U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Evidence-Based Design for Healthcare Lighting: Where's the Evidence?

DOE Healthcare Lighting Webinar Series

October 4, 2016

CLEMSON UNIVERSITY

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DOE Healthcare Webinar Series

The Nurses' Perspective on Hospital Patient Room Lighting

Sept 13, 2016 Robert Davis & Andrea Wilkerson, PNNL
Pat Lydon, Legacy Health

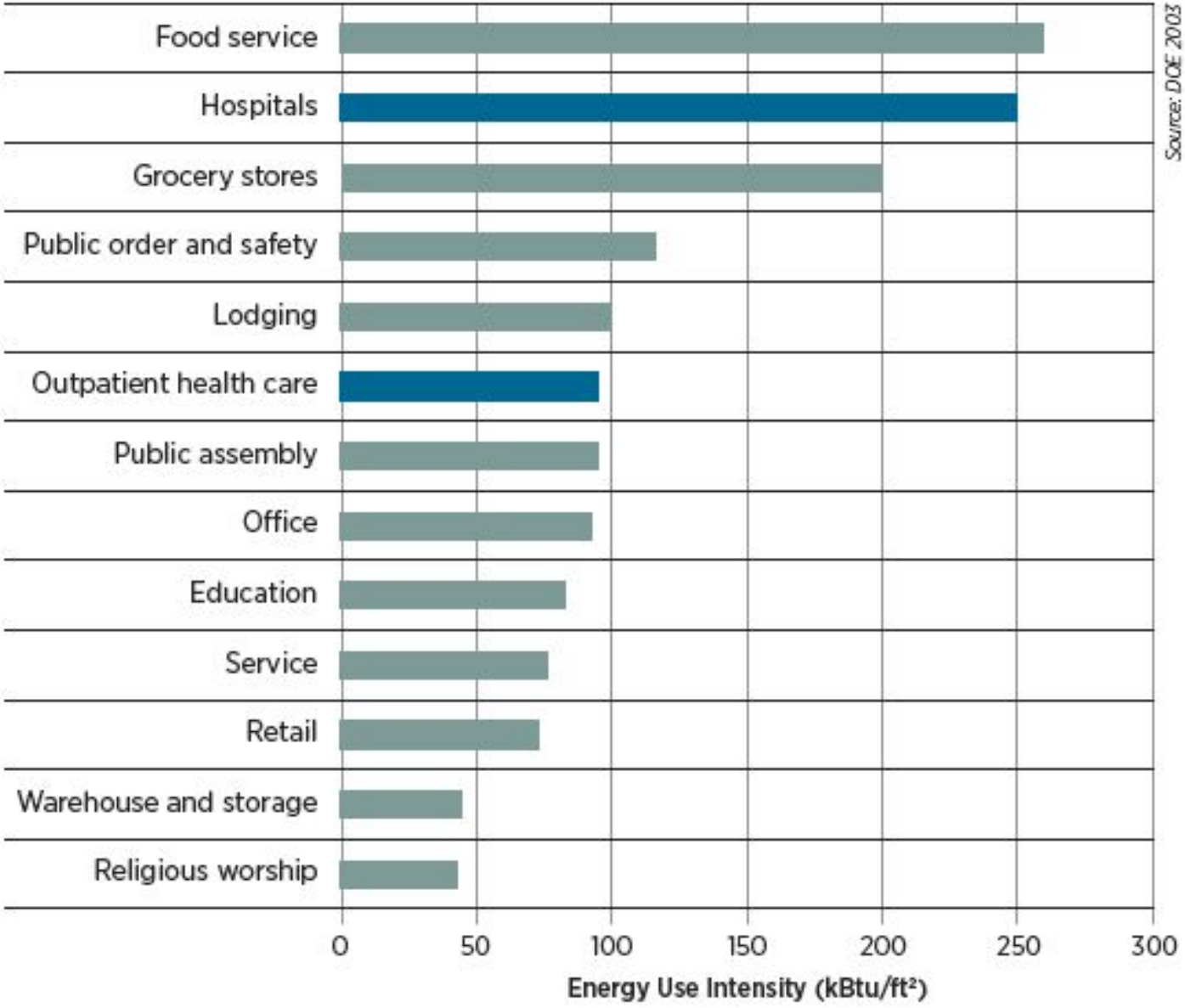
Evidence-Based Design for Healthcare Lighting: Where's the Evidence?

Oct 4, 2016 Robert Davis & Andrea Wilkerson, PNNL
Anjali Joseph, Clemson University

Tuning the Light in Senior Care

Oct 18, 2016 Robert Davis & Andrea Wilkerson, PNNL
Connie Samla, Sacramento Municipal Utility District

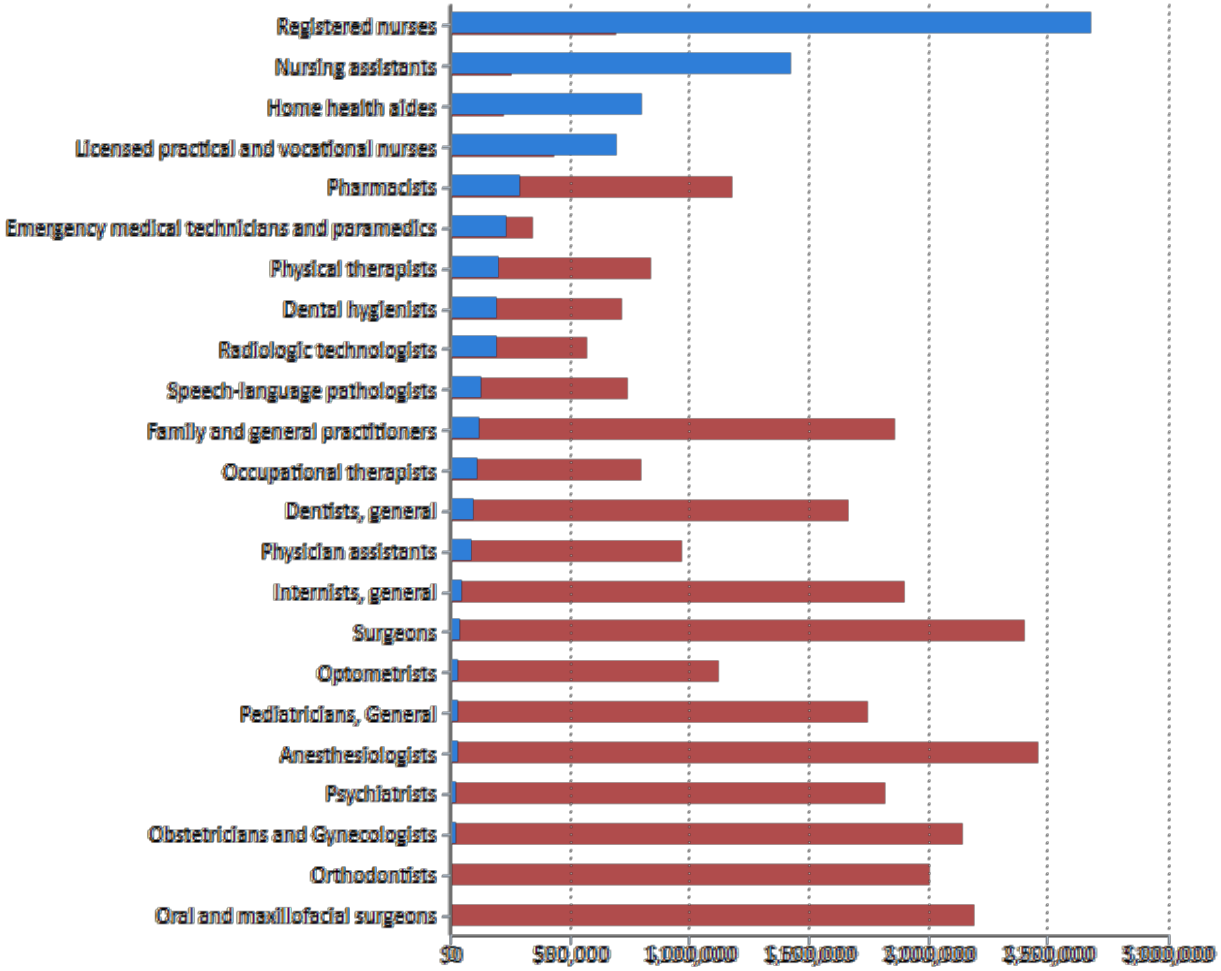
Healthcare Energy



Advanced Energy Retrofit Guide: Healthcare Facilities, US DOE, Sept 2013

Healthcare Employment and Wages

Employment Wage for Selected Healthcare Occupations (May 2014)



Projected % change in employment from 2014 to 2024:

↑16% Nurses

↑ 7% All occupations

U.S. Bureau of Labor and Statistics

Healthcare by the Numbers

$2,300 **$3,300** **$4,300** Average healthcare spending per household in 2014[1]

Consumer prices for hospital services since 1997 have **Doubled** **Tripled** **Quadrupled**[1]
(Compared with a 50% increase in all items over same period.)

25% **50%** **75%** Projected growth in video doctor consultations per year between 2015 and 2020[2]

Healthcare executives indicating ROI in personalization technologies **23%** **43%** **73%** [3]

25% **45%** **65%** Healthcare executives strongly agree that within 3 years companies need to focus as much on training machines as training people [3]

[1] U.S. Bureau of Labor and Statistics [2] Forbes [3] Accenture Consulting

Holistic View of Lighting for Healthcare

- Energy & sustainability
- Circadian rhythms / Non-visual effects of light

Holistic View of Lighting for Healthcare

- Energy & sustainability
- Circadian rhythms / Non-visual effects of light
- Task performance: Visibility, stress
- Perceptions: Mood, agitation, pleasant vs. institutional environments
- Safety: Errors, fall risk

What evidence can help us provide lighting to better address these needs?

Literature Review Goals

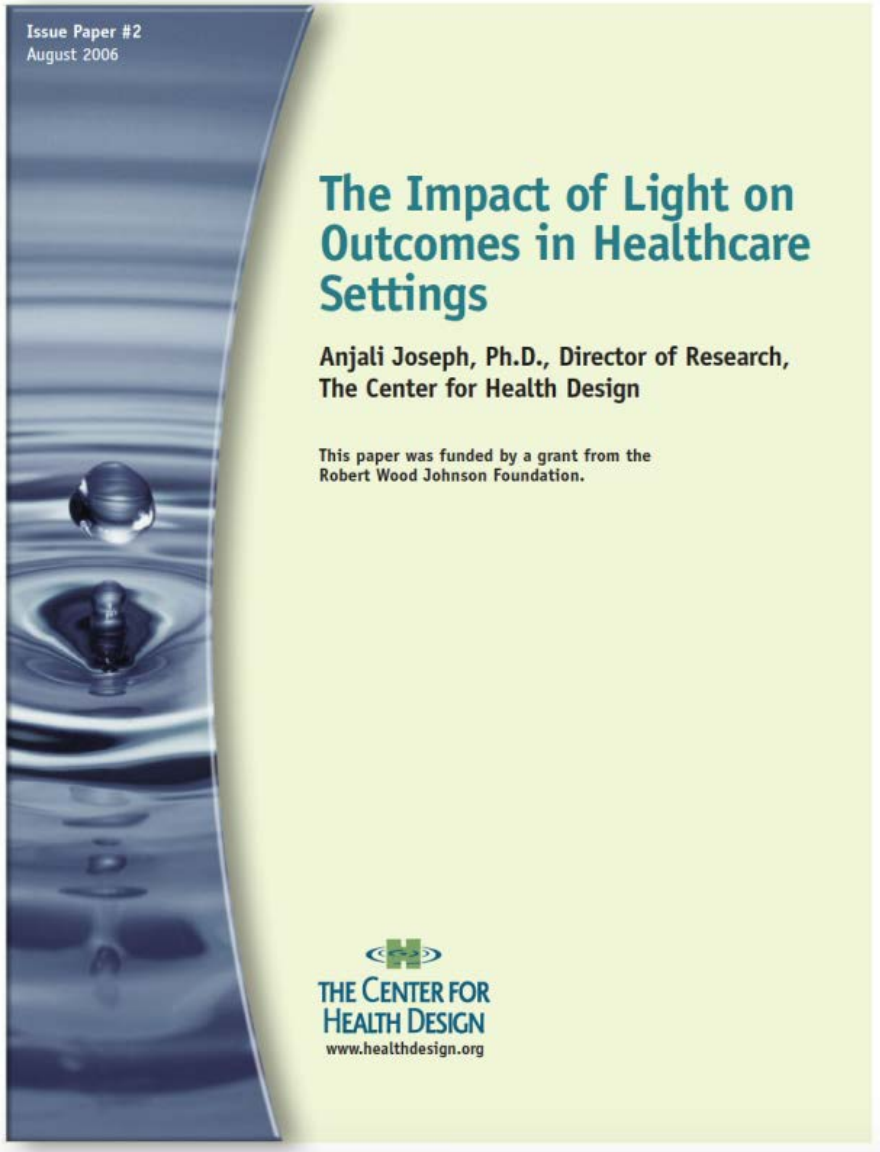
Impact of light in healthcare environments

Update to Joseph, 2006 study

Broad view - not just lighting publications

Design recommendations?

Areas for future research?



01 Light in buildings

02 Light impacts human health and performance

Visual impacts of light

Non-visual impact of light

03 Design implications

Literature review: Goals & Methods

- Study builds upon Joseph, 2006 article
- Criteria for inclusion and exclusion
  - Healthcare and long-term care environments
  - Focus on lighting and daylight
  - Focus on health outcomes
  - Published in peer-reviewed journals
  - Published after 2000

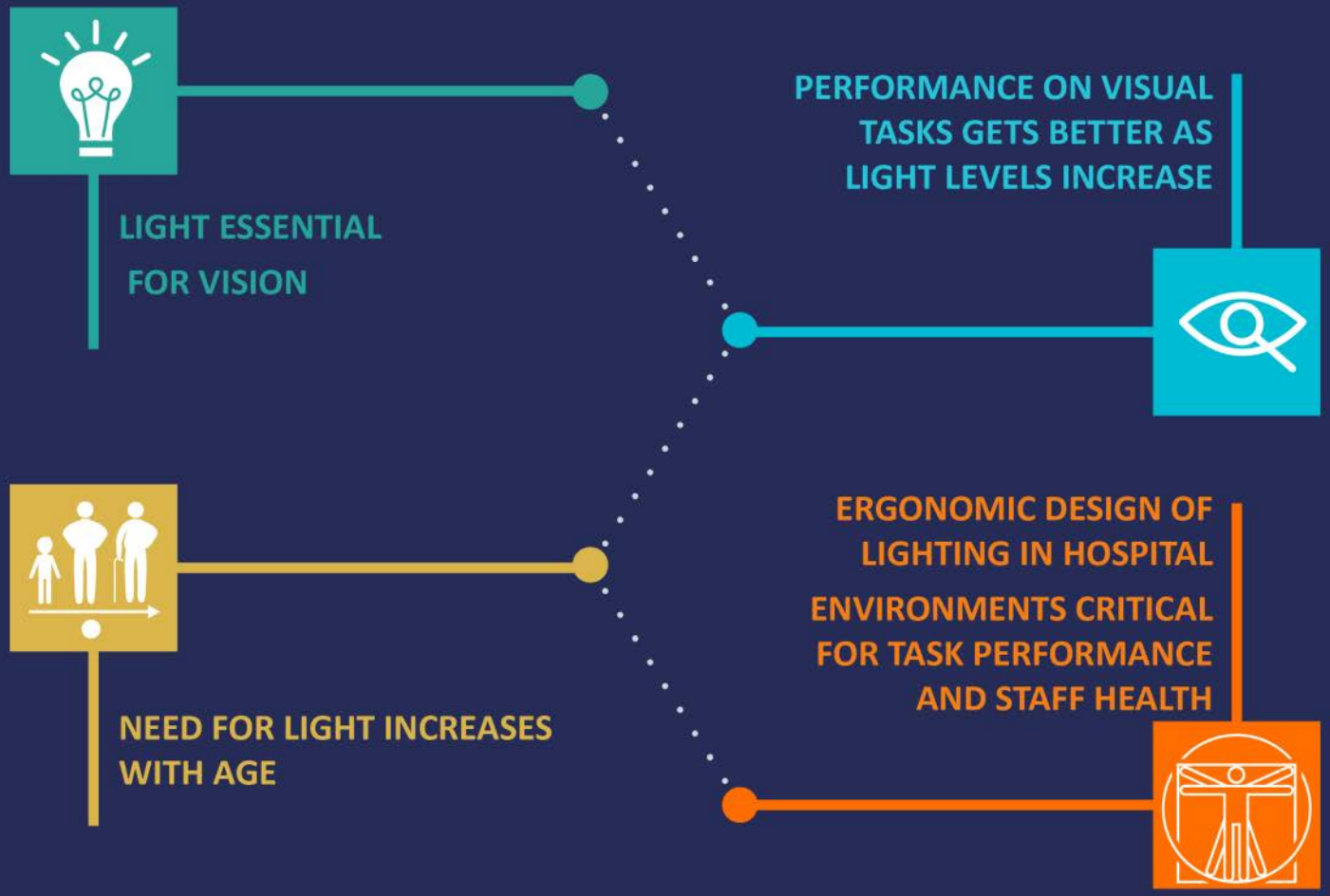
http://cdx.dexigner.com/news/xw/28214.jpg

http://pagethink.com/media/uploads/project-gallery-images/lg_lakeway_waiting_area_natural_light02.jpg


TASK PERFORMANCE
PERCEPTION OF QUALITY/ SATISFACTION
SAFETY
FALLS
ERRORS
STAFF SAFETY

Lighting and Task Performance

Performance of visual tasks



Task Performance

- Inverse relationship between illuminance levels and eye fatigue in night shift workers (Azmoon, 2013)
- Dim light conditions during night shifts made patient care and decision making more difficult (Nilsson et al., 2009)
- 87% of nurses believe that providing adequate lighting in the medication room was a contributing factor for task accomplishment (Mahmood et al. 2012).
- Task performance and job duties: Inadequate lighting has a negative effect on staffs' work performance (Dianat et al. 2013).

Light and worker stress

- Surgeons experienced lighting difficulties during surgeries, especially involved with deep wounds and a narrow entrance to the cavity (Knurs et al., 2011)
- In OR environments, non-significant inverse relationship between illuminance levels and stress among anesthesiologists and nurses (Morghen, et al 2009)
- Nurses in cancer-care environments felt exhausted in windowless environments (Edvardsson, et al, 2006)
- 30 minute bright light exposure significantly reduced perception of stress and burnout syndrome (Kakooei et al., 2009).

https://teecom.com/projects/palomar-medical-center-west/

http://cosmeticlocal.com/wp-content/uploads/2014/11/1272_R9A5958.jpg

Task Performance: Better evidence in the future?

Morghen at al. (2009) – Illuminance and stress

Journal of Occupational Medicine & Toxicology

- Shows illuminance in three categories
  - <700 lx, 700-1500 lx, >1500 lx
  - Reduced stress at higher illuminance
- Lists illuminance ranges, CCT, CRI
  - SPD? Location for illuminance measures?
- Reported that factors other than lighting (familial and working conditions) were stronger influences on the reported stress levels

Task Performance: Better evidence in the future?

Mahmood et al. (2012) – Lighting and errors

Intl Journal of Health Care Quality Assurance

- Studied environmental factors and effects on work errors & job satisfaction; broad look at different factors
- Adequate lighting in medication area seen as one of the top environmental solutions for avoiding errors
    - Indicates the importance that nurses place on lighting for performing their tasks
- Error / performance measures? (Incomplete records)
- Aspects of the lighting that contributed?

Task Performance: Better evidence in the future?

Kakooei et al. (2009) - Stress during night shift

Intl Journal of Occupational Hygiene

- Bright light exposure: 2000 lx at eye for 30 minutes, 6400 K CFL (normal lighting at 150 lx)
- Significantly reduced perception of stress and burnout syndrome
- Did not affect anxiety symptoms, somatic symptoms, depression, or social function
- Small sample – 15 nurses
- All based on self-report through survey
- No details on configuration, SPD, glare

http://cosmeticlocal.com/wp-content/uploads/2014/11/1272_R9A5958.jpg

Lighting and perceptions

Lighting conditions and mood

01
Bright Light

. Subjects in high threat health-care situations perceived a brighter room as more spacious, experienced more positive affect and indicated higher intention to self-disclose compared to a dimly lit room (Okken, 2013)

02
Dim light

Bright light vs. dim light in counseling rooms. Dim lighting resulted in (Miwa & Hanyu, 2006):

. More pleasant and relaxed feelings in subjects
. More favorable impression of interviewer
. More self disclosure to interviewer

Reducing Perceptions of Pain

- Spinal cord surgery recovery patients on the brighter side of the unit:
  - Perceived lower stress
  - Perceived less pain
  - Took 22% less analgesic medication per hour
  - Incurred 21% less pain medication costs (Walch et al., 2005)

Dublin Methodist Hospital, Ohio

Reducing agitation

- Alzheimer's disease and agitated behaviors
- Control changing light conditions by (LaGarce, 2002):
  - Full spectrum fluorescent lighting
  - Micro-slatted glazing to lessen effects of changing sun angles
  - Electronic controls to maintain light intensity

- Study revealed a significant drop in disruptive behaviors when residents were in the constant light levels compared to varying light levels (LaGarce, 2002)

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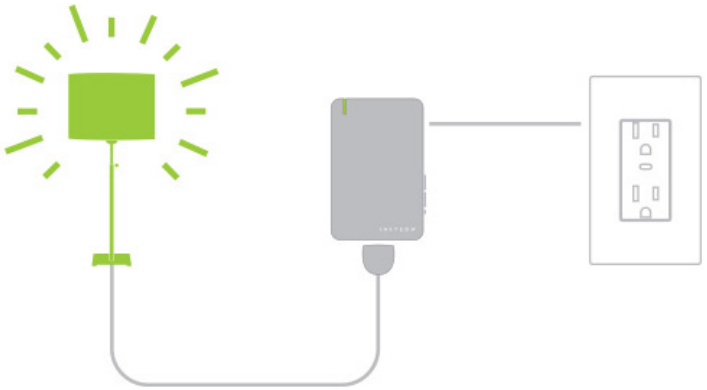


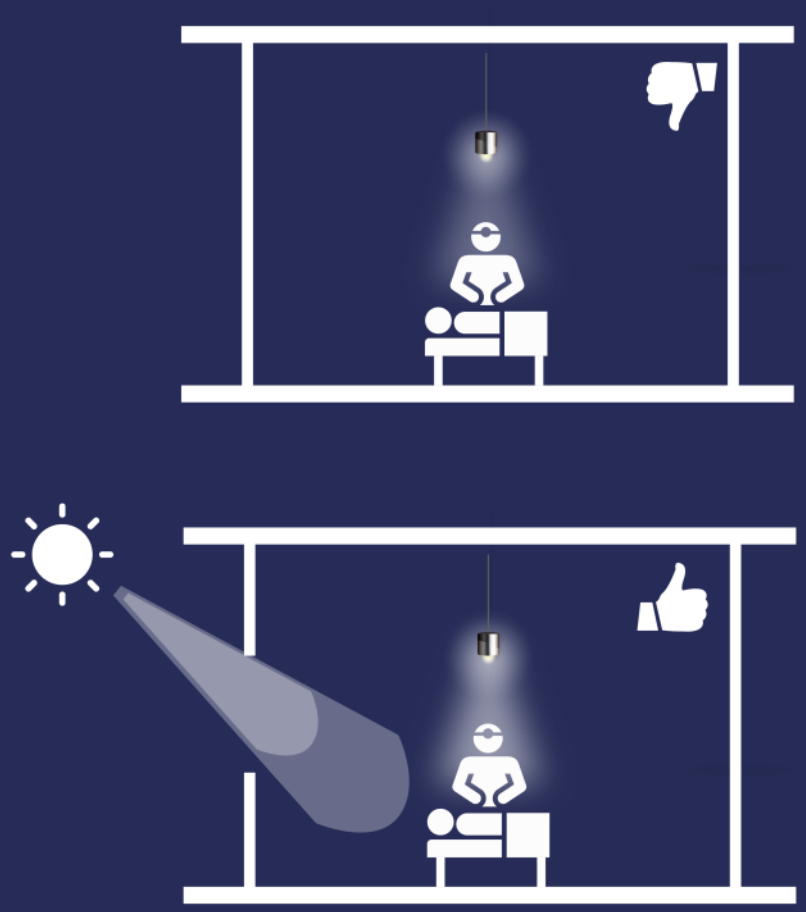
Windows, daylight and stress

- Nurses working in units with windows vs. windowless units experienced:
  - Higher levels of communication and laughter
  - Reduced behavior indicators of sleepiness and deteriorated mood (Zadeh, et al, 2014)
  - Frequency of communication behavior increased in wards with windows and daylight, compared to windowless wards (Zadeh et al., 2014).
- Turkish hospital found that nurses exposed to 3+ hours of daylight experienced:
  - Less stress
  - More satisfaction with work (Alimoglu & Donmez, 2005)
- Nurses working in an experimental room with full spectrum lighting and spatial patterning experienced less stress (Gray, et al 2012)

Dublin Methodist Hospital, Dublin, Ohio

Lighting and staff satisfaction

- Correlation between positive perception about the lighting levels and job satisfaction (Djukic et al., 2010)
- Lighting characteristics (light source, light level, and light color) correlated with employee's satisfaction with lighting (Dianat et al. 2013)
- Inadequate illumination of the operating field (32%) was considered as one of the reasons for surgeon's discomfort during operations (Matern and Koneczny, 2007).
- Dascalaki et al. (2009) the general OR lighting space was perceived insufficient by 32%. Almost a quarter of OR staff indicated that insufficient lighting levels associated with surgical needs around the operating table.



Lighting & Perceptions: Better evidence in the future?

Okken et al. (2013) – Affective experiences

Health Environments Research & Design Journal

- Brighter room perceived as spacious and positive, enhancing self- disclosure intentions in “high threat” condition
- “Low threat” condition: room brightness did not have a significant effect (intimacy)
- 90 subjects, ratings based images of rooms
- Repeat in real spaces with detailed lighting documentation?
- Confirm rating scales with other measures?

When the world is closing in: Effects of perceived room brightness and communicated threat during patient-physician interaction

Lighting & Perceptions: Better evidence in the future?

Miwa & Hanyu (2006) - Interior design effects

Environment and Behavior

- Counseling room bright (750 lx) or dim (150 lx) and with or without decorations
- Dim lighting provided a more peaceful, enjoyable feeling, developed a positive impression of the interviewer and promoted the intention to self-disclose
- Color quality? Distribution? (Dim incandescent vs. bright fluorescent) – no details on SPD or distribution

Lighting & Perceptions: Better evidence in the future?

Gray et al. (2012) - Interior design effects

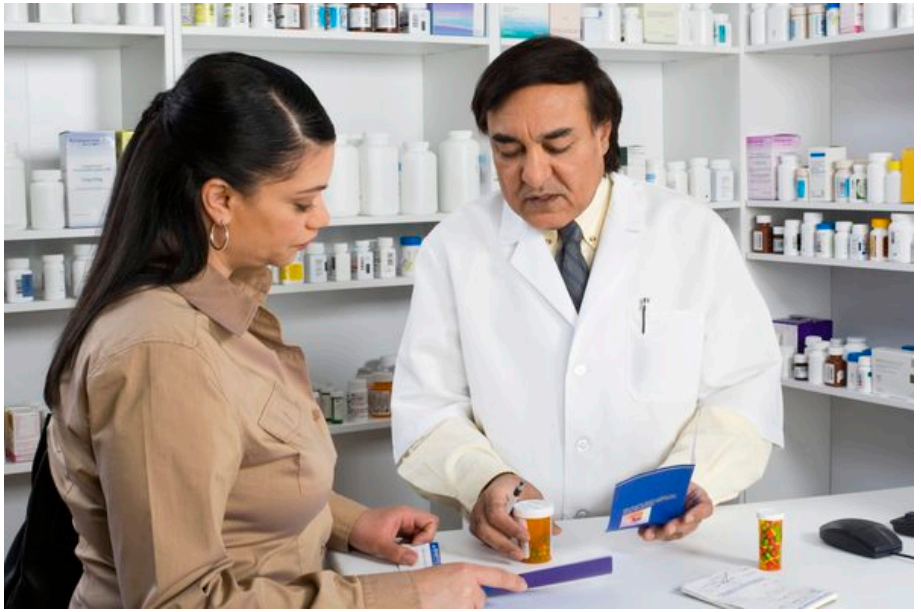
Health Environments Research & Design Journal

- Pilot study in a clinical simulation center – practice cardiac resuscitation on human patient simulator (HPS)
- Two rooms: ***Control*** with 3500K fluorescent and normal finishes; ***Experiment*** with "full spectrum" fluorescent and spatial color patterning design to group equipment
- Significant reduction in stress and increase in alertness in ***Experiment*** room
- Décor vs. lighting? SPDs? Light levels and distribution?

Lighting and safety outcomes

Reducing errors

- Higher lighting levels were associated with fewer medication-dispensing errors in pharmacy (Buchanan & Baker, 1991)
- Survey findings of nurses in long term care facilities to reduce medication errors included (Mahmood, et al, 2012):
  - Provide adequate lighting in the medication room (74.1%)
  - Provide suitable nursing station lighting (72.2%)
  - Provide adequate dining room lighting (66.7%).
  - Providing adequate lighting in the medication room was a contributing factor in this space for them to accomplish tasks (86.8%).



http://imgaws.ehowcdn.com/600x600p/photos.demandstudios.com/getty/article/117/183/78056393.jpg

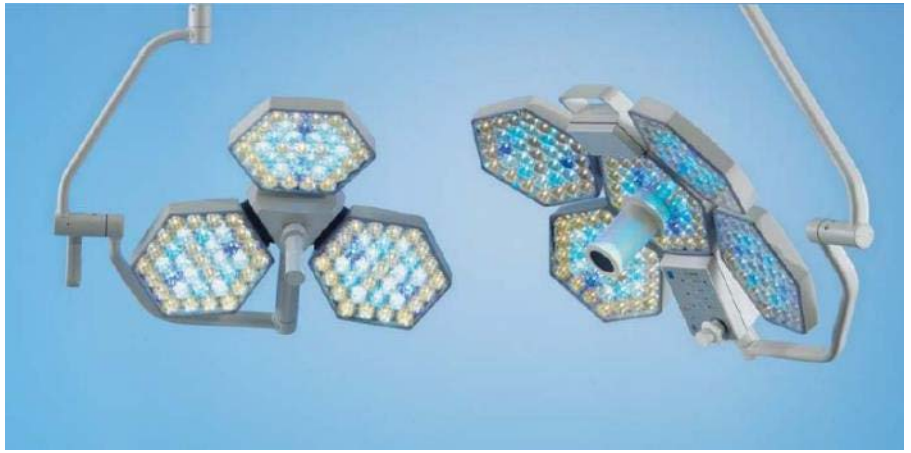
Reducing errors

- Challenge in balancing lighting needs for patient care activities during medication administration (reading drug labels, color distinction) and creating a healing environment (low light at night) (Graves, et al, 2014)
- Reviewing yearly medication errors Zadeh et al. (2014) found that the probability of medication errors in the windowed ward was 22% lower than windowless conditions.

http://chemistscorner.com/wp-content/uploads/2014/04/reading-the-label.jpg

Lighting and Ergonomics

- Key ergonomic issues related to surgical luminaire placement and design were related to mechanical problems (Knulst et al, 2011; Matern and Koneczny, 2007)):
  - Collisions of the luminaire against other objects
  - Out of reach positioning of lighting features.
  - Entanglement of lighting arms
  - Inability to adjust lights with only one hand
  - inadequate luminance level for the operating field



http://www.wemed1.com/products/surgical-lights-operating-room?mode=list

Lighting design and safety in the OR

- Luminaire positioning that required frequent repositioning were responsible for 64% of interruptions of surgical tasks in the operating room (Knulst, et al 2011)
- Poor ergonomics of OR light contributes to discomfort for surgeons and hazards due to bumping etc. (Matern et al, 2007)

Lighting and Ergonomics

- Usability improvement recommendations from the survey of surgeons included (Knulst, 2011):
  - Ease of focusing,
  - Ease of aiming force for moving,
  - Ease of moving,
  - Reduced collisions, entangling,
  - Increased maneuverability,
  - Easy access by surgeons, residents, and nurses.

Reducing Falls among elderly

- Low light levels contribute to gait instability, gait speed and falls among the elderly, especially for those at risk of falling (Figueiro, 2011, Kesler, 2005)
- Elderly at risk for falls performed walking tasks best under ambient illumination conditions (ceiling mounted lights) and worst with night lights alone. (Figueiro, 2011)
- The pathway plus night lights increased gait velocity and reduced step length variability compared to the night lights alone in those at greater risk of falling (Figueiro, 2011)

http://ageinplace.com/wp-content/uploads/2013/11/pathlights-system-stair-lighting-seniors-elderly2.jpg

Lighting & Safety: Better evidence in the future?

<u>Kesler et al. 2005 – Walking in the dark</u>

Journal of NeuroEngineering and Rehabilitation

- Gait analysis for healthy older adults, compared to those with gait disorders (HLGD)
- Usual vs. dim lighting conditions (1000 lms vs. 5 lms)
- Both groups slowed under dim lighting, but also became more variable and unsteady for HLGD group
- Illuminances? SPDs? Other visual cues?

Lighting & Safety: Better evidence in the future?

<u>Figueiro et al. (2011) – Elderly and Fall Risk</u>

BioMed Central Geriatrics

- Ambient (650 lx), night lights (0.015 lx), night lights + pathway laser lines (0.015 lx)
- Measured speed & stability: step & stride length, velocity
- Ambient best; laser lines improved the night light for high fall risk individuals
- Reported illuminance at cornea for all; most details on lighting equipment – variability? Glare? CCT / SPD?
- Suggested need for commercial solutions *(low energy use)*

Strong evidence that light is critical to human functioning

Light impacts outcomes in healthcare facilities

Key findings

01
Adequate lighting conditions are essential for performance of visual tasks

02
Poor lighting conditions can result in errors

03
Daylight can help alleviate pain and reduce depression

04
Exposure to light can help alleviate sleep problems among elderly

05
Lighting levels preferred by people are significantly higher than today's indoor lighting standards

06
Need to correspond to levels where biological stimulation can occur

Natural Light

- Natural light should be incorporated into lighting design
  - Beneficial to patients and staff
  - Light delivered at low / no cost
  - Light delivered in a form preferable to most people

- Provide opportunities to control daylight to prevent glare and thermal discomfort

http://designisaward.shawcontractgroup.com/DesignAward/GlobalWinners

http://www.archilovers.com/projects/67226/the-royal-children-s-hospital.html

Lighting design

- Lighting should be glare free, shadow free for elderly
- Light levels in transitional spaces balanced with those of adjoining spaces
- Need higher light levels for visual tasks
- High color quality lighting recommended where fine color discrimination is needed
- Need higher exposure to bright light for stimulating circadian system
- Adequate variation in light levels in residential environments for elderly to support sleep-wake patterns

http://perkinswill.com/sites/default/files/styles/pw_hero_image/public/project-imagery/jhh_adultlobby_main3.jpg?itok=IVS5S8b1

Future research needs to document:

- Illuminances in key locations to assess averages & uniformity
- Full SPDs of lighting available at different times of day
- Metrics for assessment of key issues like flicker, glare, etc.
- Full descriptions of methods & participants
- Limitations of scope of application

References

Slide 3
U.S. Department of Energy - Advanced Energy Retrofit Guide: Healthcare Facilities
https://buildingdata.energy.gov/cbrd/resource/1325
U.S. Energy Information Administration - Commercial Buildings Energy Consumption Survey (CBECS)
http://www.eia.gov/consumption/commercial/

Slide 4
U.S. Bureau of Labor and Statistics – The Economics Daily
http://www.bls.gov/opub/ted/2015/registered-nurses-have-highest-employment-in-healthcare-occupations-anesthesiologists-earn-the-most.htm

Slide 5
U.S. Bureau of Labor and Statistics – Spotlight on Statistics
http://www.bls.gov/spotlight/2016/a-look-at-healthcare-spending-employment-pay-benefits-and-prices/home.htm
Forbes – Doctors' Virtual Consults With Patients to Double by 2020
http://www.healthcareitnews.com/news/top-5-healthcare-it-trends-2015-poised-shake-industry
Accenture Consulting – Healthcare Technology Vision 2015
https://www.accenture.com/us-en/insight-healthcare-technology-vision-2015