Non-visual Light Health in Neonatal Intensive Care Units through Light Measurement, Simulation, and Design

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ABSTRACT

Almost all life forms can detect and decode light information for adaptive advantage. Only in recent years, scientists have uncovered the importance of lighting design beyond facilitating vision. The eyes function in a dual manner, and the second function is to facilitate the internal body clock. The photobiological research is still evolving but preliminary findings show that light-sensing opsins within the retina interact with genes oscillating to circadian rhythms. Encephalopsin, also known as Opsin3 or OPN3, is a 480 nm, blue-light-responsive opsin. Melanopsin, encoded by the gene Opn4, is selectively sensitive to short-wavelength light (peak absorption ~479 nm). Neuropsin, also known as Opsin 5 or OPN5, is a photoreceptor in the retina and skin, but is also expressed inside the brain, and can exhibit an absorption maximum at 380 nm of violet light from the sun. Those neurons, working as photoreceptor signals, send information that impact fetal health, including circadian rhythms and visual systems.

Research in neonatal intensive units (NICU) shows that surplus exposure and brightness can be extremely damaging to the growth of premature babies, but circadian light regimes can exert a positive influence on fetals' brains, eyes and other development. It is necessary to control and manage the amount and the spectra of light on neonatal care, and determine which wavelengths, intensity and duration, are most important for supporting womb-like development.

This research aims to develop daylighting and electric lighting (tunable light fixtures) design guidelines for NICU settings. Along with appropriate glazing and shading systems, electric lighting systems could provide the targeted range of wavelengths and intensities. Multi-spectral simulation methods will be employed to derive informed design decisions based on parameters such as site, local climate, building form, and materials in the context of NICU design. The simulation workflow will be developed to quantify opsin illuminances (melanopsin, encephalopsin, and neuropsin) along with photopic values to study the role of daylight and electric lighting in fetal development. The quantities will be evaluated based on available standards (melatonin suppression at an hourly time scale for compliance with the Recommend NICU Standard 2020) and the emerging research results.

Proposed Research Methods:

- Understand research about basic neonatal ophthalmology and NICU design standards we are using now
- Make methodology & Simulation workflow for opsins
- Based on the research outcome, give a design guideline that can be understood and used by lighting designers and medical planners

Quarterly Deliverables:

Autumn 2021:

- Abstract: develop a specific research question, briefly introduce the background and value

- Introduction and Literature Review: Introduce what others researched on, demonstrate the need and objectives of the research

- Literature Review: find the relevant research articles (opsin system, visual and non-visual light, metric others are using and what I decide to use) The effect of spectra on health, mainly circadian rhythms with added specifics on the impact of spectra on neonatal care (non-visual opsins 3,4,5 role in human health).

- Methodology: explain the setting, the software, and relevant metrics that will be used, simulating daylighting (with measured spectra) and electric lighting (with candlepower distribution curve of the luminaire) in Lark. Also need to feel comfortable with the software, understand its capabilities and limitations.

- Three Meetings with CCHMC to understand the standard and workflow of NICU; how they collect and analyze the data and knowledges about ophthalmology for this research

Winter quarter:

- simulations, analysis, etc.

- Dive deep into non-visual light simulation workflows

- Revising Lark to suit the new workflows

Spring quarter.

- Research outcome and give a Design guidelines/recommendations

- Conclusion