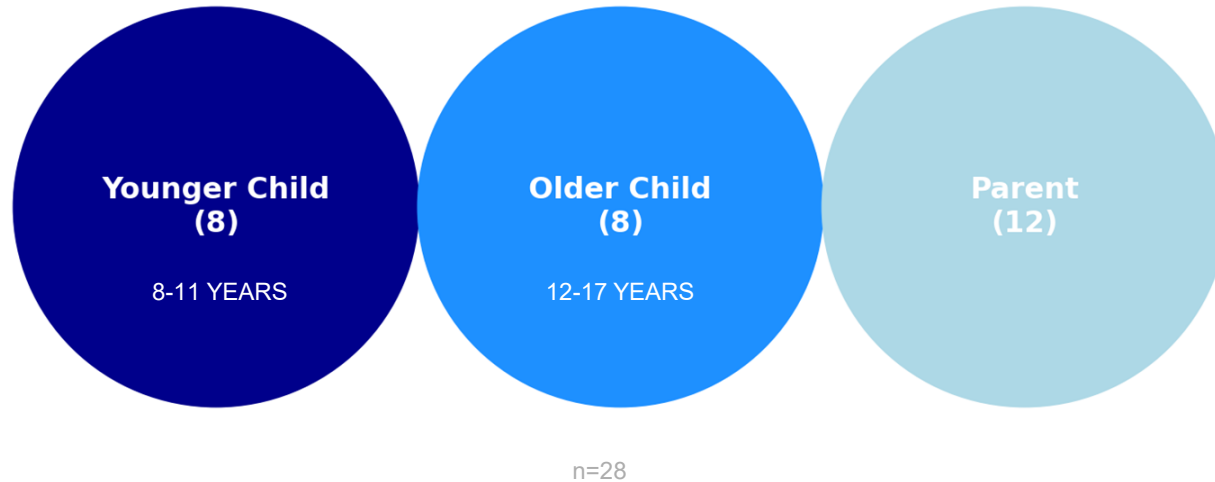




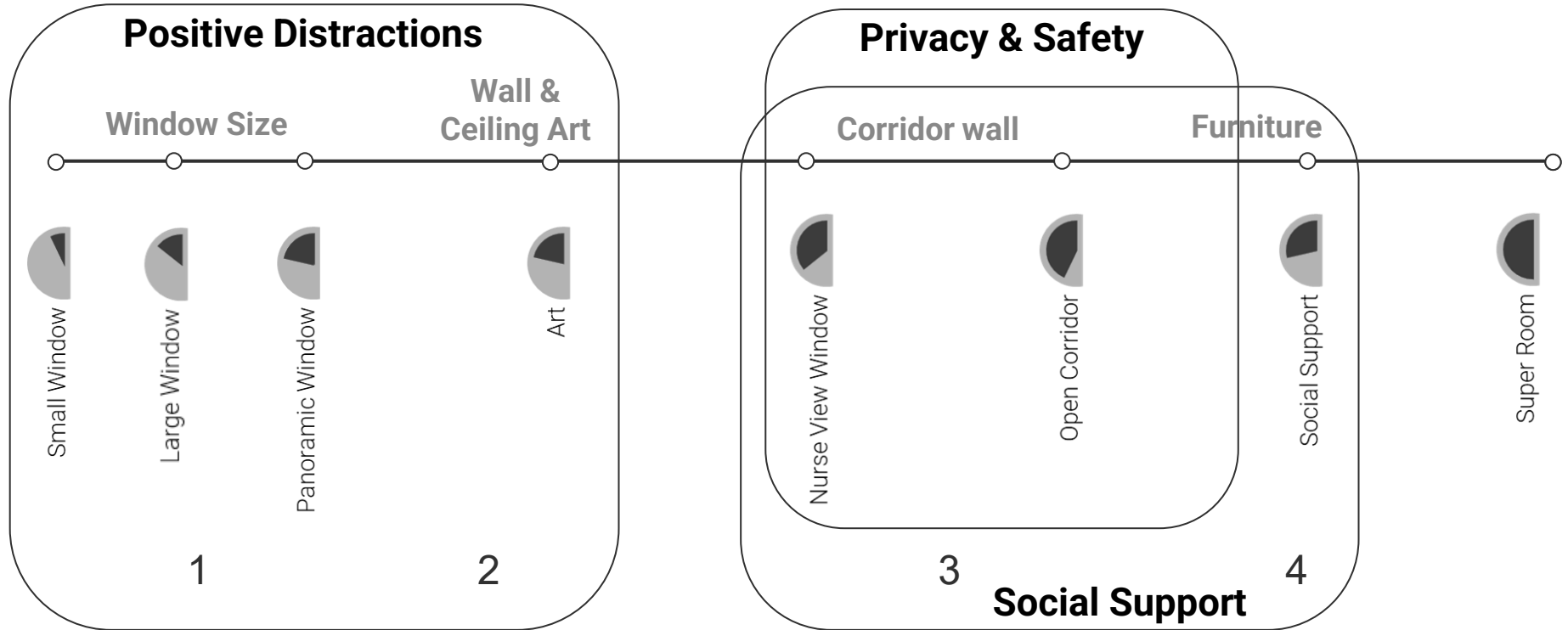
# Process: Typical session in VR



# Demographic Characteristics



# Applying Ulrich's Supportive Design Theory



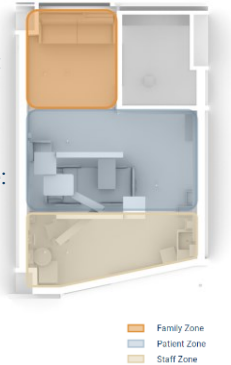
# Outboard Layout

Family Zone:  
6.67 m<sup>2</sup>

Patient Zone:  
12.29 m<sup>2</sup>

Staff Zone:  
8.70 m<sup>2</sup>

Total  
~27.5m<sup>2</sup>



# Inboard Layout

Family Zone:  
8.57 m<sup>2</sup>

Patient Zone  
8.93 m<sup>2</sup>

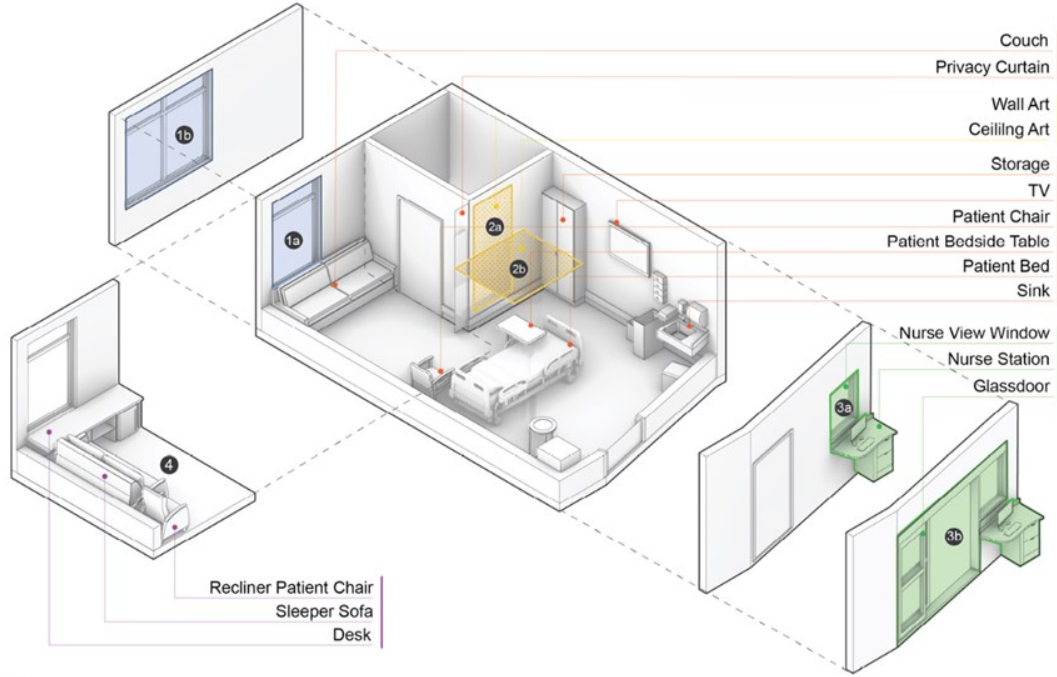
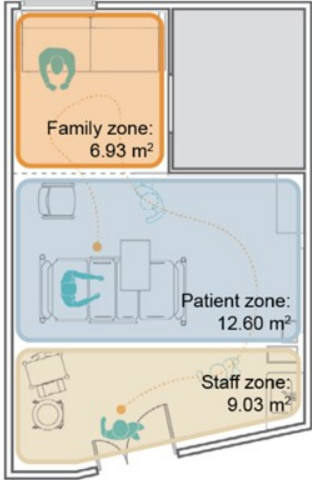
Staff Zone:  
8.52 m<sup>2</sup>

Total ~26m<sup>2</sup>

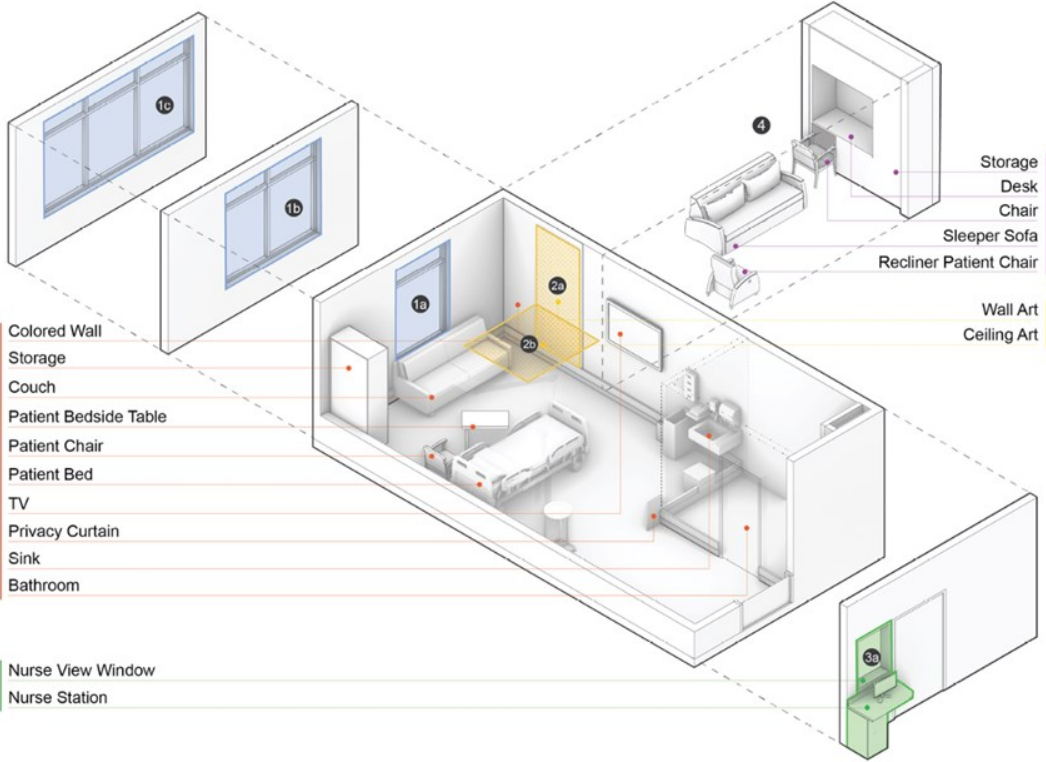
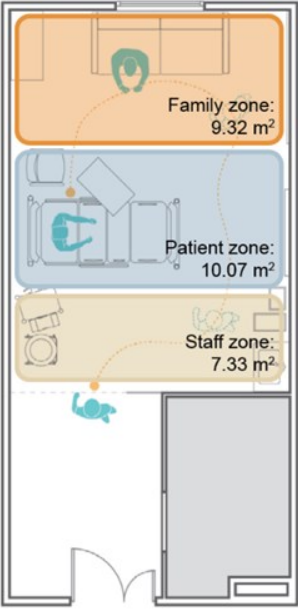


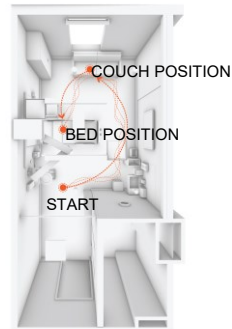
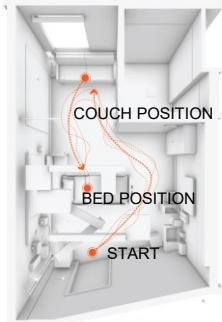
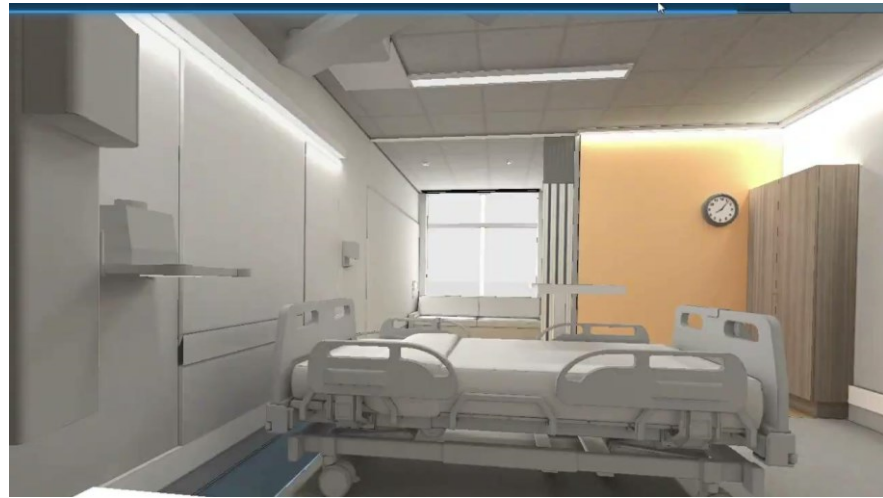
Credit:Shepley Bulfinch Architects, Boston for room layouts and 3D models

# Outboard Layout: Ulrich's Theory in Application

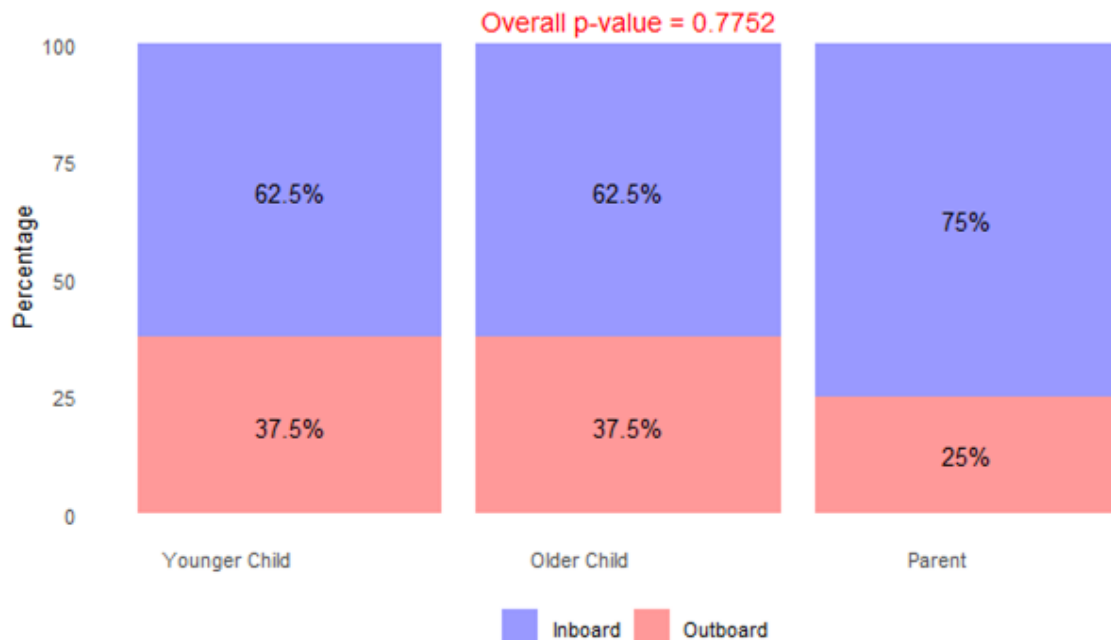


# Inboard Layout: Ulrich's Theory in Application





# Comparison of Layout preferences between Groups

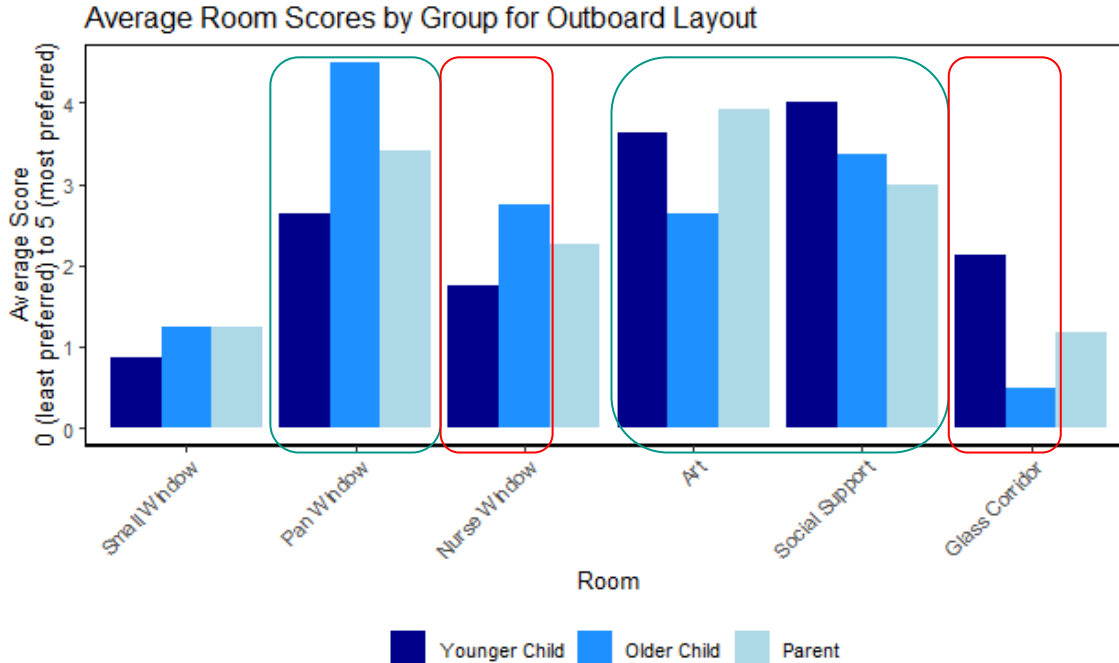


- Numerically, more participants preferred the Inboard over the Outboard layout across all groups
- Statistical tests were not significant due to small sample size
- Observed trend could inform practical design considerations
- We explored this further in the room-level analysis.

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



# Outboard Layout Rooms Ranking



## High Ranking

Younger Children

- Social Support
- Art

Older Children

- Panoramic Window
- Social Support
- Art
- Nurse Window

Parents

- Art
- Panoramic Windows
- Social Support

## Low Ranking

- Small Window
- Features impacting perception of privacy like the Nurse Window and Glass Corridor rooms had mixed responses across groups.

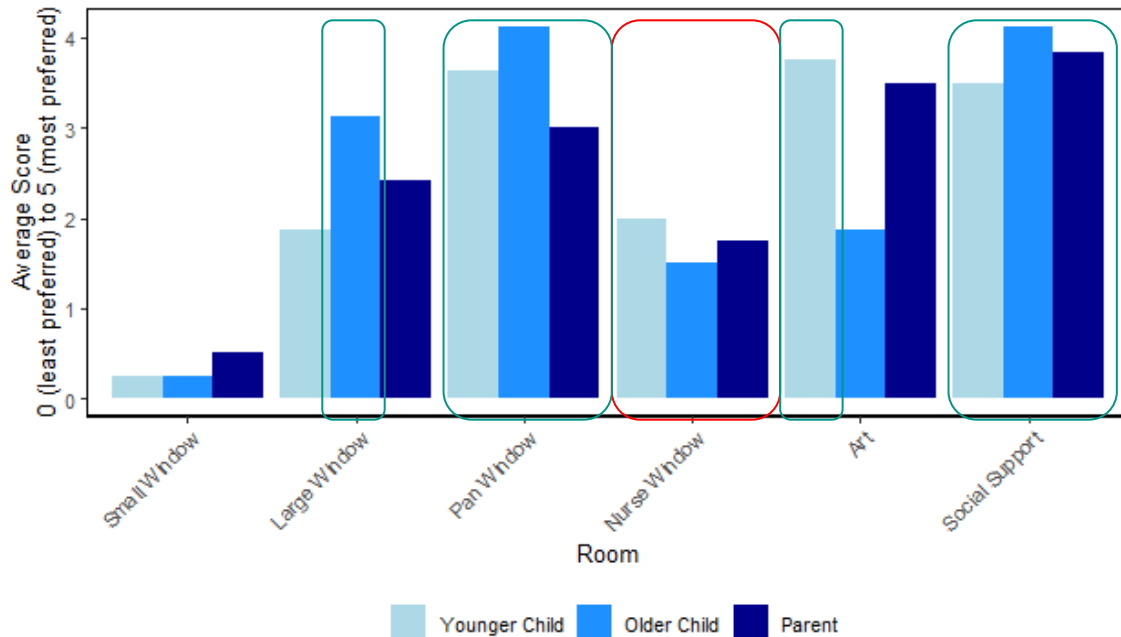
Significant variance in 'Panoramic Window' (Outboard) preferences (Kruskal-Wallis).

**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)

# Inboard Layout Rooms Ranking

Average Room Scores by Group for Inboard Layout



## 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).

## 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)

# Rooms with Significant Differences between Groups



Outboard: Panoramic Window



Outboard: Art



Inboard: Art



Inboard: Large Window

## Outboard Layout

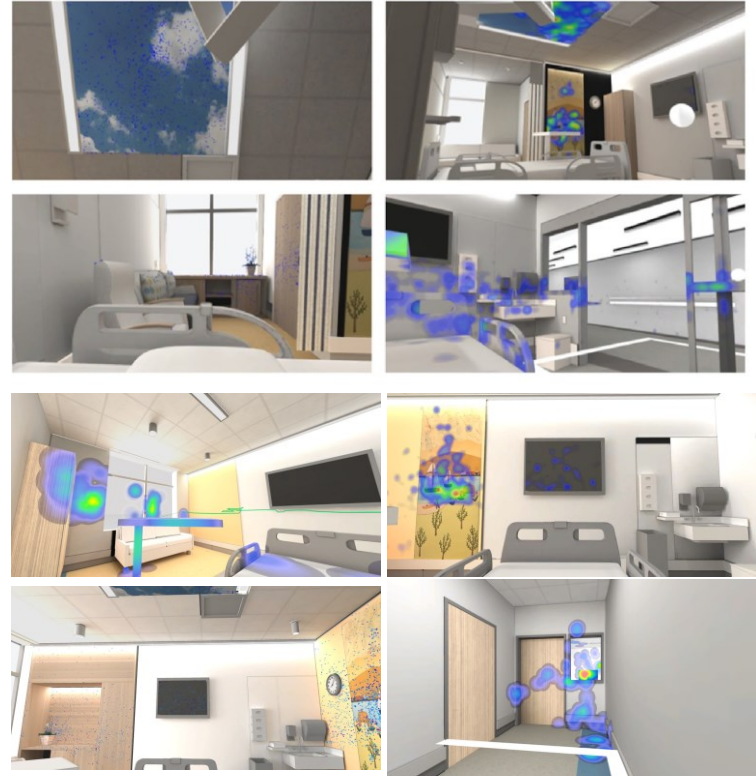
- **Panoramic Window** room stood out, being the favorite across different groups (significant at  $p = 0.0109$ )
- **Art** was nearly significant ( $p = 0.0624$ ), hinting at potential differences that require further exploration.

## 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.

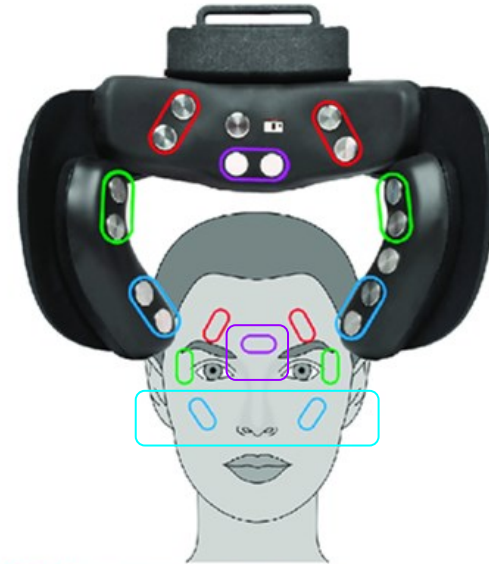


**What are the patterns that emerge from eye tracking data in response to different room design objects among Younger Children, Older Children, and Parents?**

# 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

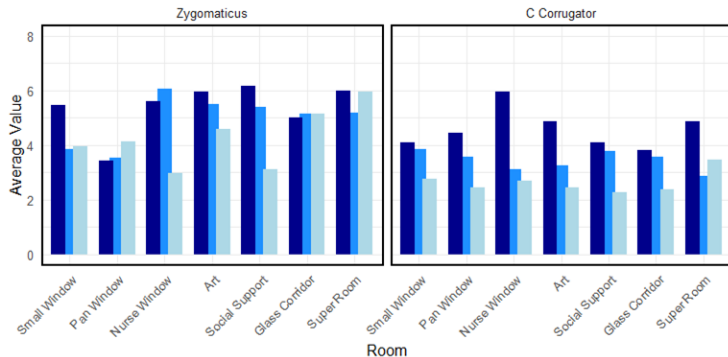


**Frontalis:** Left and right side of the forehead  
**Orbicularis:** Left and right side of the eyes.  
**Zygomaticus:** Left and right side of the cheeks.  
**Corrugator:** Measures the corrugator and procerus in the midline.

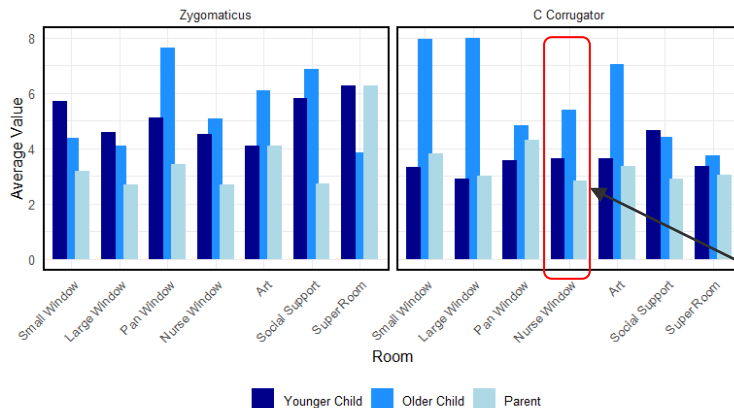
What are the patterns that emerge from physiological data in response to different room designs among Younger Children, Older Children, and Parents?

# Physiological Sensor Data by Room, Group and Layout

Average Sensor Values by Room and Group for Outboard Layout



Average Sensor Values by Room and Group for Inboard Layout



## Outboard Layout

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

## Inboard Layout

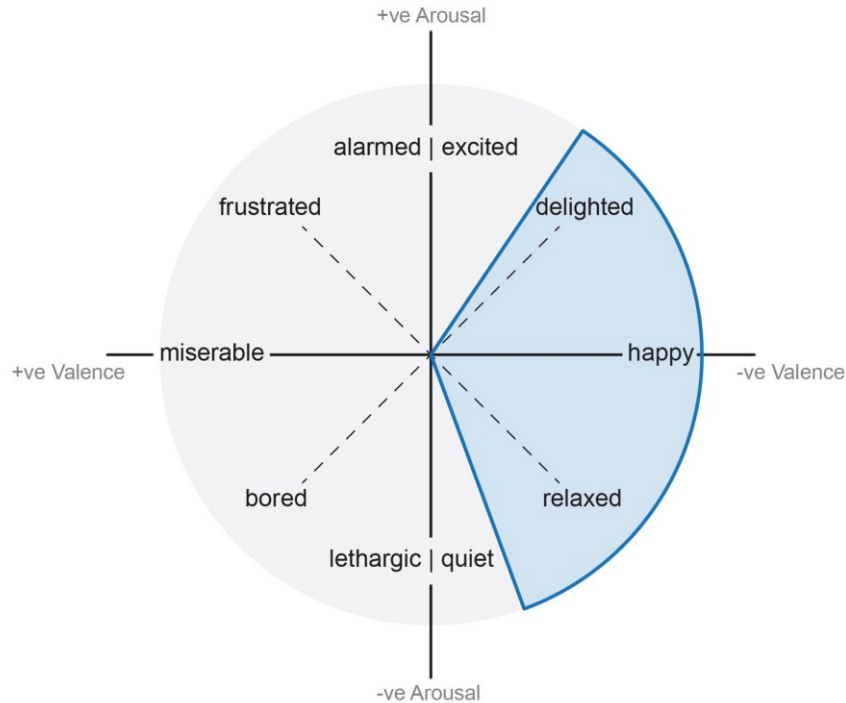
- Art room had strong positive response particularly from parents
- Smaller Windows had noticeable negative response from Older Child

"Small window did not feel comfortable."

"The larger the windows the better"

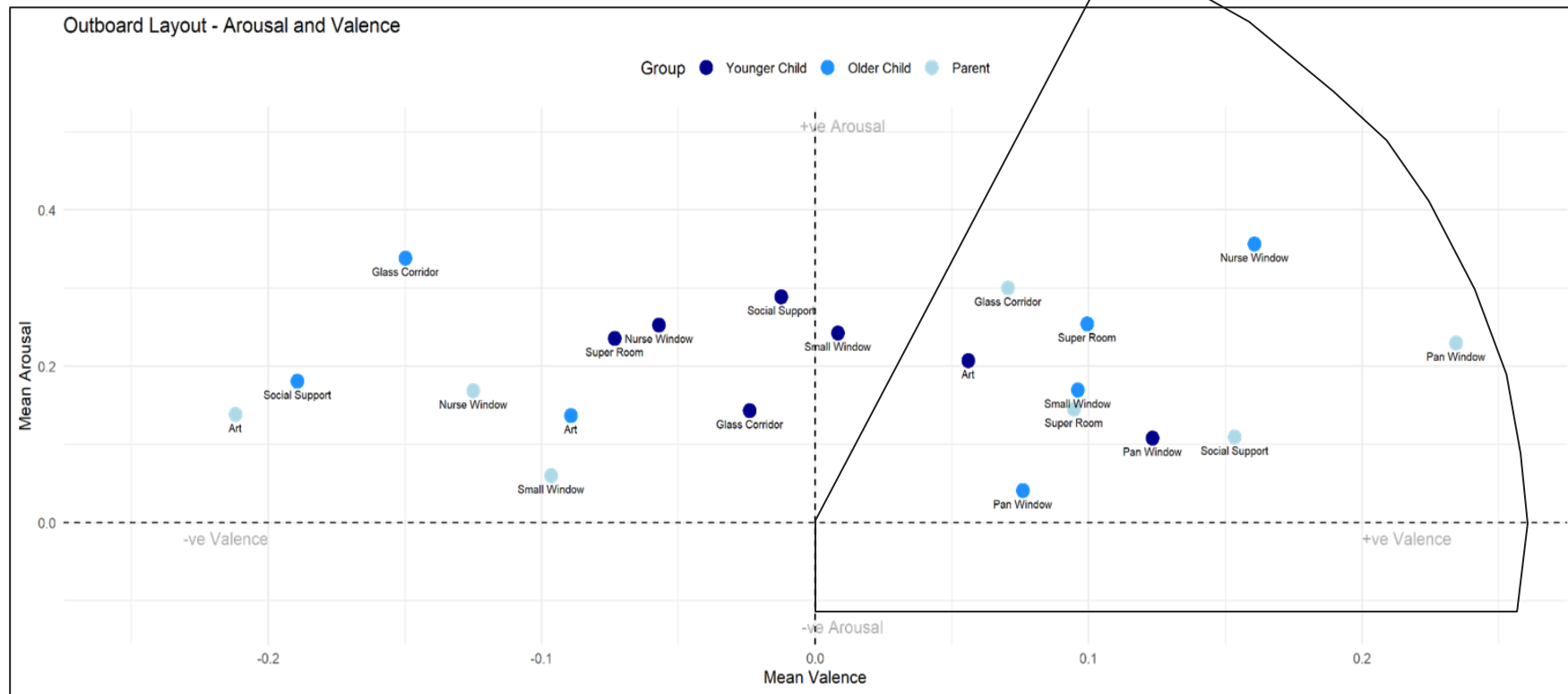
"I really liked the room with the Nurse View Window as I feel cared for and that I am not shut out from what is happening outside the room"  
– Older Child Subject

# Circumplex Model of Emotion - Arousal and Valence



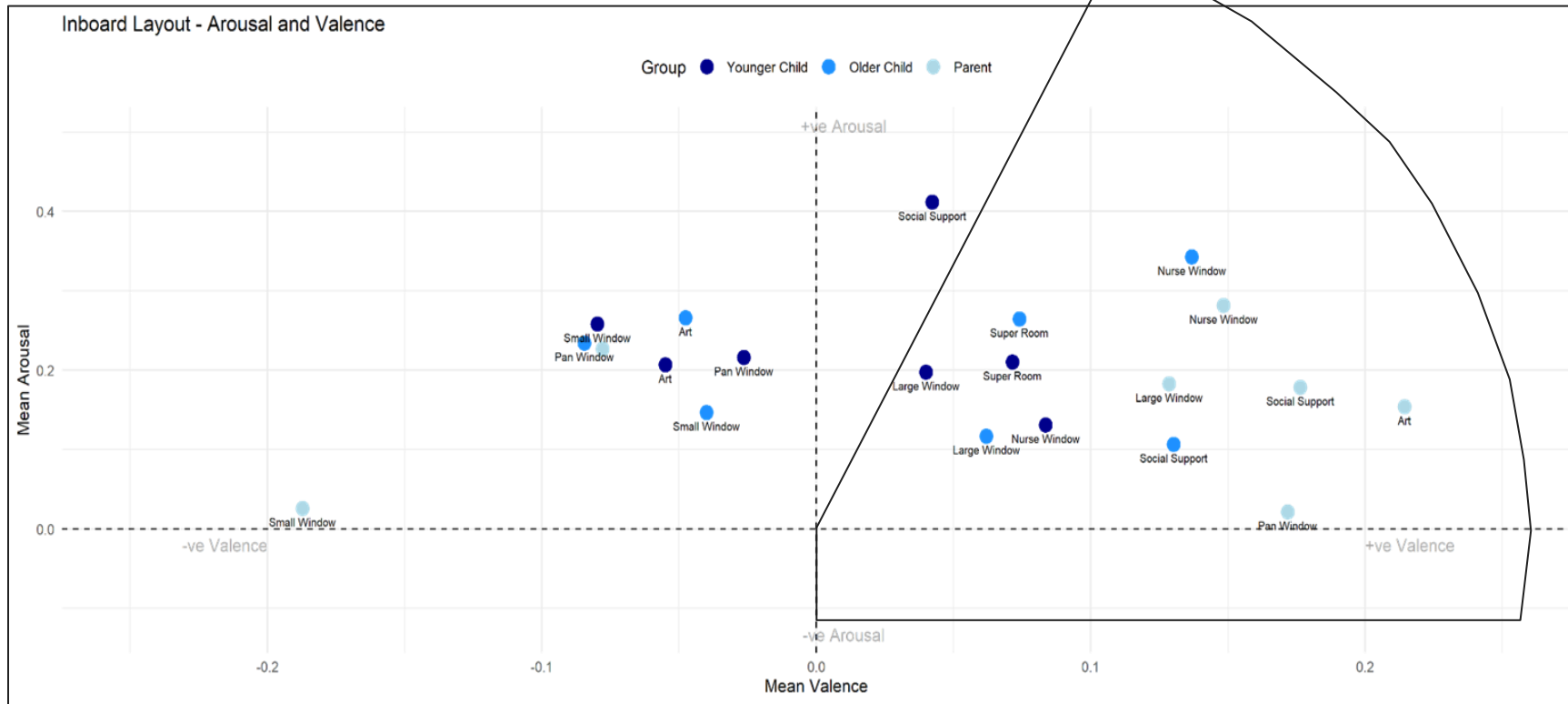
How do design elements within outboard and inboard layouts affect emotional responses (arousal and valence) across different demographic groups?

# 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.



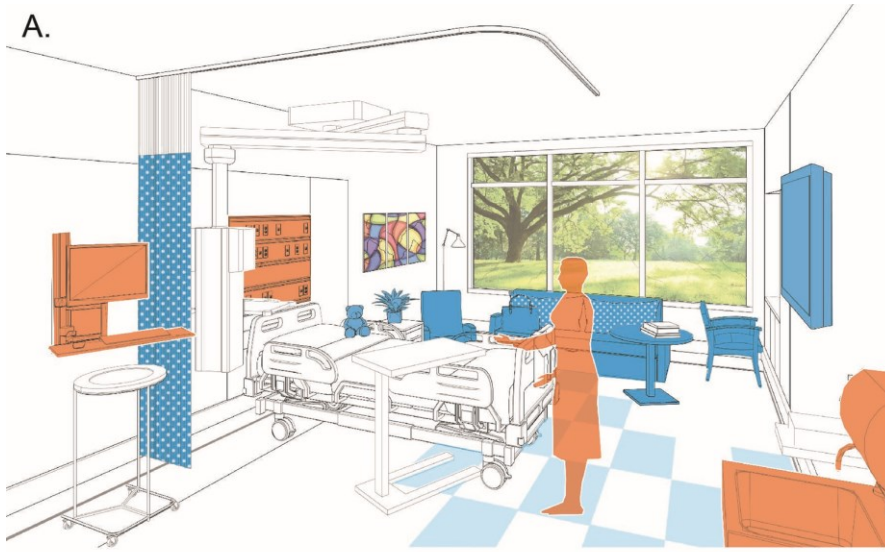
Photo Credit: <https://www.onceuponaroom.org/houston>

# 4

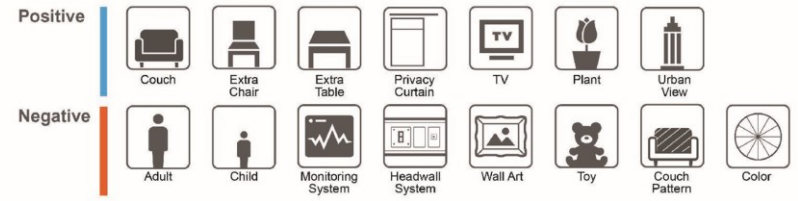
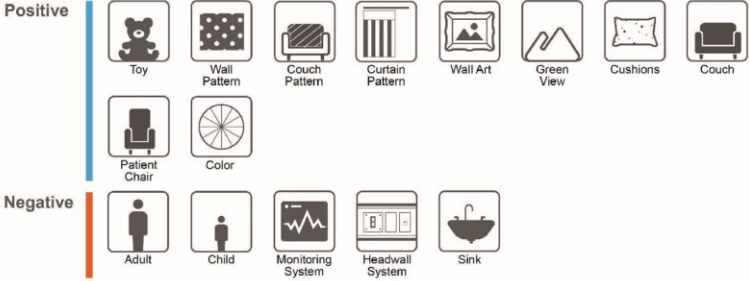
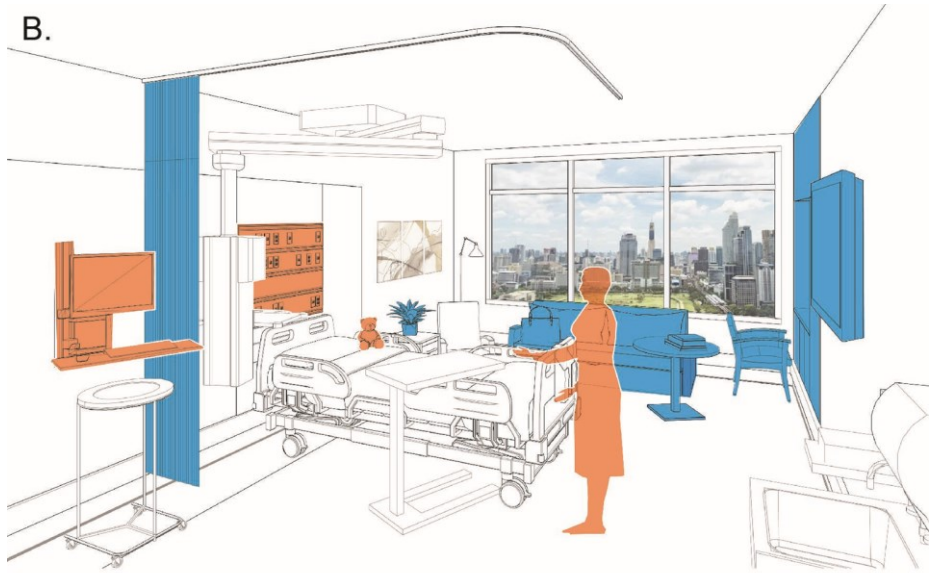
## Design Implications

# Summary of Findings

A.

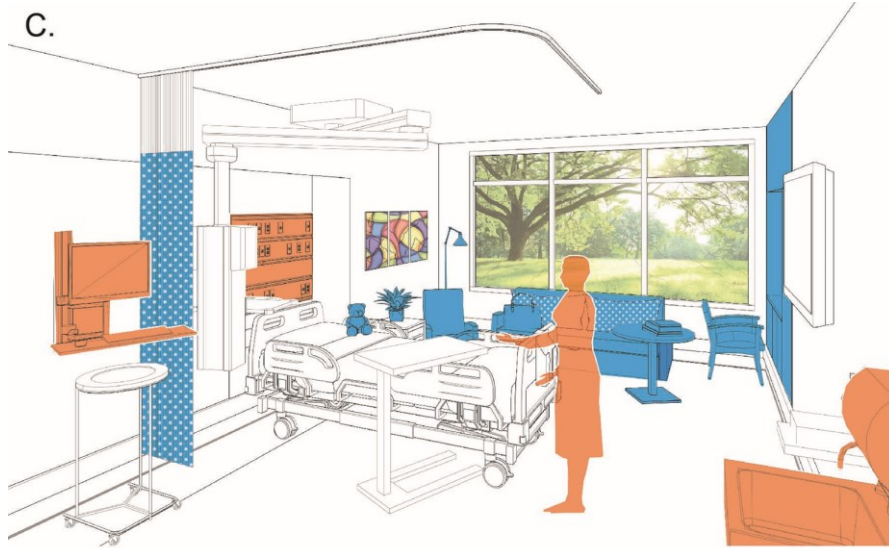


B.



# Summary of Findings

C.



**Flexible Design:** Adapt rooms to accommodate diverse needs.

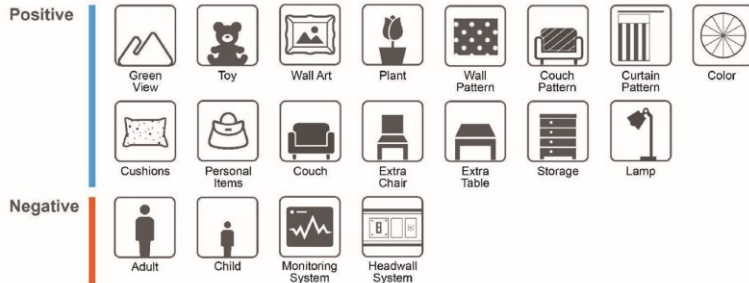
**Privacy Balance:** Maintain privacy while ensuring necessary visibility in room layouts.

**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.

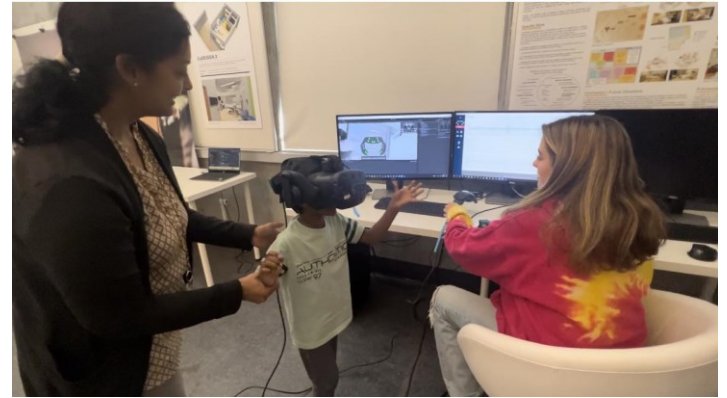


Photo Credit: XRLab Berkeley

## 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.



Positive



Negative



## 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.



Positive

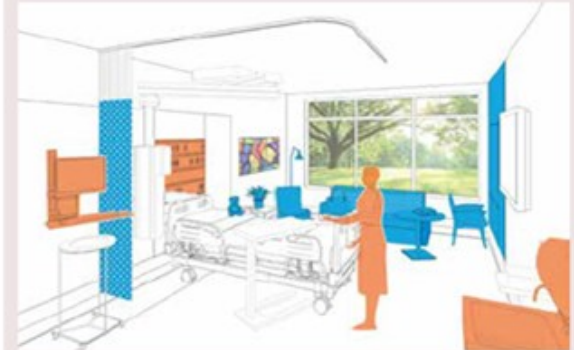


Negative



## Parent

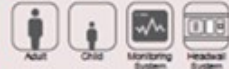
- **Like:** Homely environments with concealed medical equipment that can support the emotional and psychological well-being of their children.
- **Dislike:** Sterile environments, clinical views, as well as spaces that lack personal touches or feel cluttered.
- **Implication:** Design should prioritize 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.



Positive



Negative



# Thank you!

## Contact

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Photo Credit: XRLab UC Berkeley