LightLogR: Reproducible analysis of personal light exposure data

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Summary

The effects of light on human health and well-being are best studied with real-world and personal light exposure, measured through wearable devices. More research groups incorporate these kinds of data in their studies, and important connections between light and health outcomes are drawn and their relevance gauged. Yet with few or missing standards, guidelines, and frameworks, setting up measurements, analysing the data, and comparing outcomes between studies is challenging, especially considering the significantly more complex time series data from wearables than single, spot measurements in past laboratory studies. In this paper, we introduce one building block to facilitate these efforts in the form of an open-source, permissively licenced software package for R statistical software: `LightLogR`. As part of a developing software ecosystem, `LightLogR` is built with the challenges of current and future datasets in mind. The package standardizes many tasks when importing and processing personal light exposure data, provides deep and quick insights into the datasets through summary and visualization tools, and incorporates all major metrics used in the relevant literature, all while embracing the inherently hierarchical, participant-based data structure.

Statement of need

Personalized luminous exposure data is progressively gaining importance in various sectors, including research, occupational affairs, and fitness tracking. Data are collected through a proliferating selection of wearable loggers and dosimeters, varying in size, shape, functionality, and output format. Despite or maybe because of numerous use cases, the field lacks a unified framework for collecting, validating, and analyzing the accumulated data. This issue increases the time and expertise necessary to handle such data and also compromises the FAIRness (Findability, Accessibility, Interoperability, Reusability) of the results, especially in meta-analyses.

`LightLogR` was designed to be used by researchers who deal with personal light exposure data collected from wearable devices. These data are of interest for various disciplines, including epidemiology, chronobiology, sleep research, and even lighting design. The package is intended to streamline the process of importing, processing, and analysing these data in a reproducible and transparent manner. Key features include:

- a growing list of supported devices with pre-defined import functions tailored to their data structure (17 at the time of writing, see Table 1)
- preprocessing functions to combine different time series, aggregate and filter data, and find and deal with implicitly missing data
- visualization functions to quickly explore the data. These function are based on the popular `ggplot2` (Wickham 2016) plotting package and are designed to be easily customizable to construct publication-ready figures (see, e.g., Figure 1).
- a large and growing set of metrics that cover most if not all major approaches found in the literature (at the time of writing 61 metrics across 17 metric families, see Table 2)), accessible via a consistent function interface.

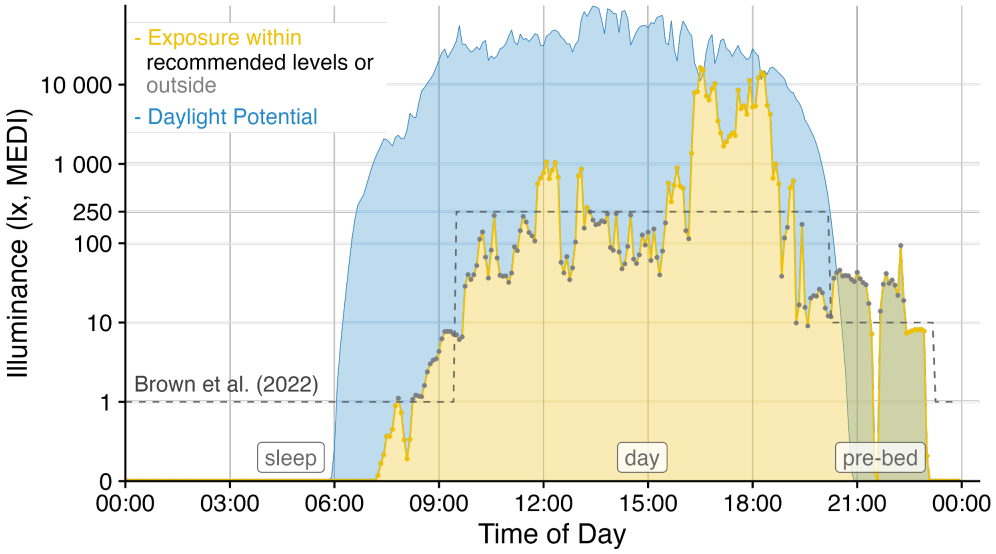

Figure 1: Light logger data can powerfully convey insights into personal light exposure and health-related outcomes. `LightLogR` facilitates the import and combination of different data sources into one coherent data structure, as seen here by combining environmental daylight availability and personal light exposure with data from a sleep diary. The visualization functions in the package further allow tweaking to produce publication-ready results.

Table 1: devices supported in version 0.4.1

Device Name	Manufacturer
Actiwatch Spectrum	Philips Respironics
ActLumus	Condor Instruments
ActTrust	Condor Instruments
melanopiQ Circadian Eye (Prototype)	Max-Planck-Institute for Biological Cybernetics
DeLux	Intelligent Automation Inc
GENEActiv (with GGIR preprocessing)	Activeinsights
Kronowise	Kronohealth
Lido	University of Lucerne
LightWatcher	Object-Tracker
LIMO	ENTPE
LYS Button	LYS Technologies
Motion Watch 8	CamNtech
XL-500 BLE	NanoLambda
OcuWEAR	Ocutune
Speccy	Monash University
SpectraWear	University of Manchester
VEET	Meta Reality Labs

Table 2: metrics available in version 0.4.1

Metric Family	Submetrics	Note	Documentation
Barroso	7		`barroso_lighting_metrics()`
Bright-dark period	4x2	bright / dark	`bright_dark_period()`

Metric Family	Submetrics	Note	Documentation
Centroid of light exposure	1		`centroidLE()`
Disparity index	1		`disparity_index()`
Duration above threshold	3	above, below, within	`duration_above_threshold()`
Exponential moving average (EMA)	1		`exponential_moving_average()`
Frequency crossing threshold	1		`frequency_crossing_threshold()`
Intradaily Variance (IV)	1		`intradaily_variability()`
Interdaily Stability (IS)	1		`interdaily_stability()`
Midpoint CE (Cumulative Exposure)	1		`midpointCE()`
nvRC (Non-visual circadian response)	4		`nvRC()`, `nvRC_circadianDisturbance()`, `nvRC_circadianBias()`, `nvRC_relativeAmplitudeError()`
nvRD (Non-visual direct response)	2		`nvRD()`, `nvRD_cumulative_response()`
Period above threshold	3	above, below, within	`period_above_threshold()`
Pulses above threshold	7x3	above, below, within	`pulses_above_threshold()`
Threshold for duration	2	above, below	`threshold_for_duration()`
Timing above threshold	3	above, below, within	`timing_above_threshold()`
Total:			
17 families	**61 metrics**		

LightLogR is already being used in several research projects and scientific publications across the scientific community, such as:

- cohort study to collect light exposure data across different geolocations (Guidolin et al. 2024)
- cohort study to collect year-long datasets of various types of environmental and behavioral data (Biller et al., n.d.)
- power analysis method for personal light exposure (Zauner, Udovicic, and Spitschan 2023),
- intervention study on the effects of light on bipolar disorder (data collection in progress),
- intervention study on sex and seasonal changes in human melatonin suppression and alerting response to moderate light (publication in progress),
- intervention study on exposure to bright light during afternoon to early evening on later evening melatonin release in adolescents (**note: Preprint this week, Rafael Lazar will send DOI**),
- observational study on the wearing compliance of personal light exposure (Stefani et al. 2024),
- observational study on the differences in light exposure and light exposure related behavior between Malaysia and Switzerland (preregistration in progress).

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