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Chronotype and light exposure analysis in German and UK shift- working nurses

Workshop „Light, health and shift work“
13 October 2016, Dortmund

Outline

1. Shift-working nurses' field study
2. Methodology
3. Subjects compliance
4. Light exposure analysis –
smoothing and example data

1. Shift-working nurses' field study

- Study "Determination of the actual light exposure from natural and artificial sources with regard to circadian effects in shift-working employees" →
 - a field study with shift-working nurses
 - 24 h-measurement of personal light exposure
 - information of subjects' "internal" time
- Joint project of the Federal Institute for Occupational Safety and Health (BAuA) and the Public Health England (PHE)

BAuA

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baua:

- **Aim** →
patterns of light exposure typical for a particular shift, a chronotype, geographic location or a season
- **Objective measure** →
dosimetric data on actual light exposure and activity of shift- and day-working nurses →
24 h, one week, three different seasons
- **Subjective measure and chronotype questionnaires** →
 - a sleep and an activity diary involving well-being and satisfaction scale
 - sleep-habits questionnaires to assess the chronotype



Analysis of the measured light exposures is based on the method of exponential moving average*

* Price, L. „On the Role of Exponential Smoothing in Circadian Dosimetry“, *Photochem. Photobiol.* 90, 1184 (2014)

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2. Methodology

Subjects and geographic locations

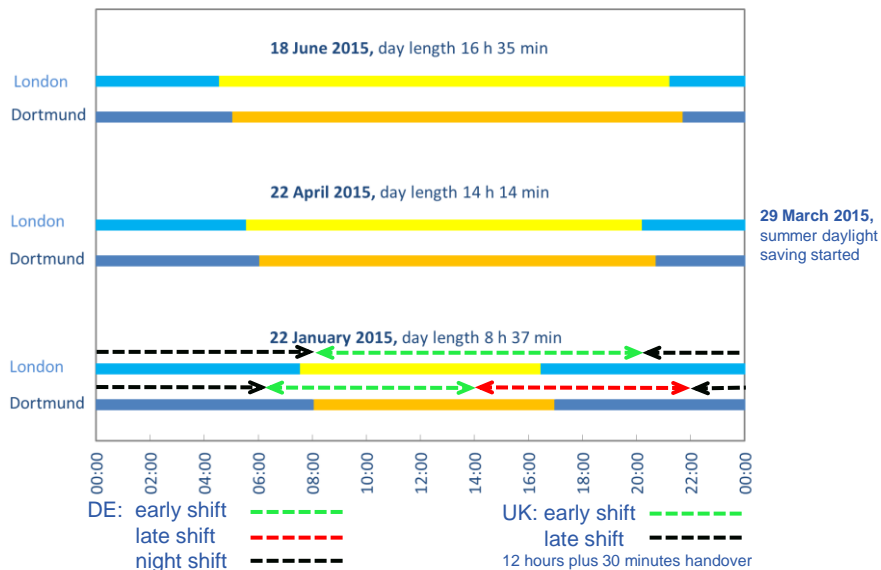
- 85 nurses → 43 UK (employees of the King's College Hospital, London) + 42 Germany (employees of the Klinikum Dortmund)
- same latitude, Δ longitude 7.5° → sunrise is separated by 30 minutes

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Seasons and shifts → light exposure measured at work and outside of work for a week in January, April and June 2015 → variation in the day length



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Measuring devices

UK



MotionWatch 8 (CamNtech)

- worn when the subjects were in bed for sleep (sleep duration and sleep data quality)

Actiwatch Spectrum detector (Philips Respironics)

- worn when out of bed for light exposure and activity data
- when in bed, placed face-up on bed-side table for bedroom light levels data during sleep

DE



GENEActiv Original (GENEActiv)

- worn when the subjects were in bed for sleep (sleep duration and sleep data quality)

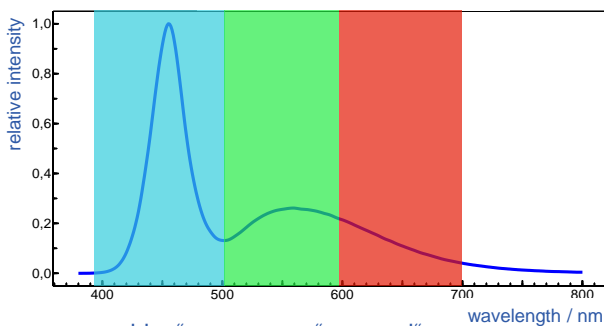
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Light measurements

Typical spectrum of a cold white LED (blue line)



„blue“
sensor

„green“
sensor

„red“
sensor



Actiwatch Spectrum devices were attached to clothing at chest height; could be transferred easily between badges for convenience

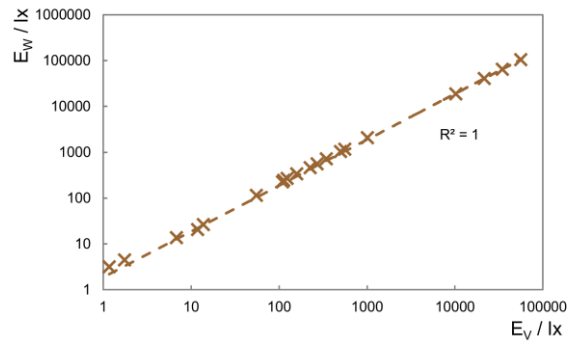
Photo: Völkner / FOX

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- Importance of a prior characterization and, if necessary, calibration of the light exposure detectors!
- Dortmund → 23 Actiwatch Spectrum devices
 - negligible dark signals
 - linear over a broad range of illuminances



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- calibration carried out with three artificial light sources (a halogen, a fluorescent and a warm-white LED lamp) as well as the daylight (see also a poster) → average calibration factors

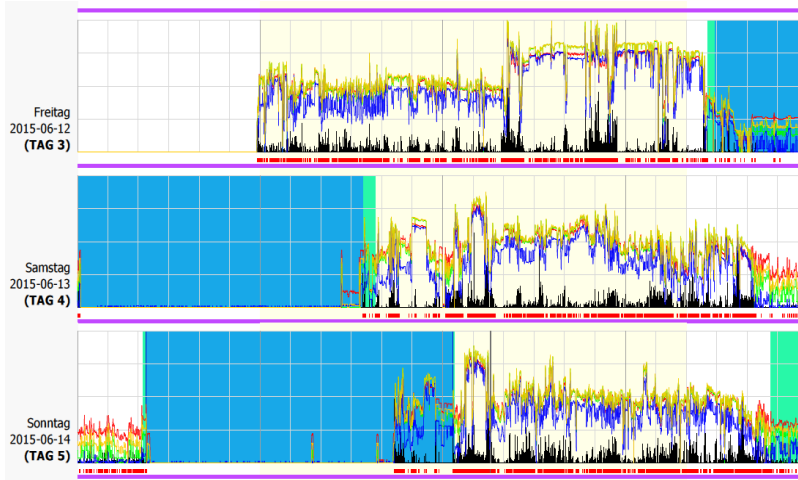
	k_R	k_G	k_B	k_W
daylight	0.98	2.28	1.11	2.16
halogen lamp	0.99	2.15	1.23	1.77
fluorescent lamp	1.00	2.20	1.06	1.84
warm white LED	0.98	2.24	1.23	1.35

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- apply calibration factors → calibrated measurements
- continuous 168-hour dosimetric data per subject per season



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Information obtained from the questionnaires

Initial questionnaire → age, gender, BMI, smoking, alcohol, coffee and tea consumption, home location, etc.

Lighting and outdoor activity questionnaire → light and lighting sources in the workplace and at home, indoor and outdoor activities

Sleep and Activity Diary

- information about events that affect the light exposure
- in 30 minutes blocks throughout each 7 day period
- well-being and satisfaction on scale of 1 to 5 between sleeps

Daily activities

EXAMPLE: On the next eight pages (1 per day), show how you spent that day, as shown below.

DAILY DATE	INDOORS, including cars and public transport										OUTSIDE		
	Asleep (h total)	Driving, i.e. in car	Passenger in public transport	At work	Time with hands	Sport	Other activities, please specify	Watching	Cozily	At home (e.g. garden)	At home (if applicable)	Time with hands	Other activities, please specify
05:00-05:30	X												
05:30-06:00	X												
06:00-06:30	X												
06:30-07:00	X												
07:00-07:30	X												
07:30-08:00	X												
08:00-08:30				X									
08:30-09:00				X									
09:00-09:30	X												
09:30-10:00					X								
10:00-10:30	X				X								
10:30-11:00	X				X								
11:00-11:30	X				X								
11:30-12:00	X				X								
12:00-12:30									X				
12:30-13:00					X								
13:00-13:30	X				X								
13:30-14:00	X				X								
14:00-14:30	X				X								
14:30-15:00	X				X								
15:00-15:30	X				X								
15:30-16:00	X				X								
16:00-16:30	X				X								
16:30-17:00	X				X								
17:00-17:30	X				X								

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Munich Chronotype Questionnaire (MCTQ or MCTQ^{Shift}) → a sleep-habits questionnaires to assess the chronotype

Participant number
v

**Munich Chronotype Questionnaire for Shift-Workers
(MCTQ^{Shift})**

Prof. Dr. Till Roenneberg
Institute of Medical Psychology
Ludwig-Maximilians-University, Munich

Between two free days after daytime shifts

Image 1: I go to bed at _____. (Please remember to swap sensors)

Image 2: Note that some people stay awake for some time when in bed!

Image 3: I actually get ready to fall asleep at _____.

Image 4: I need _____ minutes to fall asleep.

Image 5: I wake up at _____.

ALARM (with image 5): with alarm without alarm

Image 6: I get up at _____ (Please remember to swap sensors)

I usually take a nap: Yes No

If Yes: I usually take a nap between _____ and _____.

There are particular reasons why I cannot freely choose my sleep times on free days after daytime shifts:

Yes No

If Yes:

Child(ren)/pet(s)

Hobbies

Others, please state: _____

Participant number
v

**Munich Chronotype Questionnaire
(MCTQ)**

Prof. Dr. Till Roenneberg
Institute of Medical Psychology
Ludwig-Maximilians-University, Munich
(Please note this version has been adapted from the original)

Between two work days

Image 1: I go to bed at _____. (Please remember to swap sensors)

Image 2: Note that some people stay awake for some time when in bed!

Image 3: I actually get ready to fall asleep at _____.

Image 4: I need _____ minutes to fall asleep.

Image 5: I wake up at _____.

ALARM (with image 5): with alarm without alarm

Image 6: I get up at _____ (Please remember to swap sensors)

I usually take a nap: Yes No

If Yes: I usually take a nap between _____ and _____.

There are particular reasons why I cannot freely choose my sleep times on working days:

Yes No

If Yes:

Child(ren)/pet(s)

Hobbies

Others, please state: _____

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Subjects of the Klinikum Dortmund

- n = 42 → 34 female, 8 male
- 33 shift workers and 9 day workers

Variable	Range	Average
Age / whole years	22 - 54	36
BMI / kg/m ²	21 - 42	26
Shift worker / for years	0.5 - 34	13 (shift workers only, n = 33)
Number of children	1-3	1.7 (n = 19)

Light sources → mainly fluorescent lamps at work
→ mainly halogen lamps at home

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Subjects of the King's College Hospital

- n = 43 → 33 female, 10 male
→ 39 shift workers and 4 day shift workers
- All nursing staff working for the Liver and Intensive Treatment Unit (approximately 1 in 3 of the nursing staff on the ward)

Variable	Range	Average
Age (whole years)	23 - 53	33.6
BMI (kg/m ²)	16.6 - 37.1	24.2
Nurse - for years	0.5 - 30	10.0
Shift worker - for years	0.9 - 24	9.1 (shift workers only, n = 39)
Commute (km straight)	0.2 - 36.4	5.8
Number of children	1 - 3	1.2 (of 21 nurses with >0)
Child age (whole years)	1 - 17	7.7 (< 18 years only, n = 17)

3. Compliance results

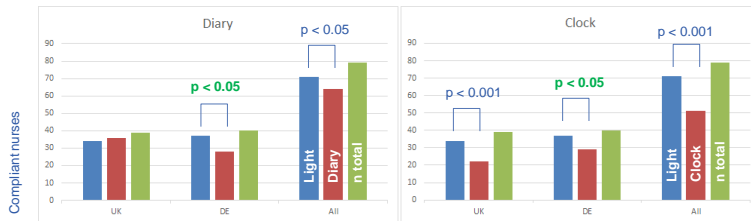
Compliance with 4 tasks:

- Quality Rate wellbeing and satisfaction on scale of 1 to 5 between sleeps, stating their waking and falling-asleep times
Throughout each 7 day period, subjective outcome task
- Diary Complete an activity diary, in 30 minute blocks
Throughout each 7 day period
- Light Wear Actiwatch Spectrum dosimeter badge when out of bed
Place Actiwatch facing upwards on bedside table when in bed
Wear (Motionwatch 8 in UK, GENEActiv in DE) on the wrist in bed
24 hours x 7 days plus sleep quality and activity data
- Clock Complete a sleep-habits questionnaire to assess their chronotype
Once per visit period (not daily)
12 questions day-shifts, up to 20 for UK and up to 28 for DE shifts
MCTQ and/or MCTQ_Shift

Compliance results (April visit)

d3 = compliance on day 3 | d1-7 = compliance over the week

Task	UK d3	DE d3	All d3	UK d1-7	DE d1-7	All d1-7
Quality	24 nurses	35 etc.	59	25	35	60
Diary	36	28	64	-	-	-
Light	34	37 (use 35)	71	34	37 (use 35)	71
Clock	-	-	-	22	29	51
n total	39	40	79	39	40	79



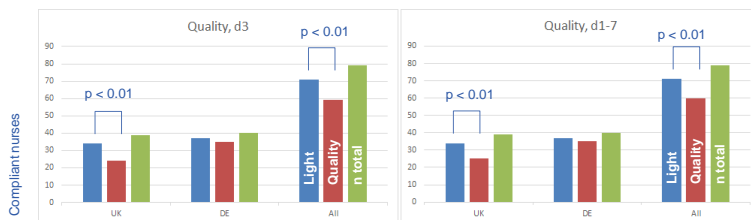
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Compliance results (continued)

Task	UK d3	DE d3	All d3	UK d1-7	DE d1-7	All d1-7
Quality	24	35	59	25	35	60
Diary	36	28	64	-	-	-
Light	34	37 (use 35)	71	34	37 (use 35)	71
Clock	-	-	-	22	29	51
n total	39	40	79	39	40	79



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Use Quality to select test population

Task	UK d3	DE d3	All d3	UK d1-7	DE d1-7	All d1-7
Quality	24	35	59	25	35	60
Diary	36	28	64	-	-	-
Light	34	37 (use 35)	71	34	37 (use 35)	71
Clock	-	-	-	22	29	51
n total	39	40	79	39	40	79

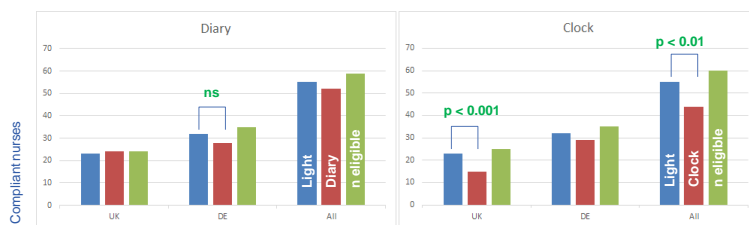
Task	UK d3	DE d3	All d3	UK d1-7	DE d1-7	All d1-7
Diary	24	28	52	-	-	-
Light	23 (use 19)	32 (use 30)	55 (use 54)	23 (use 20)	32 (use 30)	55 (use 54)
Clock	-	-	-	15	29	44
n eligible	24	35	59	25	35	60

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Compliance results (Quality eligibility)



Task	UK d3	DE d3	All d3	UK d1-7	DE d1-7	All d1-7
Diary	24	28	52	-	-	-
Light	23 (use 20)	32 (use 30)	55 (use 54)	23 (use 20)	32 (use 30)	55 (use 54)
Clock	-	-	-	15	29	44
n eligible	24	35	59	25	35	60

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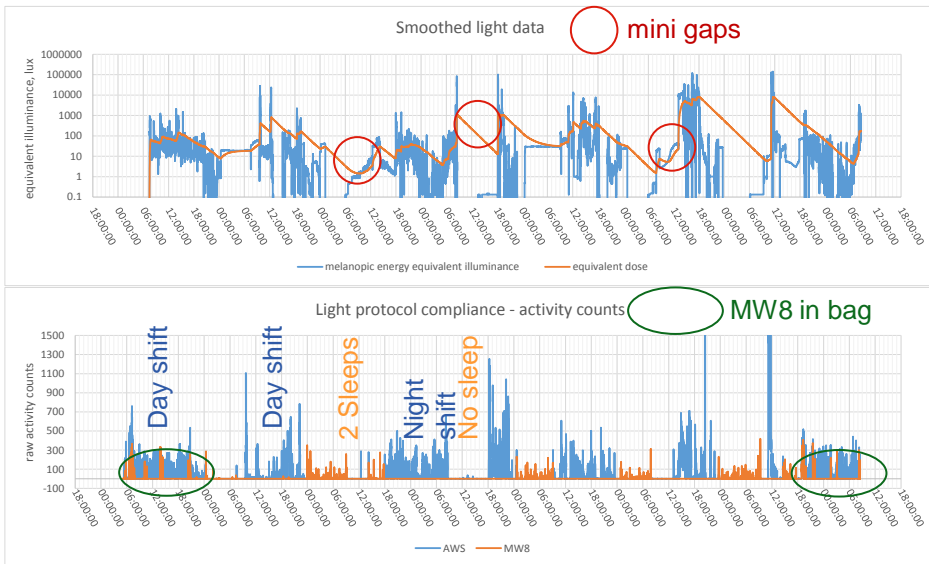
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Compliance results summary

- The light protocol tended to have consistently high compliance rates
- Light protocol compliance was **never** statistically lower than for any of Clock/Diary/Quality, even after selection for “Quality” compliance
- We then tested whether compliance for Clock/Diary/Quality was lower than for Light protocol. Statistically true for:
 - **DE** and **All** vs Diary (**ns*** for “Quality” compliant nurses)
 - **UK**, **DE** and **All** vs Clock (**UK** and **All** for “Quality” compliant)
 - **UK** and **All** vs Quality
- N(0,1) approximation for binomial data (1-tailed tests). n~24-79 was considered appropriate for these tests, but as a precaution, (n-5) cap significance levels were adjusted using the t-distribution. For a $\alpha=5\%$ 1-tailed test with n=24, say, 1.645 σ is substituted by 1.711 s. Expressed as a relative change in the p-value, this is 15%. This percentage change is larger with lower α . (***n=35, 28 cf 32**)

4. Smoothing and example data

Example data and smoothed data (90 minute half-life)



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Crude error estimation

Contributions to standard measurement error:

e1% ~ 16% Spectral*

e2% ~ 35% Cosine*

e3% ~ 10% Non-linearity*

e4% Temperature*

e5% Relative eye position and direction

e6% Variation within sampling interval*

etc.

Total measurement error ~ 50%

Smoothed total error perhaps ~ 25%

*estimates for AWS worn at chest height

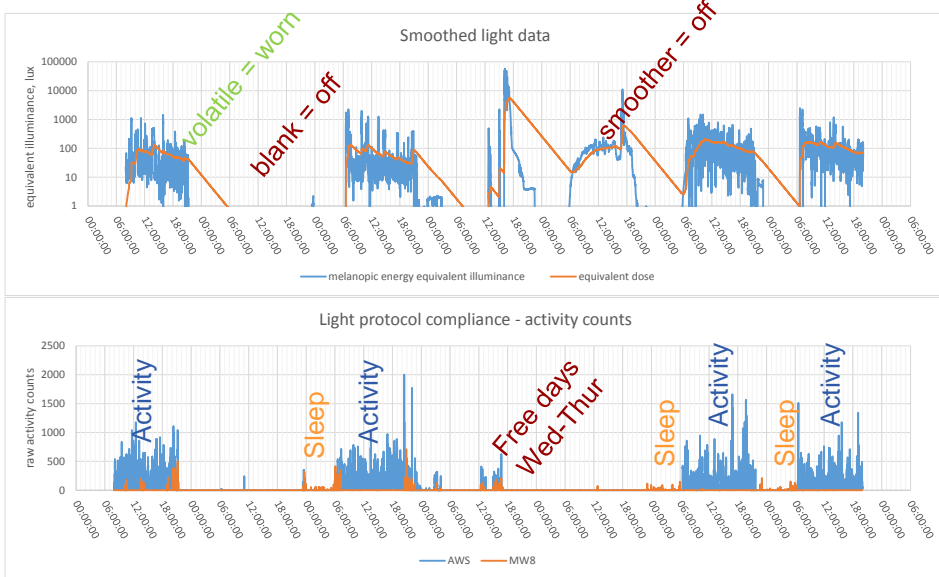
NB e1, e2, e5, e6 often tend to cancel out when smoothing

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Example – missing data

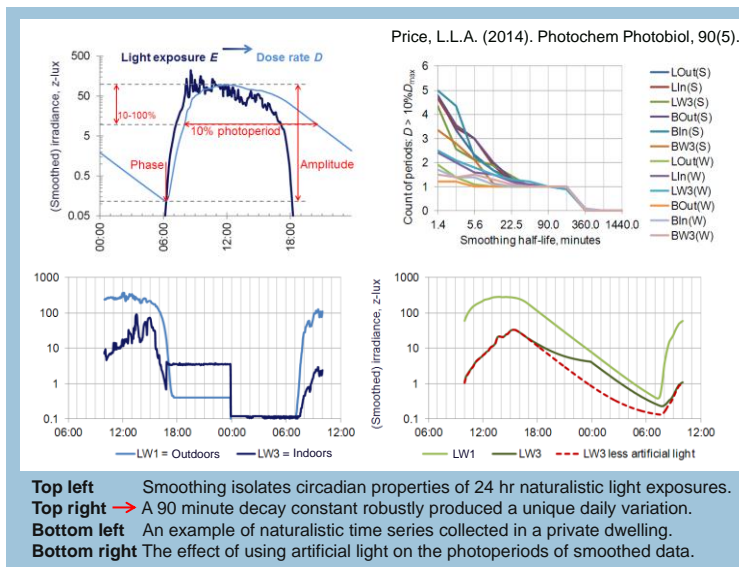


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Smoothing

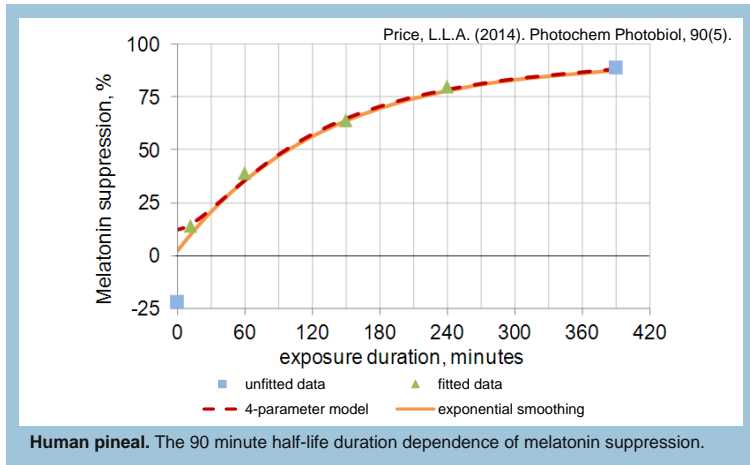


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Smoothing and light exposure duration



Data: Chang, A-M. et al (2012) J Physiol, 590(13).
 4-parameter model: Zeitzer, J.M. et al (2000). J Physiol, 526(3).

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Example – mainly day shifts



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Thank you for your attention!