Developing a ‘healing building envelope’ in healthcare design
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(Image: https://www.advancedglazings.com/case-studies/healing_power_of_daylight)
This research is an attempt to converge my personal experience of studying & working in two distinct labs at the Georgia Institute of Technology over the course of my master’s degree, the High-Performance building lab and SimTigrate design lab. In my opinion, the Healthcare sector is one of the most energy-intensive ones, considering the nature of its operation and use. Combining high-performance building strategies in the healthcare sector can result in creating more sustainable, energy-efficient, and healing healthcare environments.
Research Objectives

- This research will focus on the **importance of daylighting** and its impact on circadian rhythms within a **patient room** setting of a healthcare facility.
- This objective will be achieved through an experiment that will **simulate design parameters** like the window-to-wall ratio and **shading mechanisms** like louvers/fins to evaluate the performance of the **building envelope**.
- Daylighting within the patient rooms will be evaluated using metrics such as **spatial daylight autonomy (sDA)** and **annual sunlight exposure (ASE)**
- The **equivalent melanopic lux (EML) levels** will be evaluated using the circadian lighting software ALFA.

Icons courtesy: [https://thenounproject.com/](https://thenounproject.com/)
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Icons courtesy: [https://thenounproject.com/](https://thenounproject.com/)
Introduction
History of daylighting

1. An **oculus** that symbolized the ruler as God.

2. A city aiming for sky, whereas the **streets scramble for daylight**.

3. A **zoning resolution** that shaped the city and its neighborhoods.

Image 1: https://www.transformit.com/Daylighting-Past-Present-Future
Daylighting in healthcare design

Research Question:
Which patient room setting provides a more comforting experience for its occupants?

4. a) Patient room setting with controlled lighting and no exposure to daylighting & exterior views.

5. b) Patient room setting with a balance of daylighting and views of nature.
Lighting design especially daylighting plays a major role in accentuating such therapeutic environment settings.

Figure 1: Therapeutic environment framework
Literature review
Daylighting in healthcare setting

1. Impact of daylighting
   - For patients
     - Creates a therapeutic environment
     - Impacts circadian rhythms
     - Accelerates healing
   - For Healthcare staff
     - Improves overall work performance
     - Provides better physical and mental health

Efficient healthcare experience

Figure 2: daylighting and its impacts on patients & health care staff

Research\(^1\) indicates that daylighting affects the human circadian system and cognitive performance.

Icons courtesy: https://thenounproject.com/

The circadian rhythm is controlled by the brain’s hypothalamus.

- It operates via a small bundle of cells called the suprachiasmatic nucleus (SCN).
- The SCN is connected to the optic nerve behind the eye and receives information about the varying levels of light and darkness from our environment throughout the day and night.

Image 6: https://leddynamics.com/understanding-circadian-rhythm-and-how-tuning-leds-can-increase-health-wellness
Daylighting and building envelope: window to wall ratio

- **Window-to-wall ratio** is one of the primary factors affecting daylighting performance.
- Previous research focused on considering varying window-to-wall ratios to analyze their impact on daylighting performance through a simulation framework.

Another important design parameter impacting daylighting performance is the shading device.

Shading devices primarily aid in reducing the glare potential and help in reducing the heat gain which results in the reduction of HVAC cooling loads to some extent.

Identifying gaps in existing literature

The existing literature indicates that **daylighting has a significant impact** on the circadian rhythms of patients within a patient room setting. However, **specific gaps in the literature review** which have been identified are as follows:

- Analyzing **spatial daylight autonomy and annual sunlight exposure** to assess daylighting and glare effects during occupied hours.

- The impact of **different orientations on patient room building envelope design**, with an emphasis on automated **interior and exterior shading devices** impacting daylighting performance.

- Assessing the combination of daylighting & circadian electrical lighting in impacting the patient healing experience during **variations in climatic conditions**.

Icons courtesy: [https://thenounproject.com/](https://thenounproject.com/)
Research methodology
**Research methodology framework**

**Research Goal:**
To identify gaps in the existing literature on daylighting in healthcare settings
To assess the ambient daylighting conditions and equivalent melanopic lux levels (EML) regulating circadian rhythms within a patient room setting through a simulation framework study
To understand the impact of varying climatic conditions on daylighting and evaluate options for electrical circadian lighting

**Objectives:**
To identify gaps in the existing literature on daylighting in healthcare settings
To assess the ambient daylighting conditions and equivalent melanopic lux levels (EML) regulating circadian rhythms within a patient room setting through a simulation framework study
To understand the impact of varying climatic conditions on daylighting and evaluate options for electrical circadian lighting

**Methodology:**
A 3D simulation framework-based study to analyze the impact of building envelope on daylighting and circadian rhythms

**Tools & Instruments:**
Parametric 3d modeling: Rhino/Grasshopper
Optimization platform: Colibri, Design Explorer
Circadian rhythm study: ALFA
Statistical analysis: Excel, JMP

**Inputs & outputs:**
Optimization inputs: 3d model. window to wall ratio, shading, climate, lighting thresholds
ALFA inputs: 3d model, climate, date & time, materials & finishes

Simulation study outputs: Analyzing better-performing options in terms of melanopic lux levels for patient rooms in different orientations
Experiment design framework

Stage 1: Setting up base 3D model
- Creating base 3D model of patient room
- Parametric 3D modeling platform: Rhino/Grasshopper
- Input: 3D model of patient room

Stage 2: Optimization for Daylighting
- Optimization platform: Colibri
- Input design variables: shading, window to wall ratio derived from DOE using JMP
- Input climate data, lighting levels: sDA 300lux > 50% floor area
- Output: analyzing options on design explorer
- Selecting the best permutation for parametric simulation

Stage 3: Parametric Simulation for Circadian rhythm study
- Input developed 3D geometry for patient room
- Input climate data, location, time & date, materials, lighting points

Stage 4: Visualizing results
- Visualize output results for patient room
- Is the output giving a better melanic lux level?

Yes

No
Experimental design
Experimental design backdrop

• For the purpose of the experiment study, patient rooms on the acute stabilization unit level of the Huntsman Medical Health Institute (HMHI) Receiving center in Salt Lake City, Utah will be used as the contextual backdrop.

• Building envelope parameters such as window-to-wall ratio and shading will be considered to understand their impact on daylighting in patient rooms in all orientations in the Acute Stabilization unit level of the HMHI receiving center.

• The simulation study will also consider varying climatic conditions to assess daylighting and electrical circadian lighting in order to maintain ambient melanopic lux levels in the patient room setting.

Image 11: https://commons.wikimedia.org/wiki/File:Blank_US_map_borders
Image 12: Level 3 layout of HMHI Receiving Center – FFKR Architects.

Isometric view of Acute Stabilization unit level at HMHI receiving center, Salt lake city, Utah (layout courtesy: FFKR architects)
Patient room North Orientation: Optimization for daylighting analysis
Optimization methodology framework

- For the Optimization process, a Design of Experiment (DOE) table is created using JMP by adding different parameters like window-to-wall ratio, louver/fin depth, no. of louvers/fins, and louver/fin angle. Based on the number of input parameters a total of 25 iterations would be simulated for each of the shading mechanisms (louvers/fins) resulting in a total no. of 50 iterations for each patient room orientation.

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<th>Iteration no.</th>
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<th>No. of Louvers / Fins</th>
<th>Louver / Fin angle</th>
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<tr>
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<td>45</td>
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Patient room North Orientation: **Daylighting Optimization iterations using louvers as shading mechanism**

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Patient room North Orientation: **Comparative analysis of iterations using Design Explorer**

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<th>Run</th>
<th>WWR</th>
<th>Louver depth</th>
<th>No. of louvers</th>
<th>Louver angle</th>
<th>sDA Value</th>
<th>ASE Value</th>
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<td>4</td>
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</tbody>
</table>

Sort by: Run

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8/3/2022  Radiance workshop 2022  23
Patient room North Orientation: Selection of optimum iteration

Based on the comparative analysis iteration no. 06 provides the right balance of sDA and ASE values as compared to other iterations.

**Sensitivity Analysis:**
- From the sensitivity analysis, it can be observed that no. of louvers as a parameter has a considerable impact on the sDA and ASE values followed by the window-to-wall ratio (WWR).
Patient room North Orientation: Shortlisted louvers iteration
Patient room North Orientation: Daylighting Optimization iterations using fins as shading mechanism

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Patient room North Orientation: Comparative analysis of iterations using Design Explorer
Patient room North Orientation: Selection of optimum iteration

- Based on the comparative analysis iteration no. 12 provides the right balance of sDA and ASE values as compared to other iterations.

**Sensitivity Analysis:**
- From the sensitivity analysis, it can be observed that the window-to-wall ratio (WWR) parameter has a significant impact on the sDA and ASE values.

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<tr>
<th>Source</th>
<th>LogWorth</th>
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<tbody>
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<td>No of fins</td>
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<td>Fin depth</td>
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</table>
Patient room North Orientation: *Shortlisted fins iteration*
Patient room South Orientation: Comparative analysis of shortlisted louvers and fins iterations

Optimization Analysis summary:

- After a careful study of the results derived from the optimization process studying different window-to-wall ratios and shading mechanisms like louvers and fins, it can be inferred that the fins iteration provides a better balance between the sDA and ASE values compared to the louvers iteration.
Patient room North Orientation: **Shortlisted iteration sDA analysis**

**Input parameters:**
- Window-to-wall ratio (WWR) – 70%
- Fin depth – 0.30m
- No. of fins – 2
- Fin angle – 0°

**Spatial daylight autonomy (sDA) output:**
- sDA value – 84.63%

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Diagram showing the spatial daylight autonomy (sDA) analysis with the following labels:
- Patient room
- Toilet
- Fins

Legend:
- **sDA**
  - >100
  - 75
  - 50
  - 25
  - <0

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8/3/2022 Radiance workshop 2022
Patient room North Orientation: **Shortlisted iteration ASE analysis**

**Input parameters:**
- Window-to-wall ratio (WWR) – 70%
- Fin depth – 0.30m
- No. of fins – 2
- Fin angle – 0°

**Annual Sunlight Exposure (ASE) output:**
- ASE value – 2.61%
Patient room South Orientation: Optimization for daylighting analysis
Patient room South Orientation: Daylighting Optimization iterations using louvers as shading mechanism
Patient room South Orientation: **Comparative analysis of iterations using Design Explorer**

<table>
<thead>
<tr>
<th>Run_</th>
<th>WWR</th>
<th>Louver depth</th>
<th>No. of louvers</th>
<th>Louver angle</th>
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</tr>
</tbody>
</table>

Sort by: Run_
Patient room South Orientation: Selection of optimum iteration

- Based on the comparative analysis iteration no. 08 provides the right balance of sDA and ASE values as compared to other iterations.

**Sensitivity Analysis:**
- From the sensitivity analysis, it can be observed that no. of louvers as a parameter has a considerable impact on the sDA and ASE values followed by the window-to-wall ratio (WWR).
Patient room South Orientation: Shortlisted louvers iteration
Patient room South Orientation: Daylighting Optimization iterations using fins as shading mechanism
Patient room South Orientation: Comparative analysis of iterations using Design Explorer
Patient room South Orientation: Selection of optimum iteration

- Based on the comparative analysis iteration no. 20 provides the right balance of sDA and ASE values as compared to other iterations.

**Sensitivity Analysis:**
- From the sensitivity analysis, it can be observed that the window-to-wall ratio (WWR) parameter has a significant impact on the sDA and ASE values.
Patient room South Orientation: **Shortlisted fins iteration**
Patient room South Orientation: Comparative analysis of shortlisted louvers and fins iterations

Optimization Analysis summary:

- After a careful study of the results derived from the optimization process studying different window-to-wall ratios and shading mechanisms like louvers and fins, it can be inferred that the louvers iteration provides a better balance between the sDA and ASE values compared to the fins iteration.
Patient room South Orientation: **Shortlisted iteration sDA analysis**

**Input parameters:**
- Window-to-wall ratio (WWR) – 60%
- Louver depth – 0.60m
- No. of louvers – 5
- Louver angle – 15°

**Spatial daylight autonomy (sDA) output:**
- sDA value – 62.43%
Patient room South Orientation: **Shortlisted iteration sDA analysis**

**Input parameters:**
- Window-to-wall ratio (WWR) – 60%
- Louver depth – 0.60m
- No. of louvers – 5
- Louver angle – 15°

**Annual Sunlight Exposure (ASE) output:**
- ASE value – 12.14%
Patient room East Orientation: Optimization results of daylighting analysis
Patient room East Orientation: Shortlisted iteration sDA analysis

Input parameters:
- Window-to-wall ratio (WWR) – 60%
- Louver depth – 0.30m
- No. of louvers – 4
- Louver angle – 45°

Spatial daylight autonomy (sDA) output:
- sDA value – 62.97%
Input parameters:
• Window-to-wall ratio (WWR) – 60%
• Louver depth – 0.30m
• No. of louvers – 4
• Louver angle – 45°

Annual Sunlight Exposure (ASE) output:
• ASE value – 55.04%
Patient room West Orientation: Optimization results of daylighting analysis
Patient room West Orientation: **Shortlisted iteration sDA analysis**

**Input parameters:**
- Window-to-wall ratio (WWR) – 70%
- Louver depth – 0.30m
- No. of louvers – 5
- Louver angle – 30°

**Spatial daylight autonomy (sDA) output:**
- sDA value – 60.90%

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![Patient room layout](image1)

![Patient room isometric view](image2)
Input parameters:
- Window-to-wall ratio (WWR) – 70%
- Louver depth – 0.30m
- No. of louvers – 5
- Louver angle – 30°

Annual Sunlight Exposure (ASE) output:
- ASE value – 59.55%
Conclusion
Moving Forward

- The next stage of this research will focus on evaluating the equivalent melanopic lux (EML) levels for each of the shortlisted iterations of patient rooms and assessing the impact of daylighting and electrical lighting on the circadian rhythms of the patients.
- A 3d model developed on Rhino of the shortlisted iterations for each orientation would be used to evaluate the EML to assess the impact of daylighting and electrical lighting on the circadian rhythms of patients.
- The resultant simulation analysis would provide a framework for designing patient rooms in healthcare settings by balancing daylighting and electrical circadian lighting.

Image 13&14: https://www.solemma.com/alfa
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Thank you! Q&A