Health and well-being responses to daylighting in northern buildings

Presenting by

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Northern Canada (50°N)

People
Light-related health & wellbeing

Building
Daylighting design & performance

Climate
Strong day/night cycles (photoperiods)
Questions

• How do Northern buildings respond to the climate and people’s light-related needs?

• What are the potential health and wellbeing responses of occupants to daylighting inside Northern buildings?
Objective
Develop the daylighting design of northern buildings for occupants’ health and wellbeing
Light-related Health & wellbeing

- Photobiology
- Psychology
- Biophilic design

Refer to: (CIE, 2018, 2019; Dai, Huang, Hao, Lin, & Chen, 2018; DiLaura, Houser, Mistrick, & Steffy, 2011; International WELL Building Institute, 2018; Jung, 2017; Jung & Inanici, 2019; Konis, 2017; Lucas et al., 2014; Parsaee, Demers, Hébert, Lalonde, & Potvin, 2019; Rea & Figueiro, 2016)
Non-image forming effects

Day

- High alertness
- Fastest increase in blood pressure
- Cortisol release
- Lowest body temperature
- Deep sleep

Night

- Best coordination
- Fastest reaction times
- Highest body temperature
- Highest blood pressure
- Melatonin secretion
Proper Light at Proper Time

CIE (October 3, 2019), Position statement on non-visual effects of light
Light-related Health & wellbeing

• Lighting standards and practice often focus on image forming (visual) and energy efficiency aspects of light, with little or no consideration of non-image forming responses
Light-related Health & wellbeing

• An improper balance between these aspects can compromise human well-being, health and functioning related to lighting ambiance.
Light-related Health & wellbeing

• Many lighting products, especially LED systems, are available in the market that are aimed to affect non-image forming aspects.
Don’t unnecessarily decrease or restrict availability and accessibility to daylight and outdoor nature inside buildings.

*CIE (October 3, 2019), Position statement on non-visual effects of light*
Challenging conditions in Northern Canada

Very low window-to-wall ratio (WWR) recommended by National Energy Code of Canada for Buildings (NECB)

Refer to (NRC, 2015)
Northern Canada’s Climate
Northern Canada’s Climate

Cambridge Bay
[69° N]
Northern Canada’s Climate
Cambridge Bay [69° N]

- Strong photoperiods (Day/night cycles)
- Extreme cold weather

Published by (Weather spark, 2018)
Northern Canada’s Climate lighting features

Cambridge Bay [69° N]

Photoperiod

Solar elevation

- Summer solstice
- Fall/Spring equinox
- Winter solstice
Northern Buildings

most often been designed with low WWR’s to respond to thermal issues
Northern Buildings

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Northern Buildings

some few cases, such as airports, have very high WWR’s
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Observation

Openings are mostly covered by blinds in sunny and cloudy days
Daylight factor in a typical space recommended for Northern Canada

WWR = 20%
Experimental set-up

Models (n=18)
Scale 1:50

Measurement
Raspberry Pi fisheye camera
HDR imagery

Parameter
Health & wellbeing

Distribution
Color temperature

![Models (n=18)]
Scale 1:50

![Measurement]
Raspberry Pi fisheye camera
HDR imagery

![Parameter]
Health & wellbeing
Distribution
Color temperature
Experimental set-up

Outdoor lighting

Quebec City
11:15am-12:45pm
September 18, 2019
South direction
Sunny
Cloud cover = 0

Measurement
Every 15 minutes

Konica CL-200A Chroma Meter

IL5000 Research Radiometer

Parameter
Health & wellbeing

Photopic lux
Equivalent Melanopic lux
Color temperature
CIE Chromaticity
Models
Scale 1:50

Variables:
• WWR (from 10% to 80%)
• Form of openings
• Simple shadings/reflectors with different
  • Color (blue for non-image forming effects, Red for image forming effects)
  • Opaque/Transparent (blue/red)
  • Orientation (vertical/horizontal)
## Analysis

### Health and wellbeing responses

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<th>Case</th>
<th>Side view</th>
<th>Photopic</th>
<th>Melanopic</th>
<th>Ratio (M/P)</th>
<th>Back view</th>
<th>Photopic</th>
<th>Melanopic</th>
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*Legend: cd/m² - Candela per square meter, EMcd/m² - Equivalent Melanopic Luxes per square meter, Ratio (M/P) - Melanopic to Photopic Ratio*
Analysis

Health and wellbeing responses

Case

Biophilic | Heat loss | Side View | CCT | Illuminance | EML | Back View | CCT | Illuminance | EML

1

2

3

4

5

6
Analysis
Health and wellbeing responses
Analysis

Health and wellbeing responses
Analysis
Health and wellbeing responses

Indoor condition

Outdoor condition

Back View

Side View

Time

Outdoor condition

PL
EML
CCT

Indoor condition

PL
EML
CCT
Conclusion & future studies

• Photobiological and biophilic lighting requirements must be considered in building design and recommendations for Northern Canada.

• A low WWR could not provide a healthy indoor lighting environment for Northern occupants.

• Availability of daylighting and accessibility to outdoor nature and natural cycles are compromised by a low WWR.

• A high WWR could improve photobiological and biophilic aspects of indoor lighting. However, it will cause serious thermal and energy issues.

• The use of opaque/transparent reflectors could improve indoor lighting which must be developed and optimized for Northern Canada.
Conclusion & future studies

• Photobiological and biophilic lighting requirements must be considered in building design and recommendations for Northern Canada.

• Adaptive and high-performance façade systems could be developed to deal with the issues and provide northern occupants a healthy environment.

• Lighting adaptation scenarios must be developed to respond to individual’s lighting needs and local photoperiods.

• An integrated approach must be developed to assess photobiological and biophilic aspects of light in the space.
Thank you for your attention!
Any question?
References


