WEARABLE LIGHT SENSORS
IN CASE STUDY EVALUATIONS

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Presentation Outline

Short overview on “Case Studies”
Why do we need wearable devices?
Which sensors are out there?
Commercial sensors
  • Actiwatch
  • LYS Button
  • Movisens
Problems
Recommendations
Case Studies

What you should expect to see

Daylighting integration is an asset for the retail sector

Generous windows, daylight harvesting and Human-Centric LED Lighting in the pilot project IKEA Kaarst store

The project

When you arrive at IKEA Kaarst, the feeling is that you are in a building with an open and inviting atmosphere. The spacious open plan with large, bright windows, daylight harvesting technology and LED lighting creates a welcoming environment. The store is designed to provide a comfortable and enjoyable shopping experience for customers.

Monitoring

The site was monitored from February to July 2016 to evaluate the impact of daylight on the performance of the store. The monitoring system recorded the amount of daylight entering each area, as well as the temperature and humidity levels.

In addition to the monitoring data, surveys were conducted to gather feedback from customers about their experience in the store. The results showed that customers had a positive perception of the store's natural light levels and that they enjoyed the overall shopping experience.

Further Information

Company: IKEA Kaarst

Acknowledgements

Sponsorship: The Sunlight Energy Agency

Further reading:


IEA SHC Task 61 / EBC Annex 77 »Integrated Solutions for Daylighting and Electric Lighting«
Case Studies

A coherent framework for the evaluation

Monitoring protocol

Case studies

Icons: Niko Gentile
Pictures: Julio Fernandes Amodia, Rawan Abdulhaq, Ceren Yilmaz, Kieu Pham, Veronica Garcia-Hansen, Claudia David Amorim, Rafael Campama Pizarro

IEA SHC Task 61 / EBC Annex 77 »Integrated Solutions for Daylighting and Electric Lighting«
## Case Studies

### Existing buildings with a “(day)lighting touch”

<table>
<thead>
<tr>
<th>Country</th>
<th>Name</th>
<th>Building Type</th>
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<tbody>
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<td>AUS</td>
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<tr>
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<td>Automated shade and high-resolution lighting control</td>
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*Image source: Elaboration by Niko Gentile on original design by freepik.com (CC-BY 3.0).*
Why do we need wearable devices?

We want to investigate light and human experience.

Why do we need wearable devices?

During the day, a person is exposed to different lighting conditions.

We need:

• **dynamic measurement methods**  
  (static measurements do not tell us the full story)
• ways to measure **personal light exposure**
Why do we need wearable devices?

Light spectrum has influence on visual and non-visual effects of light on humans

So, we want devices that can measure:

- Full spectrum (ideally)
- Photopic illuminance (at least)
- Different wavelengths (compromise)

And we want to correlate photometric measurements with human factors (e.g. activity levels)
Which sensors are out there?

Commercial devices
- Philips Actiwatch
- LYS Button
- Movisens
- Others ...

“Research” devices
- Daysimeter
- LuxBlick
- Others ...

Image sources:
https://lystechnologies.co.uk/products/lys-1-0-wearable
https://www.lrc.rpi.edu/programs/lightHealth/img/oldDaysimeter.jpg
Philips Actiwatch Spectrum Plus

Worn on the wrist

Tracks:
- Activity
- Sleep/wake patterns
- Photopic illuminance
- RGB

Philips Actiwatch Spectrum Plus

**Illuminance measurements**

**Measured under an overcast sky outdoors**
- Need for calibration factor
- According to Markvart et al. (2015), who tested 48 Actiwatches, calibration should be device specific

**Measured under a combination of red and green light**
- Practically not usable for measuring red/green light
- Not very useful for "circadian" lighting installations

References:

Graphs from:
Graphs from:
Philips Actiwatch Spectrum Plus

Activity and sleep analysis

Caution:
Actiwatch data alone are often misleading and not sufficient due to wearing the instrument at the wrist

Image Source:
http://ak1.ostkcdn.com/images/products/7307454/7307454/Marcy-Foldable-Exercise-Bike-P14778368.jpg
LYS Button 1.0

Can be attached to clothing via clip

Tracks:
- Photopic illuminance
- Color temperature
- RGB, IR
- Activity level

Image source: https://lystechnologies.co.uk/products/lys-1-0-wearable
LYS Button 1.0

- You can get a "light stimulus" value through an app
- Additional paid software is needed to get the data as Excel file (via email link) ➔ rather expensive

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LYS Button 1.0

Illuminance measurements

Measured under daylight on a sunny day indoors

- Need for device specific calibration factor
- Directional sensitivity (rotated device gives different result)
- Error appears to be smaller for lower light levels

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<tr>
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<th>Average absolute error (lux)</th>
<th>Average relative error (%)</th>
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<tr>
<td>Below 500 lux</td>
<td>-56</td>
<td>-18%</td>
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<tr>
<td>500-1000 lux</td>
<td>-300</td>
<td>-49%</td>
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<tr>
<td>Above 1000 lux</td>
<td>-399</td>
<td>-32%</td>
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</tbody>
</table>

**LYS Button 1.0**

**Color temperature measurements**

Measured under daylight on a sunny day indoors (one measurement with blinds closed under electric light)
- average error 9%

![Image of LYS Button 1.0](https://www.konicaminolta.com.cn/instruments/products/light/cl500a/img/CL-500A.jpg)

**Color temperature**

Blue line: reference spectrophotometer (Konica Minolta CL-500A)
Green line: LYS Button

Image source:

IEA SHC Task 61 / EBC Annex 77 »Integrated Solutions for Daylighting and Electric Lighting«
LYS Button 1.0

**Activity analysis**

- Counts how many times within an interval the acceleration exceeds a limit
- Result is expressed in g
- Small investigation is needed to figure out what the results mean

Image Source:
Movisens LightMove 4

Worn on the wrist

Tracks:
- Photopic illuminance
- Color temperature
- Activity level
- Sleep/wake patterns
- Temperature

Movisens LightMove 4

**Illuminance measurements**

Unfortunately, we do not have a comparison with a calibrated sensor

LYS vs Movisens: they don’t always tell the same story
• On the shirt vs on the wrist
• Sensor inaccuracies

![Illuminance graph](image-url)

-LYS Button
-Movisens

IEA SHC Task 61 / EBC Annex 77 »Integrated Solutions for Daylighting and Electric Lighting«
Movisens LightMove 4

Activity and sleep analysis

- Measures acceleration in 3 axes and provides average
- Small investigation is needed to figure out what the results mean (although some indications for possible activities are provided by the sensor)

Remember:
Data can still be misleading due to wearing the instrument at the wrist

Image Source:
Problems

• **Not always reliable light measurements**
  Markvart et al. (2015) have found differences between devices of the same type (Actiwatch) of up to 60% → matches well with our experience

• **Wrist worn sensors: measurements do not match those a person receives at the eye**
  Aarts et al. (2017) have found differences between devices worn by the same person at different body locations (up to 27% when worn on the wrist compared to at the eyes)

• **Some sensor manufacturers claim scientific validation of their products, but often just stop communicating when asked for details**

References:
Recommendations

• Use more than one type of measuring device and compare results

• Calibration factors
  
  Needed for each individual device, but not supplied by manufacturers of these low-cost devices

  Researchers prepared to work with manufacturers on this → cost factor

• Sensor closer to the eye and facing the same way is preferable

• Combine measurement data with observations / diary entries

• Be critical when looking at the results you get
  
  Avoid making conclusions based on questionable data