CHRONOBIOLOGY & HEALTH

TRANSLATIONAL SENSORY & CIRCADIAN NEUROSCIENCE

# MeLiDos

## Work Package 2: Recommendations for wearable light loggers based on use case studies and their usability

MeLi Dos

Metrology for wearable light loggers and optical radiation dosimeters

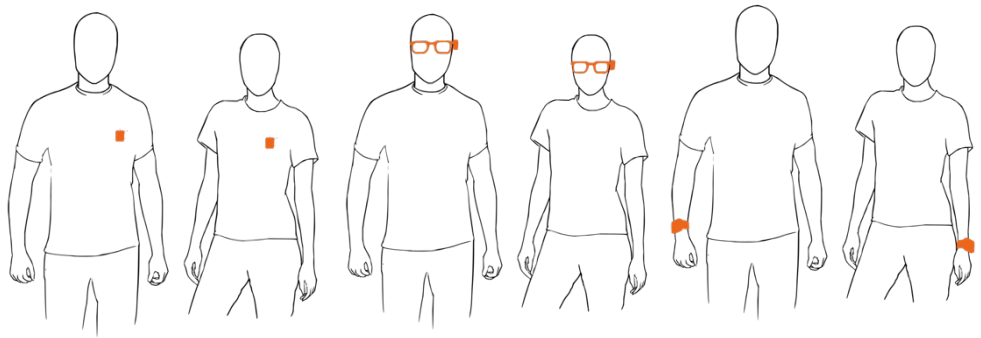
METROLOGY PARTNERSHIP | EURAMET

Co-funded by the European Union

# Wearable Light Logger Data is Complex, Because…

…there are 50+ Wearable Devices on the market that try to measure light exposure:

- Various wearing positions which all relate differently to the measure of interest (retinal exposure)
- No common set of output quantities / units
- No or very limited Metadata
- No standard output format (file format)
- No calibration standard, i.e., unknown accuracy for
  - Spectral Sensitivity
  - Angular Response
  - Linearity
  - …
- No or little help to check wearer compliance



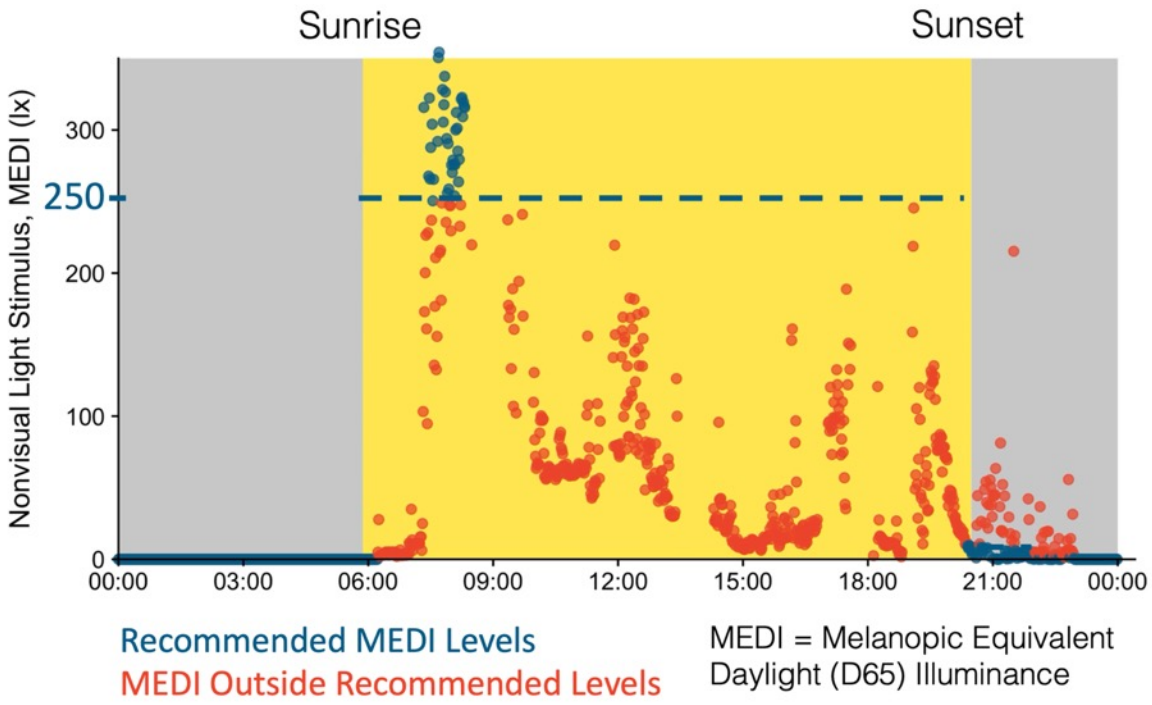
Illustrations: Max Dobberkau (MPI for Biological Cybernetics)

# Wearable Light Logger Data is Complex, Because…

Stationary Measurements: ⟷ Wearable Data:

**α-opic equivalent daylight (D65) illuminance**[3]

| | Scene 1 |
|---|---|
| Melanopsin (MEDI; lux) | 241 |




Scene Measurements (Few Datapoints, per Setting) ⟷ Time Series (Lots of Data, per Participant)

# WP 2.1

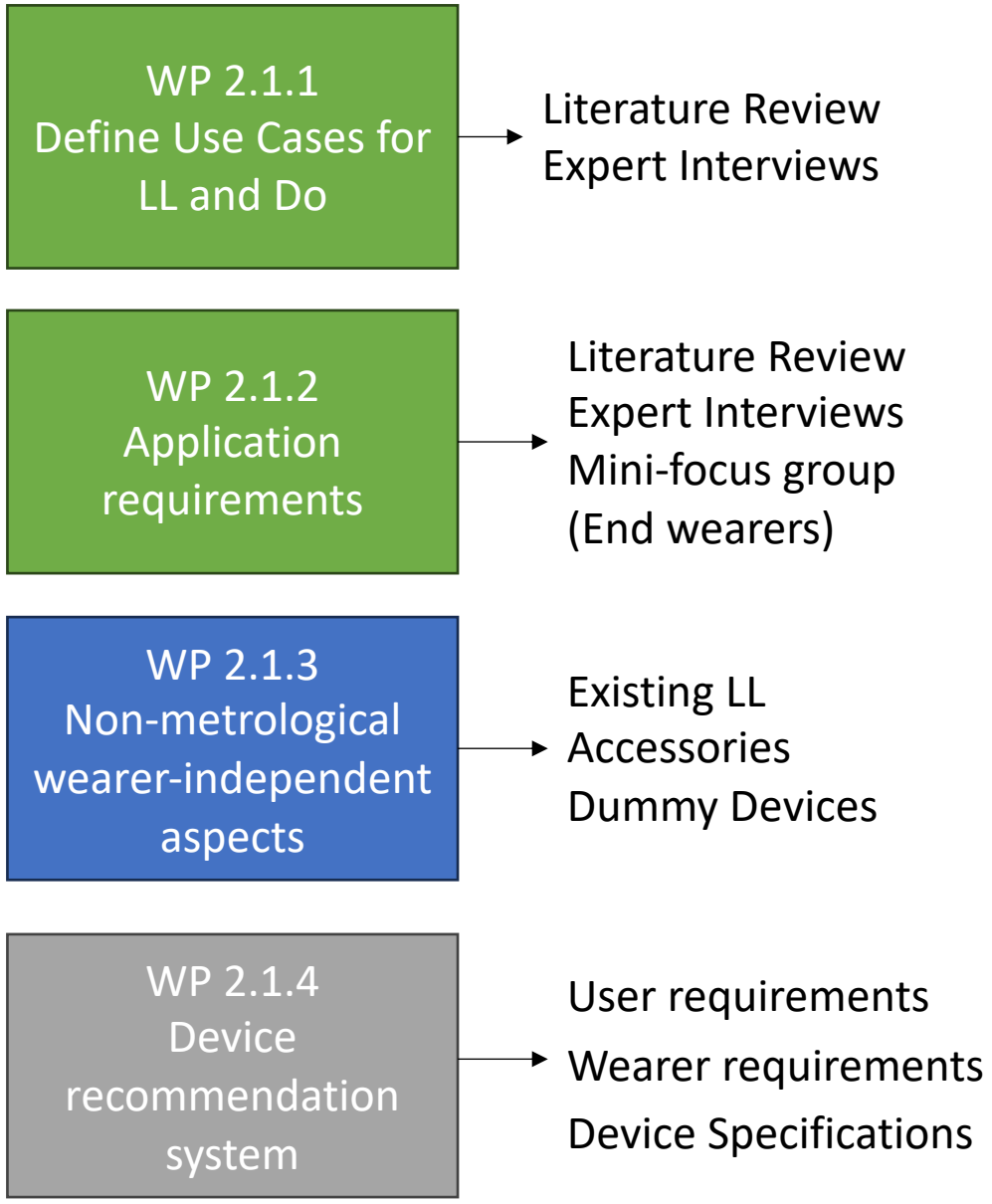
## Definition of the landscape of use cases and application requirements

# Work Package 2: Overview

Underway | Has Started | Not Yet Started

- Task 2.1: Definition of the landscape of use cases and application requirements
  - A2.1.1: Definition of the landscape of use cases (TL: THUAS)
  - A2.1.2: Definition of the application requirements from the User perspective (TL: THUAS)
  - A2.1.3: Identification of non-metrological wearer-independent aspects (TL: HSLU)
  - A2.1.4: Definition of a recommendation system for device specifications (TL: TUM)

>> Task 2.1: What device (specs) to choose, depending on use case and requirements?
Time-Frame: Until Q3 2024



# Task 2.1 How Can You Contribute?

WP 2.1.1
Define Use Cases for LL and Do

WP 2.1.2
Application requirements

Do you have experience in using light loggers and have not been interviewed? Get in touch

WP 2.1.4
Device recommendation system

Review and test recommendation system

# WP 2.2

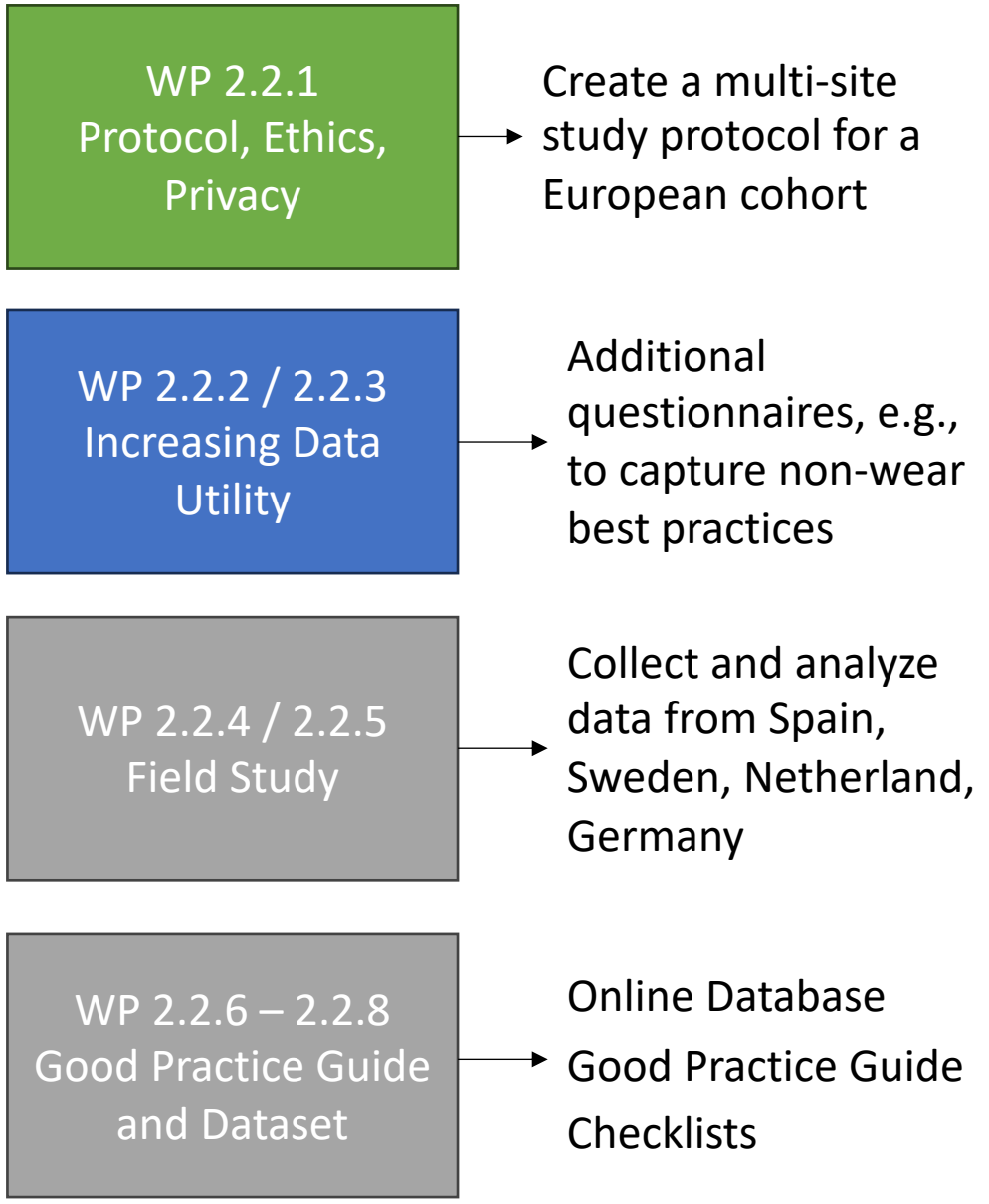
## Development of a high-quality multi-site light logging data set

# Work Package 2: Overview

Underway | Has Started | Not Yet Started

- Task 2.2: Development of a high-quality multi-site light logging data set
  - A2.2.1 Field testing: Development of research protocol, ethics approval and privacy assessment (TL: FUSP-CEU)
  - A2.2.2 Development of a consensus instrument to capture auxiliary data (TL: TUM)
  - A2.2.3 Strategies to improve the data quality (TL: HSLU)
  - A2.2.4 Field testing: Data collection (TL: FUSP-CEU)
  - A2.2.5 Field testing: Data analysis (TL: TUM)
  - A2.2.6 High quality dataset (TL: FUSP-CEU)
  - A2.2.7 Good Practice Guide and checklist for field data collection and formatting (TL: TUM)
  - A2.2.8 GPG review and submission (TL: TUM)

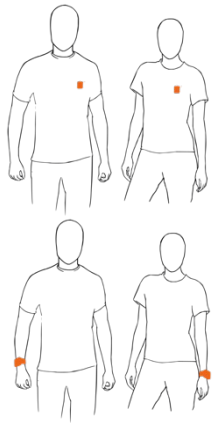
>> Task 2.2: What are good practices when collecting data with wearable light loggers?
Time-Frame: until Q2 2026



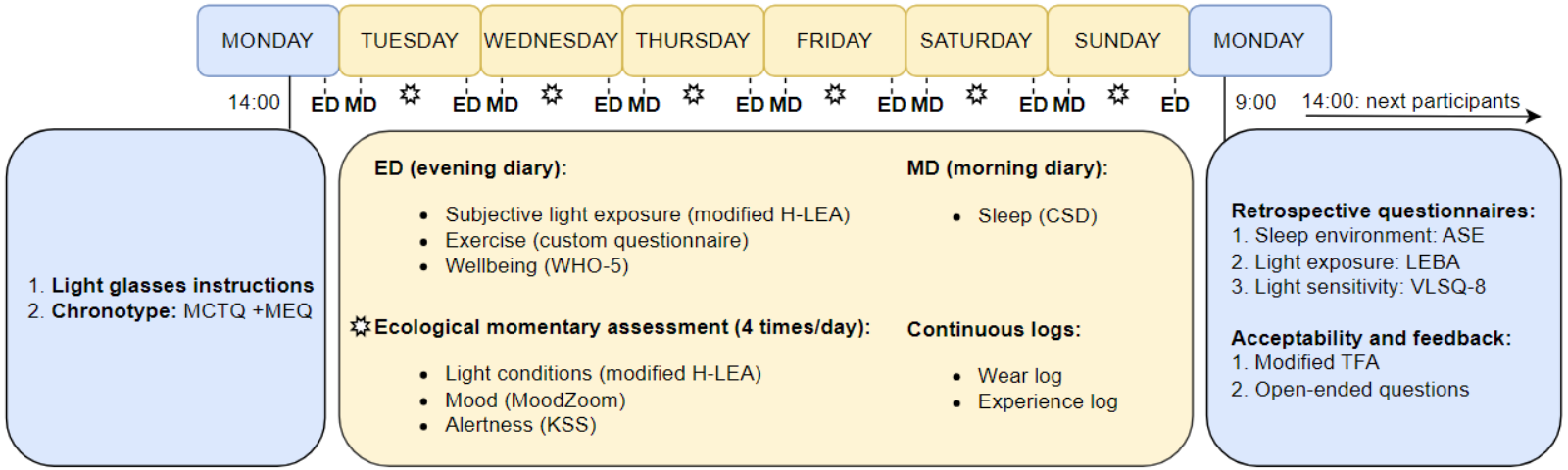
# Field Test

- Aims:
  1. Characterise individuals' light exposure over seven7 days utilizing a corneal-plane light sensor placed at the  center of a non-prescription glasses frame;
  2. Collect data across four distinct geographical locations (Spain, Sweden, Netherlands, Germany); and
  3. Investigate the correlations between recommended light exposure, physiological variables such as chronotype and light sensitivity, and behavioral outcomes including exercise, mood, and alertness.

ActLumus (Condor) on non-prescription glasses ("Light glasses") + secondary devices

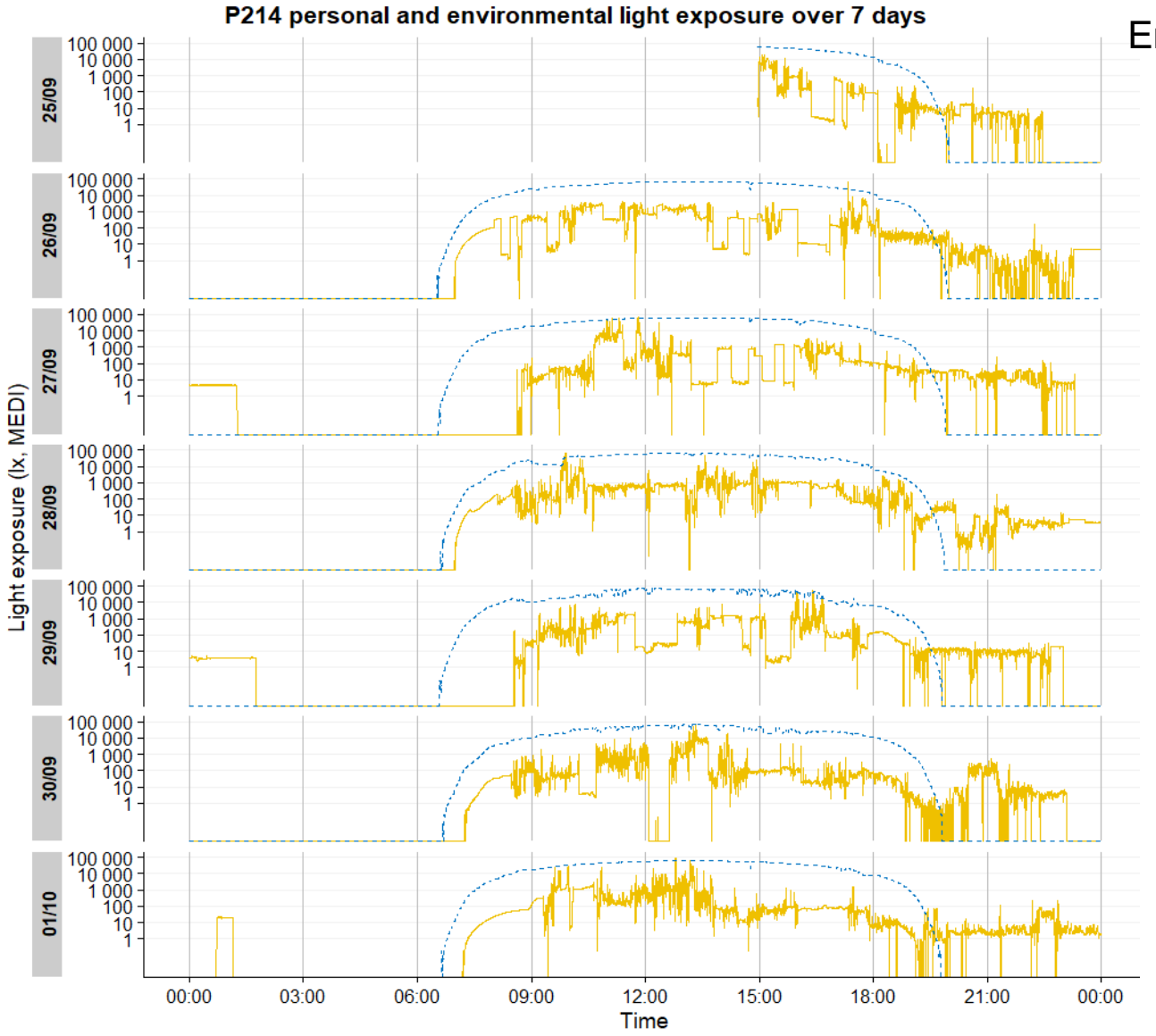


Sampling interval: 10s



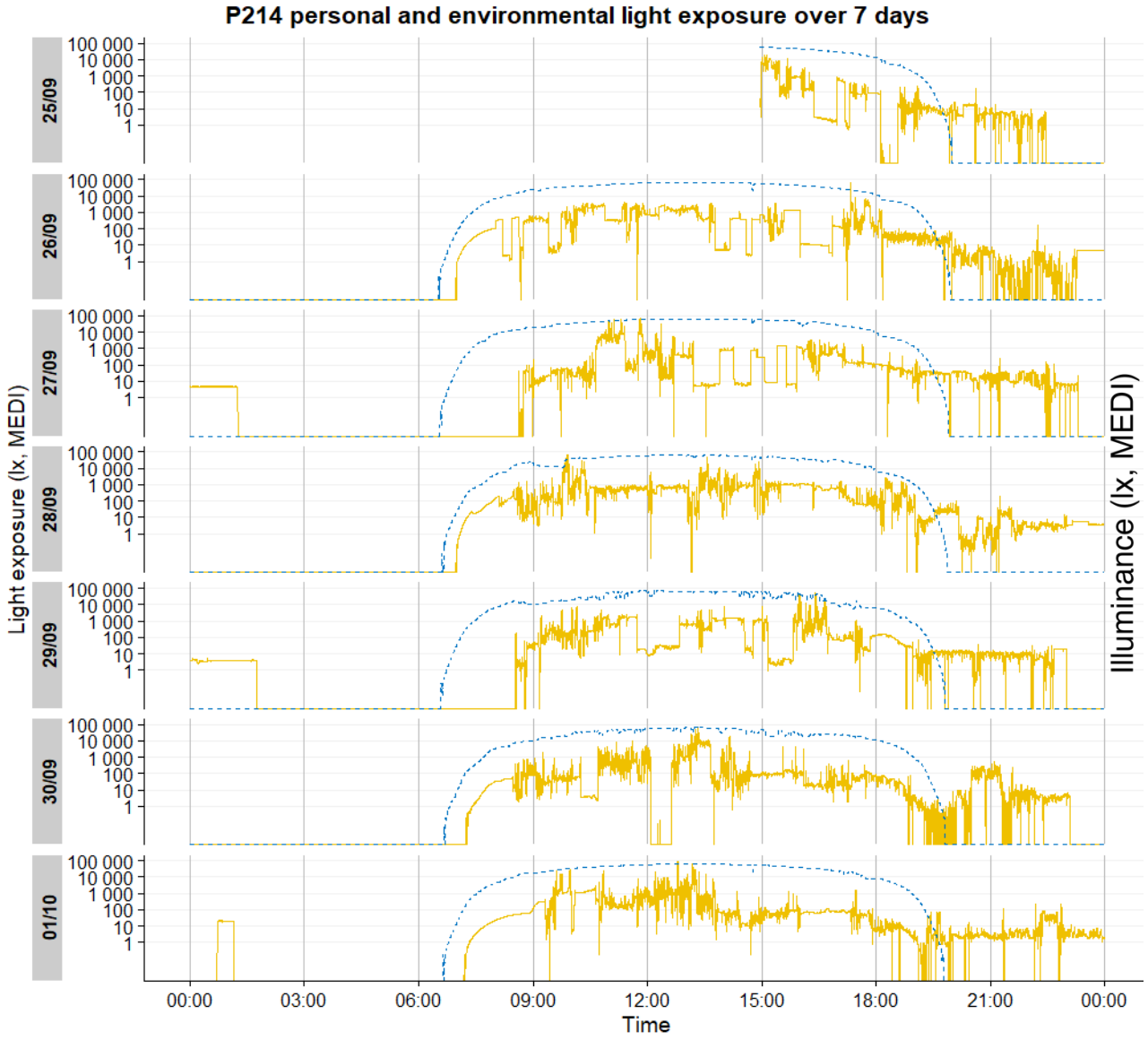

Draft Protocol

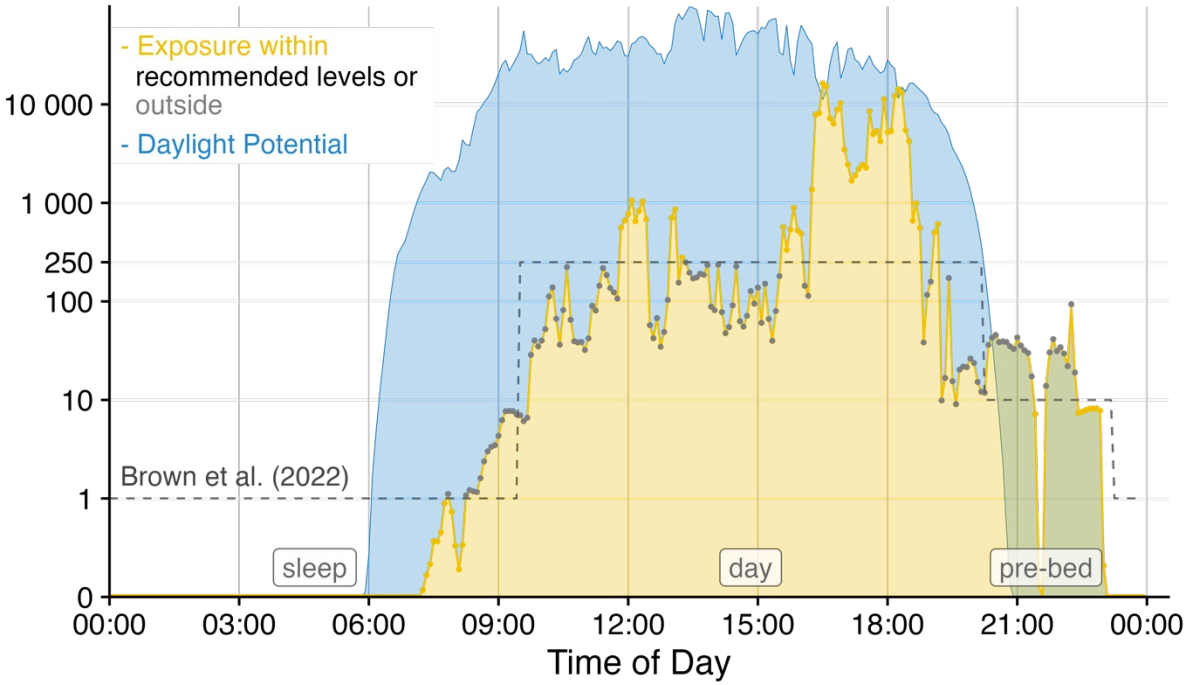
# Environmental Data




Environmental light measurement set-up

# Example Light Exposure Data



# Task 2.2 How Can You Contribute?

WP 2.2.6
High Quality
Dataset

Enrich data base by using contributed data sets

WP 2.2.7
Good Practice
Guide & Checklists

WP 2.2.8
Review &
Submission GPG

Review, test, adopt, and promote Good Practice Guide

# WP 2.3

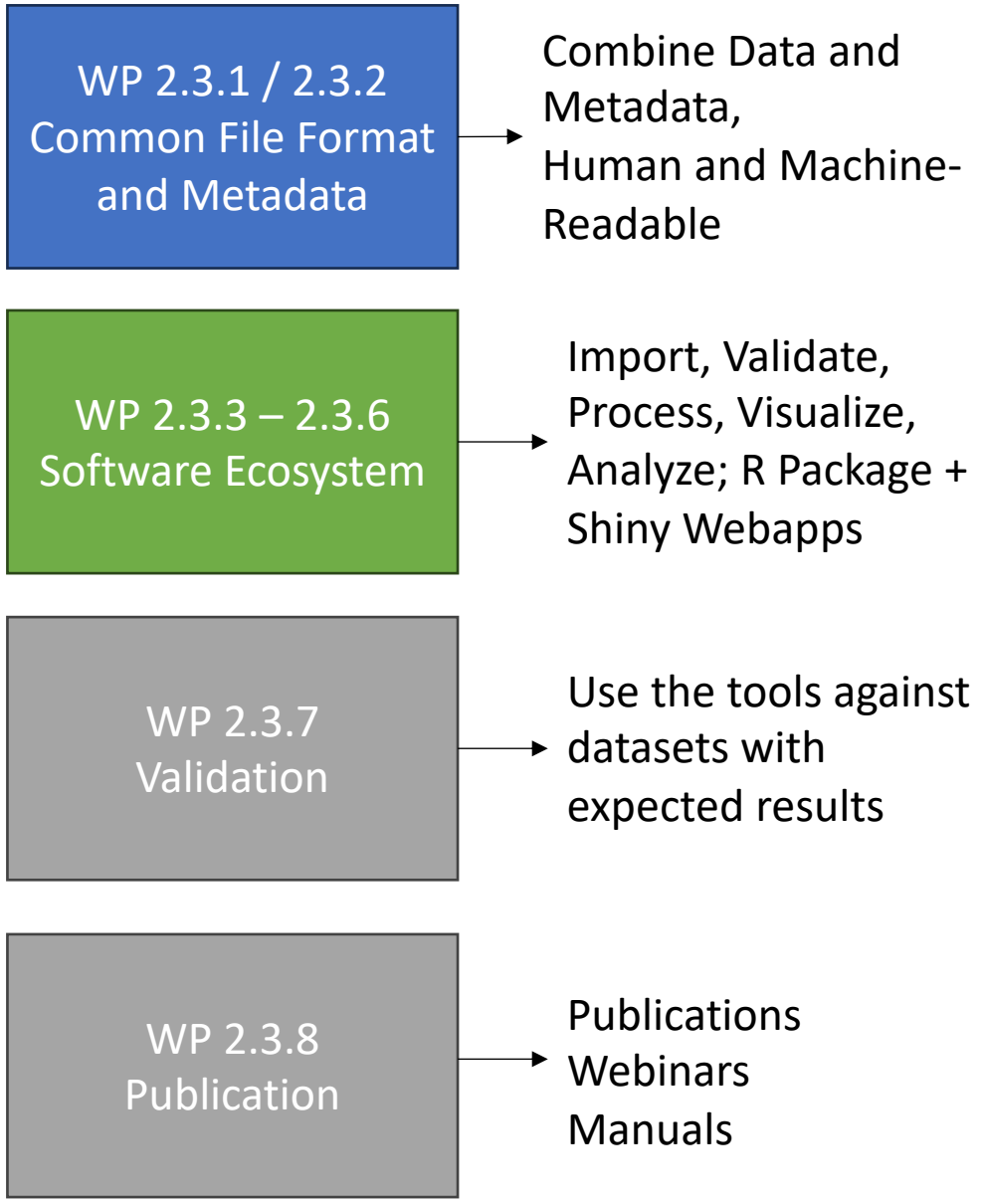
## Develop a research user software ecosystem

# Work Package 2: Overview

Underway | Has Started | Not Yet Started

- Task 2.3: Develop a research user software ecosystem
  - A2.3.1 Develop a joint accessible and interoperable data format for light dosimetry data (TL: TUM)
  - A2.3.2 Develop a metadata descriptor (TL: TUM)
  - A2.3.3 Develop a web-based and command-line-based tooling for validating data and metadata formats (TL: TUM)
  - A2.3.4 Develop a command-line tool for analysis and processing of light dosimetry data (TL: TUM)
  - A2.3.5 Develop graphical user interface tools for light dosimetry data (TL: TUM)
  - A2.3.6 Develop novel ways of visualizing light dosimetry data (TL: TUM)
  - A2.3.7 Validation of the software and user instruction manual (TL: TUM)
  - A2.3.8 Publication of the software ecosystem (TL: LNE)

>> Task 2.3: How should and can we process light logger data FAIRly (Findable, Accessible, Interoperable, Reusability) and efficiently
Time-Frame: Until Q2 2026



# LightLogR – A Joint between Light Logger Data and Analysis

```
#ActLogModel=2.0.0
+-------------+ Condor Instruments Report +-------------+
SOFTWARE_VERSION : 2.1.0
LOG_FILE_VERSION : 1.0.3
LOG_CREATION_SV : 2.1.0
SUBJECT_NAME :
SUBJECT_GENDER :
SUBJECT_DATE_OF_BIRTH : 01/01/1900
DEVICE_PLACEMENT :
SUBJECT_DESCRIPTION : -
DEVICE_ID : 1020
DEVICE_MODEL : AL0101
HARDWARE_VERSION : 1.0
FIRMWARE_VERSION : 1.2
MEMORY_SIZE : 7963136
LOG_SIZE : 156940
MEMORY_USAGE : 1.97 %
BATTERY_VOLTAGE : 4.1812
ERROR_FLAG : -
ERROR_CODE : 0
POWER_DOWN_FLAG : 0
TAT_THRESHOLD : -
ORIENTATION : 16
MODE : -
INTERVAL : -
DATA_CORRECTION : 0
DATA_CORRECTION_DESCRIPTION : None
FILE_DATE_TIME : 14/07/2023 22:31:24
CONNECTION_SYSTEM_DATE_TIME : 14/07/2023 22:31:06
CONNECTION_DEVICE_DATE_TIME : 14/07/2023 22:31:06
DEVICE_PLACEMENT :
+-----------------------------------------------------------------------+
DATE/TIME;MS;EVENT;TEMPERATURE;EXT TEMPERATURE;ORIENTATION;PIM;PIMn;TAT;TATn;ZCM;ZCMn;LIGHT;AMB LIGHT;RED LIGHT;GREEN
LIGHT;BLUE LIGHT;IR LIGHT;UVA LIGHT;UVB LIGHT;STATE;CAP_SENS_1;CAP_SENS_2;F1;F2;F3;F4;F5;F6;F7;F8;MELANOPIC EDI;CLEAR
23/06/2023
11:57:14;0;0;22.88;0.00;16;0;0;0;0;0;0;221.17;0.00;0.00;0.00;0.00;0.00;0.04;0.00;0.00;4;230;167;0.0046;0.0166;0.0175;0.028
9;0.0374;0.0393;0.0355;0.0261;188.85;0.11
23/06/2023
11:58:14;0;0;22.94;0.00;16;0;0;0;0;0;0;221.03;0.00;0.00;0.00;0.00;0.00;0.04;0.00;0.00;4;229;168;0.0046;0.0165;0.0175;0.028
8;0.0375;0.0393;0.0355;0.0260;188.06;0.11
23/06/2023
11:59:14;0;0;23.06;0.00;16;0;0;0;0;0;0;227.30;0.00;0.00;0.00;0.00;0.00;0.06;0.00;0.00;4;224;168;0.0051;0.0173;0.0183;0.030
```

| timestamp | sensor | lux | kelvin | rgbR | rgbG | rgbB | rgbIR | movement | mEDI | R' | G' | B' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 21-06-2023 00.00.12 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.00.27 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.00.42 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.00.57 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.01.12 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.01.27 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.01.42 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.01.57 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.02.12 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.02.27 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.02.42 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.02.57 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.03.12 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.03.27 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.03.42 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.03.57 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.04.12 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.04.27 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |
| 21-06-2023 00.04.42 | New Button | 0 | 1391 | 0 | 0 | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 |

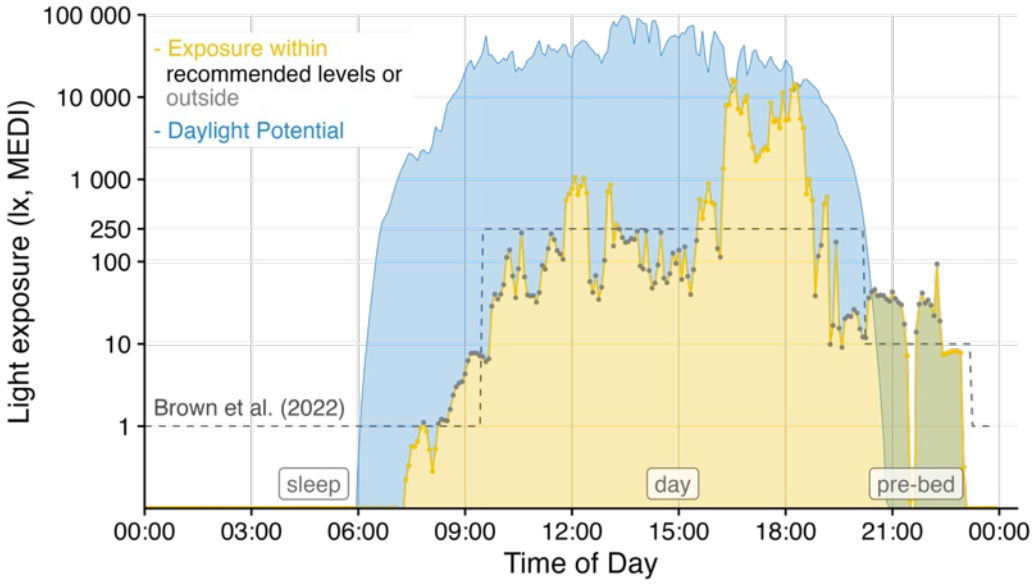
| record_id | redcap_repeat_instrument | redcap_repeat_instance | bedtime | sleep | sleepdelay | awakenings | awake_duration | offset |
|---|---|---|---|---|---|---|---|---|
| 205 | | | | | | | | |
| 205 | morning_sleep_diary | 1 | 28.08.2023 22:37 | 28.08.2023 23:20 | 15 | 3 | 10 | 29.08.2023 09:37 |
| 205 | morning_sleep_diary | 2 | 29.08.2023 23:30 | 29.08.2023 23:40 | 10 | 1 | 5 | 30.08.2023 09:21 |
| 205 | morning_sleep_diary | 3 | 30.08.2023 23:15 | 30.08.2023 23:15 | 15 | 3 | 2 | 31.08.2023 09:47 |
| 205 | morning_sleep_diary | 4 | 31.08.2023 23:00 | 31.08.2023 23:15 | 10 | 1 | 5 | 01.09.2023 09:30 |
| 205 | morning_sleep_diary | 5 | 01.09.2023 23:00 | 01.09.2023 23:10 | 5 | 1 | 40 | 02.09.2023 09:10 |
| 205 | morning_sleep_diary | 6 | 02.09.2023 22:15 | 02.09.2023 22:55 | 10 | 0 | 0 | 03.09.2023 08:47 |
| 205 | morning_sleep_diary | 7 | 03.09.2023 21:20 | 03.09.2023 21:30 | 10 | 1 | 5 | 04.09.2023 07:25 |

LightLogR

MeLi Dos

Metrology for wearable light loggers and optical radiation dosimeters

EURAMET

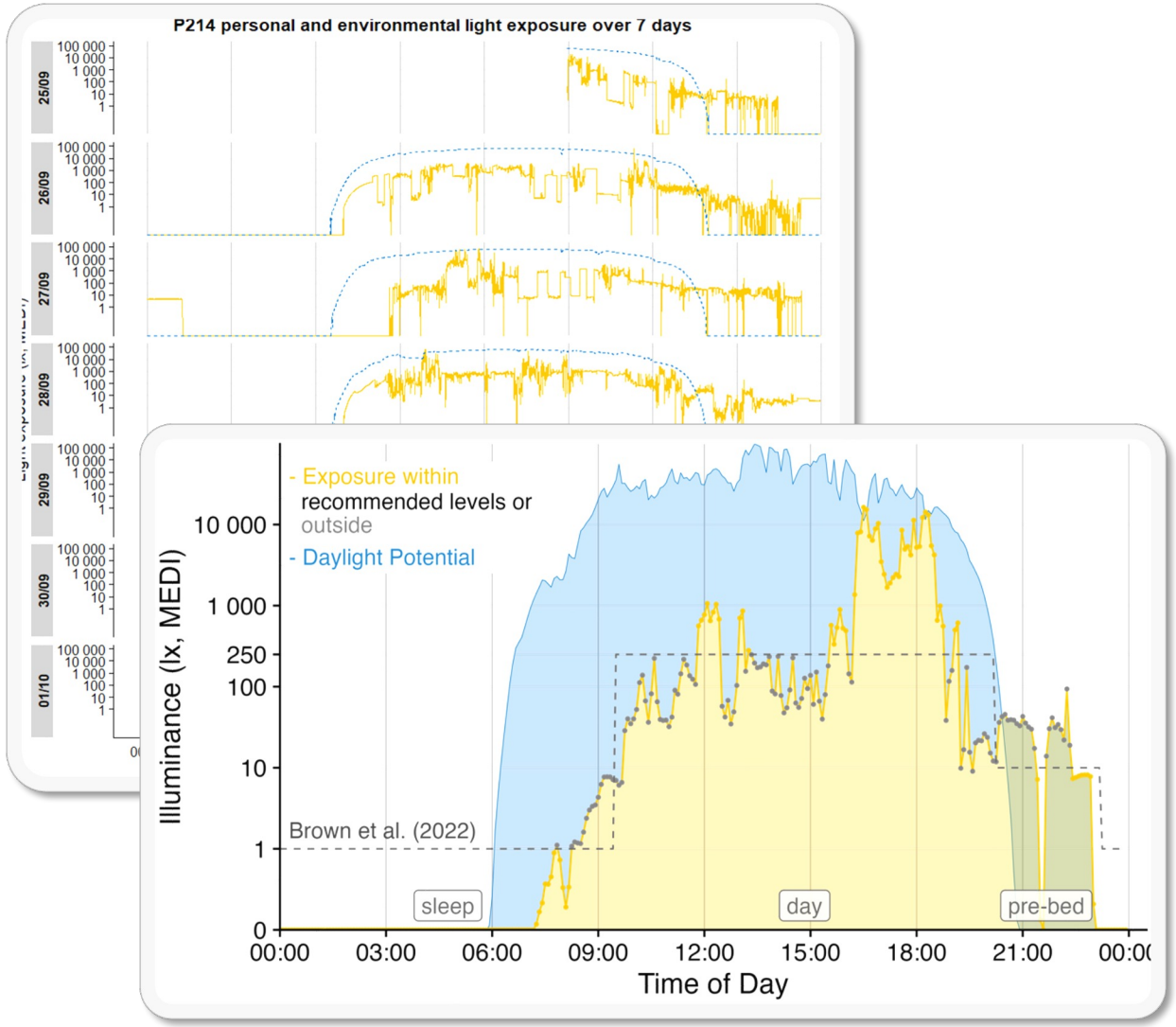


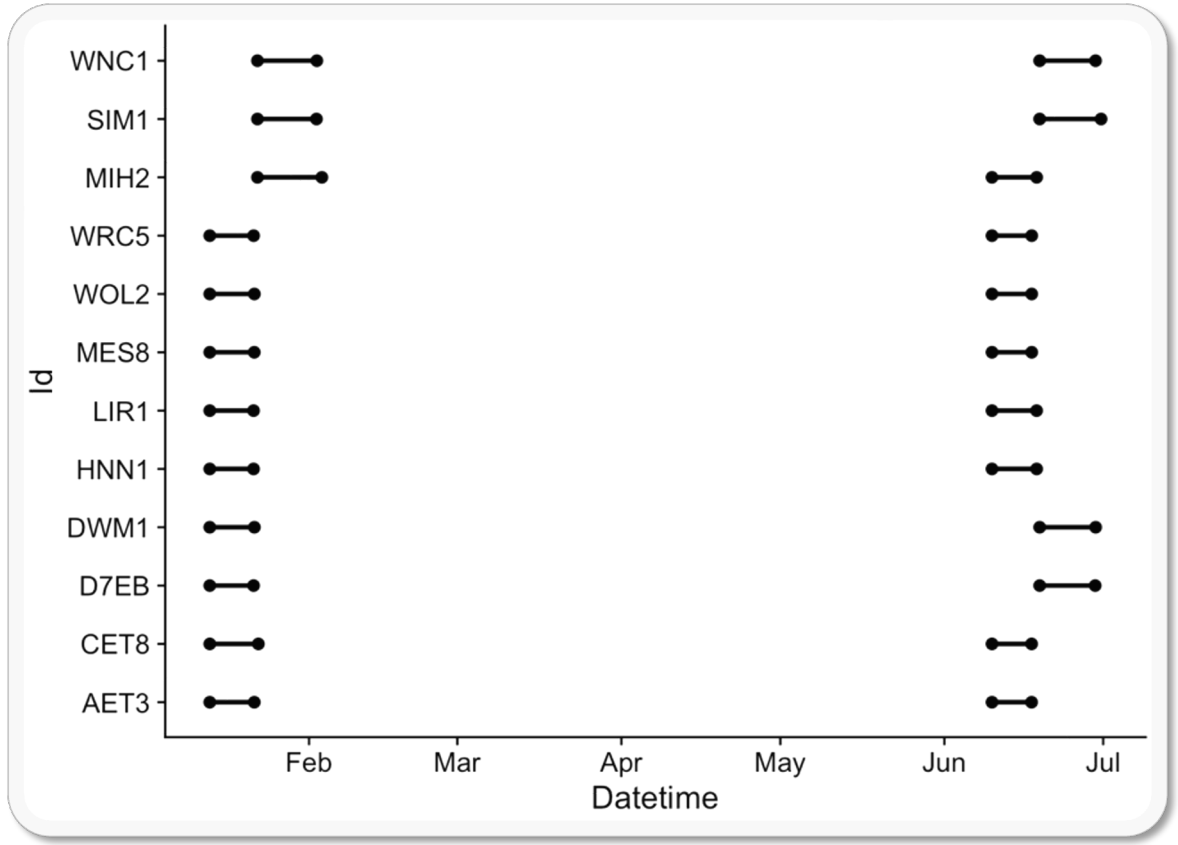

| Characteristic | Winter, N = 39[1] | Summer, N = 33[1] |
|---|---|---|
| Geometric mean (lx) | 1.05 (0.52, 1.70) | 3.01 (2.25, 4.75) |
| Geometric sd (lx) | 54 (15, 179) | 37 (19, 216) |
| Luminous Exposure (lx*h) | 689 (441, 1,161) | 4,691 (2,721, 7,944) |
| Time above 250 lux (h) | 0.58 (0.33, 1.10) | 2.53 (1.70, 3.55) |
| Time above 1000 lux (h) | 0.03 (0.00, 0.08) | 0.88 (0.45, 1.29) |
| Mean timing of Light above 250 lux (h) | 13.85 (12.16, 14.67) | 13.48 (12.48, 14.37) |
| Days without Metric | 1 | 0 |
| Intradaily Variability | 0.98 (0.64, 1.45) | 1.25 (0.95, 1.64) |
| Mean of darkest 5 hours (L5, lux) | 0.04 (0.00, 0.12) | 0.12 (0.03, 0.15) |
| Mean of brightest 10 hours (M10, lux) | 69 (41, 112) | 449 (267, 684) |

[1] Median (IQR)

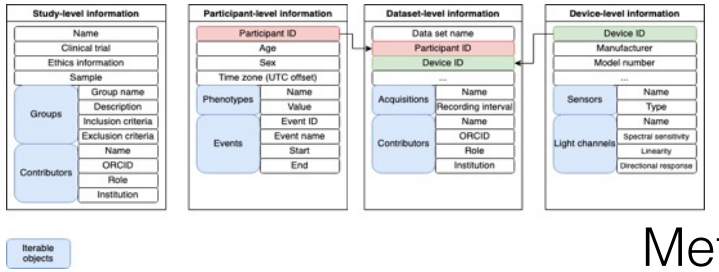

CHRONOBIOLOGY & HEALTH
TRANSLATIONAL SENSORY & CIRCADIAN NEUROSCIENCE

# LightLogR – Easily Analyze Complex Datasets



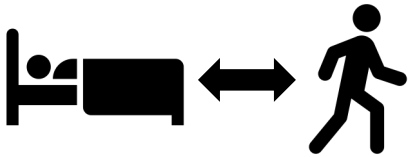



# LightLogR – Providing an End-to-End Framework for LL-Data




Validation of LL data

Processing LL data



Metadata

Auxiliary data

Device-Specific Import & Import from Database

Import LL data

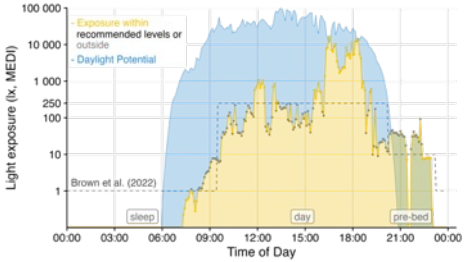
LightLogR

MeLi Dos

Metrology for wearable light loggers and optical radiation dosimeters

EURAMET

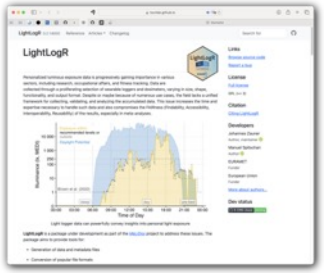
Metrics & Visualizations




| Characteristic | Winter, N = 39[1] | Summer, N = 33[1] |
|---|---|---|
| Geometric mean (lx) | 1.05 (0.52, 1.70) | 3.01 (2.25, 4.75) |
| Geometric sd (lx) | 54 (15, 179) | 37 (19, 216) |
| Luminous Exposure (lx*h) | 689 (441, 1,161) | 4,691 (2,721, 7,944) |
| Time above 250 lux (h) | 0.58 (0.33, 1.10) | 2.53 (1.70, 3.55) |
| Time above 1000 lux (h) | 0.03 (0.00, 0.08) | 0.88 (0.45, 1.29) |
| Mean timing of Light above 250 lux (h) | 13.85 (12.16, 14.67) | 13.48 (12.48, 14.37) |
| Days without Metric | 1 | 0 |
| Intradaily Variability | 0.98 (0.64, 1.45) | 1.25 (0.95, 1.64) |
| Mean of darkest 5 hours (L5, lux) | 0.04 (0.00, 0.12) | 0.12 (0.03, 0.15) |
| Mean of brightest 10 hours (M10, lux) | 69 (41, 112) | 449 (267, 684) |

[1] Median (IQR)

Documentation/ Manual




Web-based Tools For Analysis

Unit Tests & Cross-Validation Datasets

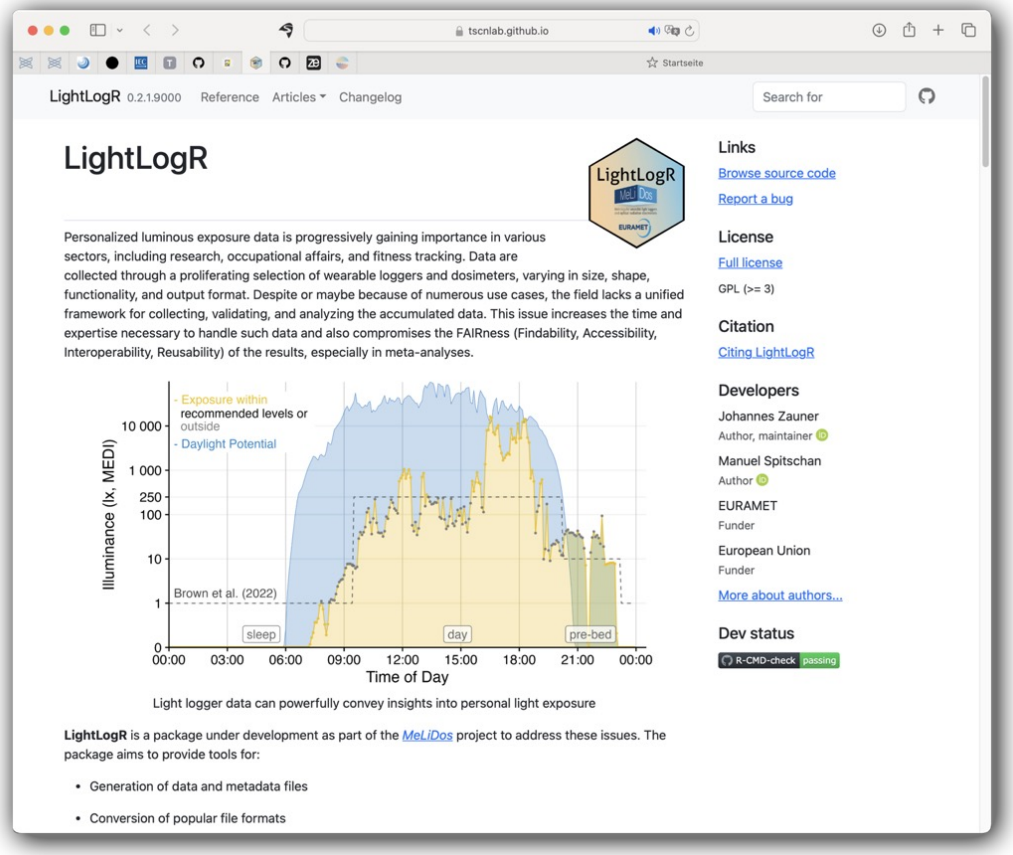
Shiny

CHRONOBIOLOGY & HEALTH
TRANSLATIONAL SENSORY & CIRCADIAN NEUROSCIENCE

# MeLiDos Aims to Harmonize the Field with Useful Toolsets

- LightLogR is under development, but already usable today!
  - Minimal effort import for many devices, with helpful automated summaries
  - Finding and handling gaps and irregularities in the data
  - Sensible handling of separate datasets (e.g., with differing measurement intervals per participant)
  - Easy but powerful visualizations for a quick overview, in-depth interactive exploration, or to create publication level figures
  - Adding Auxiliary or Reference Data with automatic handling of Datetime differences

- More is underway for LightLogR:
  - Generation of data and metadata files (common file format)
  - Verification of crucial metadata
  - Calculation of common parameters
  - Semi-automated analysis and visualization (command-line and GUI-based)
  - Integration of data into a unified database for cross-study analyses
  - Shiny Web-based application for a non-programming interface to the toolset



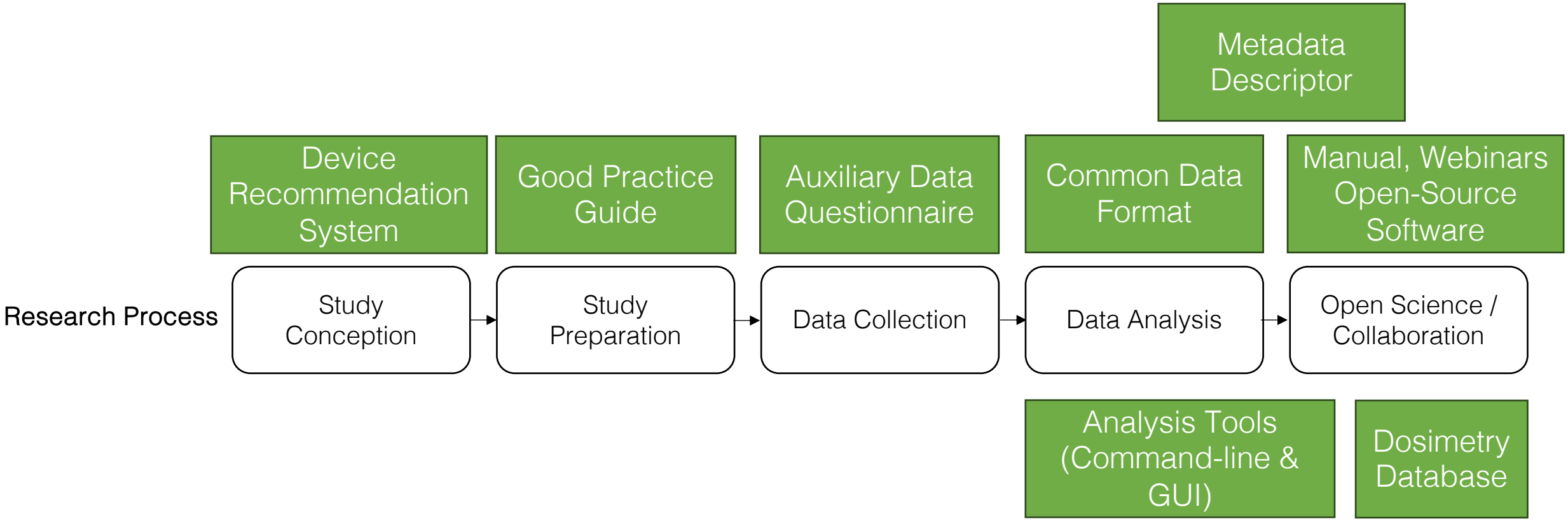

tscnlab.github.io/LightLogR/

# Task 2.3 How Can You Contribute?

WP 3.3.1 – 3.3.8
Software
Development

Review and test software & documentation, enhance usability

# WP2 Aims to Create a Toolset to Aid Users in Research



Johannes Zauner

Manuel Spitschan

**LightLogR**

tscnlab.github.io/LightLogR/

johannes.zauner@tum.de

JZauner

# Project Partners MeLiDos


Aalto University School of Electrical Engineering

baua: Bundesanstalt für Arbeitsschutz und Arbeitsmedizin

METAS Your reference.

RI. SE

CZECH METROLOGY INSTITUTE

CEU Universidad San Pablo

pmod wrc

THE HAGUE UNIVERSITY OF APPLIED SCIENCES

HSLU Hochschule Luzern

iberOptics sistemas ópticos

TÜBİTAK UME

Technical University of Munich

inegi driving science & innovation

BUILDING TRUST LNE

UNIVERSIDAD COMPLUTENSE MADRID

VSL National Metrology Institute

# Funding Statement

Co-funded by the European Union

METROLOGY PARTNERSHIP | EURAMET

Funded by the European Union. Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or EURAMET. Neither the European Union nor the granting authority can be held responsible for them.

The project (22NRM05 MeLiDos) has received funding from the European Partnership on Metrology, co-financed from the European Union's Horizon Europe Research and Innovation Programme and by the Participating States.