

EFFECTS OF LIGHT EXPOSURE ON BEHAVIOR OF ALZHEIMER'S PATIENTS - A PILOT STUDY

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Background

Alzheimer's disease (AD) patients exhibit aperiodic (random) patterns of rest and activity rather than the consolidated sleep/wake cycle found in normal, older people. This aperiodic pattern of behavior is very difficult for caregivers who must be vigilant to the needs of AD patients, because they are usually on a normal, 24-hour, circadian pattern of rest and activity.

Clinical research has shown that exposure to very bright light in the day and darkness at night can consolidate rest and activity patterns in AD patients [1]. This clinical research was based upon more basic studies of circadian regulation by light exposure in animals and humans [2,3]. This large and growing body of research shows that bright light during the day is a powerful means of entraining natural circadian rhythms in all species, including humans. Depending upon the timing, duration, intensity and spectrum of the light, circadian rhythms can be synchronized or desynchronized (phase advanced or phase delayed) with the natural, 24-hour, daylight/darkness pattern.

Very recent research has shown that the spectral sensitivity of the circadian system is very different than the spectral sensitivity of the retina used in visual activities such as reading and used to measure light in illuminating engineering. Very short wavelength (blue) light is maximally effective at affecting the circadian system [4,5,6] whereas middle wavelengths (yellow-green) are maximally effective for visual performance.

Based on our knowledge of advanced lighting technologies and our understanding of neurophysiology and psychophysics of the human retina, we undertook a pilot study to determine if exposure to blue light from light emitting diodes (LEDs) could have a clinical impact on AD patients.

Methods

The six-week study was conducted in February and March of 2002 in a senior health care facility in Clifton Park, New York. The experiment was approved by Rensselaer's Institutional Review Board (IRB) and consent forms were signed by the caregivers, family members, and patients (2 out of 4 were able to sign them). Four AD patients, exhibiting a wide range of symptoms, from very mild to severe, participated in the study. Patients followed their normal routine except they were brought to a common room for two hours between 18:00 and 20:00 hours. This two-hour period was just prior to the time they were normally taken to their rooms to sleep for the night. The common room was furnished with a couch, a table and chairs, a television and some reading materials and games. The room was illuminated to approximately 300 lux (lx) on the table by ceiling fixtures containing fluorescent lamps. Two experimenters interacted with the patients during the evening two-hour sessions.

After two weeks of acclimation to the two-hour sessions, patients were exposed to tabletop light fixtures containing red LEDs each evening for 10 days (see figures 1A and 1B). These light fixtures produced approximately 30 lx at the cornea of the patients, but, of course, this illuminance could not be rigidly controlled due to random sleep periods, agitation and absence from the room due to other unrelated, clinical conditions. The red-light exposure condition was introduced as a control because red light at this illuminance should not be effective in activating the circadian system. The red-light exposure was followed by 10 days of blue-light exposure, again producing approximately 30 lx at the cornea of the patients from a tabletop light fixture. It was expected that this condition would be effective for activating the circadian system. The last 10 days was another control condition where the patients went back to their daily routine and data were collected after 6 days. Like the red-light exposure, this condition was not expected to be effective in activating the circadian system. These expectations concerning the different light exposures were based upon calculations using the spectral sensitivity of the circadian system from Brainard et al. (2001) [4] and Thapan et al. (2001) [5] and the dose response curve for melatonin suppression at night from Rea et al. (2002) [6].



Figure 1A and 1B - Experimental Design and Apparatus
Dependent Variables

Tympanic temperatures and observations of sleep were obtained from nurses during the last four nights of the red-light, blue-light, ambient-only lighting conditions. These data were obtained at approximately 22:00, 00:00, 02:00, 04:00 and 06:00 hours from all four patients. Two patients, one with very mild symptoms and one with severe symptoms, were fitted with wrist-worn devices that measured activity during the 6-week study.

Results

Consistent with the clinical diagnoses, the patients exhibited a wide range of dementia, from very mild to quite severe. The more severe patients exhibited random periods of agitation and calm, of wakefulness and sleeping, and they often demonstrated concern over missed appointments and loved ones. The more severe patients also showed incomplete participation during the appointed two-hour session due to severe agitation, incontinence or other problems, so exposure to the test lighting conditions was irregular during the three exposure periods.

The results obtained with this pilot study, however, were very encouraging. Even though the data were variable, we found the following:

- Blue light exposure delayed the decline of their body temperatures by 2-hours compared to red light exposure.
- Patients slept better between 02:00 and 04:00 hours after blue light exposure compared to red light exposure.

- The two patients that wore the wrist activity monitors showed more activity during daylight than at night, with peak activity shifting to midday. The ratio of activities during the day to those at night (light/dark ratio) increased, which means that they were more awake during the day and more asleep at night.

Repeated Measures Analysis of Variance (ANOVA) were conducted for both dependent variables: sleep and temperature. A statistically significant time by lighting conditions interaction was found for sleep ($p = 0.0027$). The percentages of time subjects were found asleep at 02:00 and at 04:00 hours were significantly greater ($p = 0.046$ and $p = 0.013$, respectively) after exposure to blue light than after exposure to red light. An almost statistically significant time by lighting conditions interaction was found for temperature ($p = 0.08$).

Together, these findings indicated that exposure to blue light consolidated their rest/activity periods and sleep relative to the exposure to red light or typical ambient lighting. Blue light might be a clinical, effective treatment for consolidating rest/activity rhythms of AD patients, which can also benefit caregivers in institutions and at home.

It should also be noted that it was expected that the “no stimulus” condition would have results similar to the red light conditions. The results showed, however, that the “no stimulus” (ambient-only lighting) condition results were in between the blue and the red light exposure results. A study presented in a recent conference [7] showed that an after-effect of the light treatment can persist for a few weeks. This could be an acceptable explanation for the results we found in the present pilot study, and offers an important direction for further clinical research.

Conclusions

The results found in this pilot study are very encouraging and should be replicated in a larger population over longer periods of time. This pilot study is also important because it can be used to inform the design of multi-institutional clinical trials that will further expand understanding of the effectiveness of blue light exposure on consolidating the rest/activity rhythms of people with Alzheimer’s disease.

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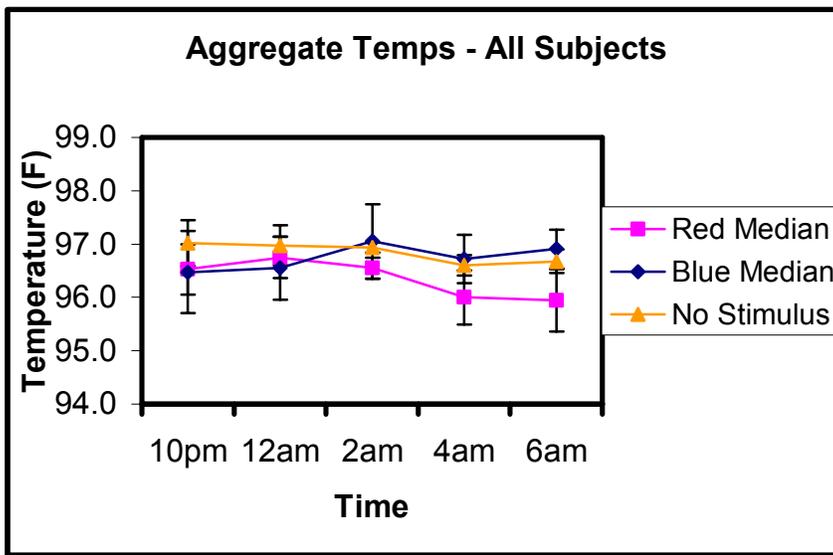


Figure 2: Aggregate temperatures for all 4 subjects. Decline of body temperature was delayed by approximately 2 hours, which is consistent with the timing of the light exposure

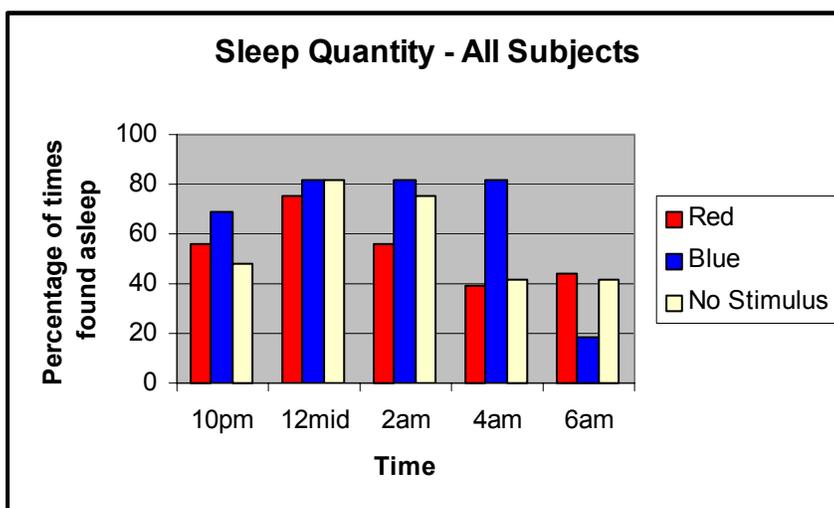


Figure 3: Sleep quantity for all subjects. Subjects slept better between 02:00 and 04:00 hours after blue-light exposure compared to red-light exposure

	SUBJECT 1 BLUE LED	SUBJECT 1 RED LED	SUBJECT 2 BLUE LED	SUBJECT 2 RED LED
Light/dark ratio	2.24	2.13	1.20	0.99
Cosine peak	11:40	12:20	11:40	04:00

Table 1: Light/dark ratio (light period from 06:00 to 20:00 hrs and dark period from 20:00 hrs to 06:00 hrs) is the ratio of activity recorded during the light period (day) to the activity recorded during the dark period (night). A higher ratio indicates relatively more activity during the day than during the night and better consolidation of rest/activity rhythms. Cosine peak time is the estimated time for peak activity during the 24 h day.

References:

1. Van Someren EJW, Kessler A, Mirmirann M, Swaab DF. 1997. Indirect bright light improves circadian rest-activity rhythm disturbances in demented patients. *Biol Psychiatry* 41: 55-963.
2. Roenneberg T and Foster RG. 1997. Twilight times. Light and the circadian systems. *Photchem Photobiol*, 66:549-561.
3. Jewett M, Rimmer DW, Duffy JF, Klerman EB, Kronauer R, Czeisler CA. 1997. Human circadian pacemaker is sensitive to light throughout subjective day without evidence of transients. *American Journal of Physiology* 273: R1800-R1809.
4. Brainard GC, Hanifin JP, Greeson JM, Byrne B, Glickman G, Gerner E, Rollag MD. 2001. Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. *Journal of Neuroscience* 21, (No16): 6405-6412.
5. Thapan K, Arendt J, Skene DJ. 2001. An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. *Journal of Physiology* 535(Pt. 1): 261-267.
6. Rea MS, Bullough JD, Figueiro MG. 2002. Phototransduction for human melatonin suppression. *J. Pineal Res.* 32:209 – 213.
7. Lewy, A. Enlightenment from studies of blind human subjects. 2002. *Presentation at the eighth meeting of the Society for Research on Biological Rhythms*, May 21-26; Amelia Island Plantation, Jacksonville FL.