

The impact of blue and red lights on objective and subjective alertness in the afternoon

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Light affects non-visual pathways in ways not fully understood. The suppression of melatonin by light at night has been postulated as the mediating factor for improved nocturnal performance and alertness. However, recent work by our laboratory shows that long-wavelength (red) light, which does not suppress melatonin, positively impacts alertness and performance at night and in the early morning. Objective alertness was measured by a reduction in alpha (8-12 Hz), alpha-theta (5-9Hz) and theta (5-7 Hz) band power in electroencephalogram (EEG) measurements. Performance was measured in terms of reaction times and memory using the Psychomotor Vigilance Task (PVT). Here we report the effects of narrowband red and blue light exposures on alertness, as measured by EEG, and on subjective sleepiness, as measured by the Karolinska Sleepiness Scale (KSS) during the middle of the afternoon when melatonin levels are very low. 13 participants (5 females) participated in three sessions separated by at least 1 week. Every session started at 14:30, and lasted for 1 hour. Subjects experienced one of 3 lighting conditions each week in a counterbalanced order: 1) dark (D) (<0.01 lx) 2) red light (RL) ($\lambda_{\text{max}}=630\text{nm}$, 40 lx), and 3) blue light (BL) ($\lambda_{\text{max}}=470\text{nm}$, 40 lx). Under D, participants were kept in front of an un-energized light box for 1 hour. Under RL and BL, the LEDs were energized for 48 minutes, preceded by a 12-minute dark (<0.01 lx) period. 2.5 minutes of EEG activity was recorded seven times during the 1-hr session, once at the beginning of the session when the LEDs were not energized and six times later. Statistical analyses showed that RL significantly decreased power in the alpha ($p=0.006$), alpha theta ($p<0.0001$), and theta ($p=0.01$) bands. Although BL and RL EEG patterns were similar, no statistical differences were found between BL and D or BL and RL. Subjects reported less sleepiness using the KSS scale after RL and BL than after D, but the differences were not statistically significant. Consistently then, light can impact alertness without affecting melatonin.

MARIANA G. FIGUEIRO

NAME Mariana G. Figueiro	POSITION TITLE Associate Professor Program Director, Lighting Research Center, Rensselaer Polytechnic Institute
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EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE	MM/YY	FIELD OF STUDY
Federal University of Minas Gerais, Brazil	BS		Architectural Engineer
Rensselaer Polytechnic Institute, Troy, NY	MS		Lighting
Rensselaer Polytechnic Institute, Troy, NY	PhD		Multidisciplinary Science

A. Positions and Honors**Positions and Employment**

1992-1994	Architect – GAFISA Construtora, Brazil.
1994-1996	Architect – Self-employed (Brazil)
1996-1998	Research Assistant – Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA
1998-1999	Manager of Program Development - Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA
1999-Pres.	Program Director, Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA
2006-2010.	Assistant Professor, School of Architecture, Rensselaer Polytechnic Institute, Troy, NY, USA
2007-2010.	Visiting Adjunct Assistant Professor, Department of Biology, Russell Sage College, Troy, NY, USA
2010-Pres	Associate Professor, School of Architecture, Rensselaer Polytechnic Institute, Troy, NY, USA
2010-Pres.	Visiting Adjunct Associate Professor, Department of Biology, Russell Sage College, Troy, NY, USA

Honors and Other Professional Experience

- Technical Reviewer for the Human Systems Integration Standards (HSIS) External Review for Lighting Requirements for NASA Space Shuttles.
- Editorial Assistant, Illuminating Engineering Society of North America *Lighting Handbook* (9th edition)
- 2000 Award of Merit for the publication Specifier Reports, Society for Technical Communication, The Mohawk Chapter
- 2006 New York State Foundation for Science, Technology, and Innovation (NYSTAR) James D. Watson Young Investigator Award
- 2007 Office of Naval Research, Young Investigator Award
- 2010 James M. Tien '66 Rensselaer Early Career Award for Faculty
- Best of Sleep Medicine 2011 was awarded to the paper: Figueiro MG & Rea MS. 2010. Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students. *NeuroEndocrinology Letters*, Vol. 31, No. 1.

B. Selected Peer-reviewed Publications

1. Rea MS, Figueiro MG, Bullough JD, Bierman A. (2005). A model of phototransduction by the human circadian system. *Brain Research Reviews*, 50(2), 213-228.
2. Figueiro MG, Saldo E, Rea M, Kubarek K, Cunningham J, Rea MS. 2008. Developing architectural lighting designs to improve sleep in older adults. *The Open Sleep Journal*, 1(12):40-51.
3. Figueiro MG. 2008. A proposed 24 hour lighting scheme for older adults. *Lighting Research and Technology*, 40: 153-160.
4. Sloane PD, Figueiro MG, Cohen L. 2008. Light as therapy for sleep disorders and depression in older adults. *Clinical Geriatrics*, 16(3): 25-31.
5. Figueiro MG, Gras L, Qi N, Rizzo P, Rea M, Rea MS. 2008. A novel night lighting system for postural control and stability in seniors. *Lighting Research & Technology*, 40:111-126.
6. Figueiro MG, Bierman A, Rea MS. (2008). Retinal mechanisms determine the subadditive response to polychromatic light by the human circadian system. *Neuroscience Letters*, 438(2):242-245.
7. Figueiro MG, Bierman A, Bullough JD, Rea MS. 2009. A personal light-treatment device for possibly improving sleep quality in the elderly: Dynamics of nocturnal melatonin suppression at two exposure levels. *Chronobiology International*. 26(4): 726-739.
8. Rea MS, Figueiro MG, Bierman A, Bullough JD. 2010. Circadian light. *Journal of Circadian Rhythms*. 8:2 (13 February 2010).
9. Miller D, Bierman A, Figueiro MG, Schernhammer E, Rea, MS. 2010. Ecological measurements of light exposure, activity, and circadian disruption in real-world environments. *Lighting Research and Technology*, 42:271-284.
10. Higgins PA, Hornick T, Figueiro MG. 2010. Rest-activity and light exposure patterns in the home setting: A methodological case study. *American Journal of Alzheimer's Disease and Other Dementias*, 25(4).
11. Figueiro MG & Rea MS. 2010. Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students. *NeuroEndocrinology Letters*, Vol. 31, No. 1.
12. Bierman A, Figueiro MG, Rea MS. 2011. Measuring and predicting eyelid spectral transmittance. *Journal of Biomedical Optics*, 16(6).
13. Rea MS, Brons JA, Figueiro MG. 2011. Measurements of light at night (LAN) for a sample of female school teachers. *Chronobiology International*, 28(8):673-680.
14. Figueiro MG, Gras LZ, Rea MS, Plitnick B, Rea MS. 2011. Lighting for improving balance in older adults with and without risk for falls. *Age and Ageing*, in press.
15. Figueiro MG, Plitnick B, Rea MS, Gras LZ, Rea MS. 2011. Lighting and perceptual cues: Effects on gait measures of older adults at high and low risk for falls. *BMC Geriatrics*, 11(49).
16. Figueiro MG, Lesniak NZ, Rea MS. 2011. Implications of controlled blue light exposure for sleep in older adults. *BMC Research Notes*, 4:334.
17. Rea MS, Figueiro MG, Bierman A, Hamner R. 2011. Modeling the spectral sensitivity of the human circadian system. *Lighting Research & Technology*, in press.

C. Research Support (see current and pending for ongoing research support)

SELECTED COMPLETED RESEARCH SUPPORT

U01 NIH/NIDA(Co-I: Figueiro; PI: Rea)

07/1/07

10/31/11

Personal light measuring device for correcting circadian disruption

Develop and evaluate of a personal light measuring device to reduce psychosocial stress.

R21 National Institute of Nursing Research (PI)

07/01/09

09/30/11

Using light to increase visual and perceptual cues and decrease falls

Investigate how horizontal and vertical lights can help increase postural control and stability.

R03 National Cancer Institute (PI)	07/01/09	09/30/11
Light as controlling stimulus for behavior cancer research		
Develop a spectral sensitivity function for nocturnal rats circadian system so that studies using human exposures can be bridged to animal models		
J90299 (PI: Figueiro)	07/1/07	11/30/07
American Institute of Architects		
Developed architectural lighting designs to improve health and well-being of older adults		
Demonstrated the effectiveness of a 24-hr lighting scheme on sleep quality of older adults.		
Topbulb/NIA-STTR (PI: Figueiro)	10/01/07	09/30/08
Sleep Therapy headset for improving sleep quality of older adults		
Evaluated blue-light goggles that can be used to improve rest/activity rhythms in Alzheimer's disease patients.		
Office of Naval Research (PI)	04/2/07	03/1/11
Alerting Effects of Light at Different Circadian Phases in Humans		
Research the effects of lighting conditions on the circadian rhythms of naval personnel.		
US Green Building Council (PI: Figueiro)	08/1/08	04/30/11
Quantifying the Impact of Daylight and Electric Lighting on Student Alertness, Performance and Well-being in K-12 Schools		
Investigate the impact of daylight and electric lighting on 8th graders circadian phase and performance.		
J50478 (PI: Figueiro)	03/01/07	02/28/09
New York State		
Investigating Retinal Mechanisms Underlying Human Circadian Phototransduction		
Investigated spectral opponency in circadian phototransduction and the possible change in spectral sensitivity over the course of the night.		
J71203 (PI: Figueiro)	05/01/06	10/31/07
OSRAM Sylvania		
Investigated the Effects of Sky White on Well-Being of Night-Shift Nurses		

Evaluated the use of high correlated color temperature on alertness and well-being of night-shift workers.

J71309 (PI: Figueiro)

08/15/08

04/14/09

The Boeing Company

The Impact of Color on Mood and Alertness

Evaluated the impact of saturated colors on mood (PANAS, Norris Scale) and alertness (EEG).

J40185 (PI: Figueiro)

07/1/08

06/30/09

Research Foundation of CUNY

Light isn't just for vision anymore: Implications for Transportation Safety

Evaluated the impact of light on driving safety.

MARK S. REA

NAME Mark S. Rea	POSITION TITLE Professor Director, Lighting Research Center, Rensselaer Polytechnic Institute
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EDUCATION/TRAINING

INSTITUTION AND LOCATION	DEGREE	YEAR(s)	FIELD OF STUDY
Ohio State University, Columbus, OH	BS	<div></div>	Psychology
Ohio State University, Columbus, OH	MS	<div></div>	Biophysics
Ohio State University, Columbus, OH	PhD	<div></div>	Biophysics

A. Positions and Honors

Positions and Employment

1978-1985	Senior Research Officer, Division of Building Research, National Research Council Canada, Ottawa, ON, Canada
1985-1986	Visiting Scientist, Electricity Council Research Centre, Capenhurst, United Kingdom
1986-1988	Manager, Indoor Environment Program, Building Performance Section, National Research Council Canada, Ottawa, ON, Canada
1988-1994	Associate Professor, School of Architecture, Rensselaer Polytechnic Institute, Troy, NY, USA
1988-1994	Associate Professor, Department of Psychology, Rensselaer Polytechnic Institute, Troy, NY
1988-	Director, Lighting Research Center, Rensselaer Polytechnic Institute, Troy, NY, USA
1994-	Professor, School of Architecture, Rensselaer Polytechnic Institute, Troy, NY, USA
1994-	Professor, Department of Cognitive Science, Rensselaer Polytechnic Institute, Troy, NY, USA

Honors and Other Professional Experience

- Fellow, Illuminating Engineering Society of North America
- Fellow, Society of Light and Lighting (United Kingdom)
- International Editorial Advisory Board, *Lighting Research and Technology* journal
- Editor-in-Chief, Illuminating Engineering Society of North America *Lighting Handbook* (8th and 9th editions)
- William H. Wiley Distinguished Faculty Award, Rensselaer Polytechnic Institute, 1998
- Gold Medal, Illuminating Engineering Society of North America, 2000
- Walsh-Weston Award, The Society of Light and Lighting, 2005, 2007
- Transportation Research Board of the National Academies, Best Paper Award 2008

B. Selected peer-reviewed publications (from 85)

1. Rea MS, Figueiro MG, Bullough JD, Bierman A. 2005. A model of phototransduction by the human circadian system. *Brain Research Reviews* 50(2): 213-228.
2. Bullough JD, Figueiro MG, Rea MS. 2006. Mice and women: Light as a circadian stimulus in breast cancer research. *Cancer Causes and Control* *Cancer Causes and*

Control 17, 375-383.

3. Figueiro MG, Rea, MS, Bullough JD. 2006. Circadian effectiveness of two polychromatic lights in suppressing human nocturnal melatonin. *Neuroscience Letters*, 406:293-297.
4. Figueiro MG, Bierman A, Rea MS. 2008. Retinal mechanisms determine the subadditive response to polychromatic light by the human circadian system. *Neuroscience Letters*, 438(2):242-245.
5. Rea MS, Bierman A, Figueiro MG, Bullough JD. 2008. A new approach to understanding the impact of circadian disruption on human health. *Journal of Circadian Rhythms*, 6:7 (29 May 2008).
6. Rea MS, Figueiro MG, Bierman A, Bullough JD. 2010. Circadian light. *Journal of Circadian Rhythms*. 8:2 (13 February 2010).
7. Figueiro MG & Rea MS. 2010. Lack of short-wavelength light during the school day delays dim light melatonin onset (DLMO) in middle school students. *NeuroEndocrinology Letters*, Vol. 31, No. 1 (in press).
8. Figueiro MG, Rea MS. 2010. The effects of red and blue lights on circadian variations in cortisol, alpha amylase, and melatonin. *International Journal of Endocrinology*, in press.
9. Figueiro MG & Rea MS. 2010. Evening daylight may cause adolescents to sleep less in spring than in winter. *Chronobiology International*, 27(6):1242-58.
10. Figueiro MG, Rea MS. 2011. Sleep opportunities and periodic light exposures: Impact on biomarkers, performance, and sleepiness. *Lighting Research & Technology*, 43(3):349-369.
11. Sharkey KM, Carskadon MC, Figueiro MG, Zhu Y, Rea MS. 2011. Effects of an advanced sleep schedule and morning short-wavelength light exposure on circadian phase in young adults with late sleep schedules. *Sleep Medicine*, 12(7):685-692.
12. Bierman A, Figueiro MG, Rea MS. 2011. Measuring and predicting eyelid spectral transmittance. *Journal of Biomedical Optics*, 16(6).
13. Figueiro MG, Gras LZ, Rea MS, Plitnick B, Rea MS. 2011. Lighting for improving balance in older adults with and without risk for falls. *Age and Ageing*, in press.
14. Figueiro MG, Plitnick B, Rea MS, Gras LZ, Rea MS. 2011. Lighting and perceptual cues: Effects on gait measures of older adults at high and low risk for falls. *BMC Geriatrics*, 11(49).
15. Figueiro MG, Lesniak NZ, Rea MS. 2011. Implications of controlled blue light exposure for sleep in older adults. *BMC Research Notes*, 4:334.
16. Rea MS, Figueiro MG, Bierman A, Hamner R. 2011. Modeling the spectral sensitivity of the human circadian system. *Lighting Research & Technology*, in press.

C. Research Support (see current and pending for ongoing research support)

SELECTED Completed Research Support

National Institute on Drug Abuse
9/30/11

J11867 (PI: Rea)

8/14/07

Personal light measuring device for correcting circadian disruption

Develop and evaluate a personal light measuring device to reduce psychosocial stress.

National Institutes of Nursing Research (PI: Figueiro)
9/30/11

7/1/09

Using light to increase visual and perceptual cues and decrease falls

Investigate how horizontal and vertical lights can help increase postural control and stability.

National Cancer Institute (PI: Figueiro)
9/30/11

7/1/09

Light as controlling stimulus for behavior cancer research

Develop a spectral sensitivity function for nocturnal rats circadian system so that studies using human exposures can be bridged to animal models.

US Environmental Protection Agency
1/31/11

J11920 (PI: Figueiro)

2/3/08

Reducing Greenhouse Gas Emissions

Provide technical expertise to reduce greenhouse emissions through lighting.

The Brigham & Women's Hospital
3/31/11

J90259 (PI: Rea)

9/1/05

Effects of Light at Night on Circadian System of Nurses

Evaluate the effects of lighting conditions on the circadian rhythms of night shift nurses.

Research and Development Solutions
11/14/09

J71235 (Rea)

9/10/07

Energy Conservation Standards

Provide technical assistance to the US Department of Energy on the development of codes and standards to improve the efficiency of lighting equipment sold in the US.

National Academy of Sciences
6/01/09

J90238 (Rea)

7/14/07

Guidelines for Roadway Lighting Based on Safety Benefits and Costs

Develop guidelines for determination of appropriate roadway lighting for existing and planned facilities based on safety benefits and total costs.

National Academy of Sciences J90325 (Rea) 6/16/08
3/15/09

Replacement Process for LED (Lighting Emitting Diode) Traffic Signals

Evaluate LED traffic signals and their replacement process for municipalities.

The Boeing Company J71309 (Figueiro) 8/15/08
4/14/09

The Impact of Color Illumination on Mood and Alertness

Investigate the impact of light color on mood and alertness.

New York State Research & Development Authority J50505 (Rea) 5/2/08
3/31/09

Innovative Lighting Approaches for Efficient and Safe Roadway Travel

Develop a roadwork lighting system that is safe and energy-efficient.

Research Foundation of CUNY J90321 (Rea) 1/1/08
3/31/09

Design and Evaluation of Effective Crosswalk Illumination

Design and evaluate an energy-efficient and safe crosswalk lighting system.

Groton Utilities J71154 (Rea) 2/1/07
1/31/08

Mesopic Street Lighting Proposal

Compare the visual effectiveness and energy use of two outdoor lighting systems.