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Effect of timed bright light treatment for rest-activity disruption in institutionalized patients with Alzheimer's disease

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SUMMARY

Background—Disturbances in rest-activity rhythm are prominent and disabling symptoms in Alzheimer's disease (AD). Nighttime sleep is severely fragmented and daytime activity is disrupted by multiple napping episodes. In most institutional environments, light levels are very low and may not be sufficient to entrain the circadian clock to the 24-hour day.

Method—The purpose of this randomized clinical trial was to test the effectiveness of timed bright light therapy in reducing rest-activity (circadian) disruption in institutionalized patients with AD. The experimental groups received either morning (9.30–10.30 am) or afternoon (3.30–4.30 pm) bright light exposure (≥ 2500 lux in gaze direction) Monday through Friday for 10 weeks. The control group received usual indoor light (150–200 lux). Nighttime sleep, daytime wake, and rest-activity parameters were determined by actigraphy. Repeated measures analysis of variance was employed to test the primary study hypotheses.

Results—Seventy institutionalized subjects with AD (mean age 84) completed the study. No significant differences in actigraphy-based measures of nighttime sleep or daytime wake were found between groups. Subjects in either experimental light condition evidenced a significantly ($p < 0.01$) more stable rest-activity rhythm acrophase over the 10-week treatment period compared to the control subjects whose rhythm phase delayed by over two hours.

Conclusions—One hour of bright light, administered to subjects with AD either in the morning or afternoon, did not improve nighttime sleep or daytime wake compared to a control group of similar subjects. However, exposure to one-hour of bright light in either the morning or afternoon may provide sufficient additional input to the circadian pacemaker to facilitate entrainment to the 24-hour day.

Keywords

actigraphy; dementia; sleep; circadian rhythms; light; nursing home

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BACKGROUND/LITERATURE REVIEW

In AD, nighttime sleep is severely fragmented and daytime activity is disrupted by multiple naps. Disturbances in the rest-activity rhythm negatively impact quality of life and are one of the primary reasons care-givers of patients with AD seek institutionalization (Hope *et al.*, 1998; Yaffe *et al.*, 2002). It may also be easier to provide nursing care to patients who have socially acceptable circadian rhythm patterns (Ancoli-Isreal *et al.*, 2002). Neurological deterioration that underlies the AD process and decreases in external zeitgebers that influence circadian rhythms (e.g. bright light) contribute to the etiology of the rest-activity disruption (Bliwise *et al.*, 1995; Yesavage *et al.*, 2003). Pharmacologic treatment for sleep disruption has proven only minimally effective and is often associated with unacceptable side effects (McCurry and Ancoli-Israel, 2003; Yesavage *et al.*, 2003).

Exposure of the eyes to light of sufficient intensity and duration at the appropriate time of day can have profound effects on the quality, duration, and timing of sleep. The effect of light on the brain is mediated by the retinohypothalamic tract and the daily light-dark cycle is the primary synchronizer responsible for entrainment of circadian rhythms to the 24-hour day (Hoban *et al.*, 1991). In an institutional environment, where light levels tend to be very low, residents may not be exposed to sufficient bright light to entrain to the 24-hour day (Campbell *et al.*, 1988; Shochat *et al.*, 2000).

Therapeutic exposure to bright light has been shown to alter nighttime and daytime sleep and wake, and rest-activity rhythms. Castor *et al.* (1991) reported significant improvement in observed sleep-wake cycles following twice-daily exposure to sunlight (9–10 am and 2–3 pm) for 2 weeks in 12 nursing home residents with dementia. Satlin *et al.* (1992) found that evening exposure to light (1500–2000 lux, 7–9 pm) decreased nighttime activity and sundowning symptoms in 10 subjects with AD. Lyketsos *et al.* (1999) administered morning light (10,000 lux) for 2 weeks to institutionalized patients with dementia and found that those patients who exhibited agitated behaviors slept more hours at night with the bright light exposure. Bright light did not, however, improve agitated behaviors in patients who did not exhibit disturbed sleep-wake cycles. Ancoli-Israel *et al.* (2003) administered light (2500 lux) between either 9.30–11.30 am or 5.30–7.30 pm for 10 days and found both groups had more consolidated sleep at night. Yamadera *et al.* (2000) found that morning bright light administration (3000 lux, 9–11 am for 4 weeks) resulted in improved mental status scores, decreased percentage of daytime naptime, decreased number of daytime naps, increased percentage of nighttime sleep time and decreased percentage of nighttime awakenings. He suggested that the utility of bright light treatment for improving circadian rhythms was a synchronizing factor and that the effects declined with more severe dementia perhaps due to more severe damage to the suprachiasmic nucleus and resultant decreased sensitivity to light. Fetveit *et al.* (2003) administered 2 hours of morning bright light (6000–8000 lux, 8–11 am for 2 weeks) and reported improved nighttime sleep efficiency, decreased nighttime wake time and sleep onset latency. Rest-activity levels also showed decreased nighttime activity and decreased mesor with no change in acrophase. Dowling *et al.* (in press) found that one hour of morning bright light exposure (9.30–10.30 am) improved rhythm stability in subjects who were not entrained to the 24-hour day. In summary, while the appropriate intensity, duration, or timing of exposure to light has not been established, research reports indicate that light can be an effective treatment strategy for sleep-activity disruption in subjects with AD.

The purpose of this study was to test the effect of timed bright light exposure on nighttime sleep, daytime wake time, and the rest-activity rhythm. We hypothesized that treatment with bright light from 9.30–10.30 am would result in the most improvement, and that afternoon light from 3.30–4.30 pm would have a lesser effect, compared to the control group. We

anticipated that morning light exposure would phase advance the rest-activity rhythm, while the afternoon light exposure would phase delay the rest-activity rhythm.

METHODS

Subjects

Residents of two large long-term care facilities in San Francisco, California who experienced rest-activity disruption and were diagnosed with AD were identified by staff. Rest-activity disruptions included insomnia, frequent nighttime awakenings, wandering at night, unusually early morning awakenings, sundowning, and excessive daytime sleepiness. Chart reviews were conducted to confirm that potential subjects met the following criteria for inclusion: a diagnosis of AD according to the National Institute of Neurological and Communicative Disorders and Stroke—The Alzheimer's Disease and Related Disorders Association (NINCDS-ADRDA) criteria (McKhann *et al.*, 1984), the ability to perceive light, and on a stable medication regimen. Potential subjects were excluded if they had other neurological diagnoses (e.g. Parkinson's disease) or were regularly taking valerian, melatonin, or sleeping pills.

Informed consent was obtained from responsible parties as approved by the Institutional Review Board and 70 subjects completed the study. Subjects (57 female, 13 male) were, on average, 84 years of age (SD = 10, range 58–98) with a mean Mini-Mental State Exam (MMSE; Folstein *et al.*, 1975) score of 7 (SD = 7, range 0–23).

Measures

Rest-activity data were collected using the Actiwatch® activity monitor (AW-64, Mini Mitter Co, Inc. Bend, OR, USA). Actiwatches are compact, battery-operated activity monitors with physical characteristics similar to a small wristwatch. Activity counts are stored in memory on board the device in one-minute epochs. Actiwatches were placed on each subject's dominant wrist and a nylon locking cable was affixed through the watchband to deter removal. Subjects wore the Actiwatch continuously during each monitoring period. Actigraphy provides a feasible technique for studying the rest-activity rhythm in institutionalized patients with dementia and has been shown to correlate well with both electroencephalogram recordings and direct observation (Ancoli-Israel *et al.*, 1997).

Procedures

This study was conducted in two phases. Phase One was designed to compare morning bright light exposure to usual room light exposure; subjects were randomly assigned to either the bright light or usual light conditions. Phase Two was designed to compare morning to afternoon bright light exposure; subjects were randomly assigned to either the morning bright light or afternoon bright light conditions. Subjects exposed to morning bright light in either Phase One or Phase Two did not differ statistically on any demographic characteristics. Subjects who received morning bright light exposure in either Phase One or Phase Two were included in these analyses.

The study protocol was 11 weeks in duration: Baseline (week 1), Intervention (weeks 2–11). The study outcome measures were assessed during weeks 1 and 11. Subjects in the experimental conditions received either morning (9.30–10.30 am) or afternoon (3.30–4.30 pm) bright light exposure (≥ 2500 lux in gaze direction) Monday through Friday for 10 weeks. During this time, subjects in the experimental groups participated in activities in a brightly lit area, either outdoors or in an indoor space with windows to let in ample natural light. APOLLO Brite Lite IV™ (Orem, UT, USA) light boxes were used when necessary to supplement the ambient light. These boxes (23″ × 12″ × 4″) provide 10,000 lux exposure at 26 inches and 2500 lux exposure at 4 feet. Light levels were monitored each day during the intervention with a Cal

LIGHT 400™ (Auburn Hills, MI, USA) calibrated precision light meter. The control group received usual indoor light (150–200 lux) and participated in their regularly scheduled activities in the usual location. The experimental groups participated in activities similar to those provided to the control group subjects.

Statistical analysis

Actigraphy data were analyzed using the Actiware™ Sleep Version 3.2. Daytime and nighttime were defined by the institutional bed and rise times of 8 am and 8 pm. While calculating the actual time in bed for each subject would have been optimal, this was not possible due to staffing constraints. Other investigators have used similar methods to define day and night intervals (e.g. Ancoli-Israel *et al.*, 2002) and these methods correlate well with actual nurse recorded time in bed. For example, Fetveit and colleagues (2003) reported actual time in bed to be approximately 12 hours in a study of 11 patients with dementia who participated in a light study. While standardizing the sleep period facilitates comparisons across subjects, an a *priori* defined nighttime could result in an underestimate of sleep efficiency due to the prolonged time in bed. We therefore also analyzed a 4-hour block of time (12 am–4 am) when all subjects were likely to have been in bed and asleep.

The primary nighttime outcome variables were sleep efficiency, sleep time, wake time, and number of awakenings. We also calculated duration of nighttime awakenings, mean night and day activity levels, and daytime wake time. Traditional cosinor analyses were used to estimate each subject's 24-hour rest-activity rhythm (Refinetti, 2000). For each subject and time condition, the parametric 24-hour fixed period cosinor model was fit to the raw actigraphy data (counts per minute) after $\log_e$ transformation. Circular decimal clock time was re-represented as two trigonometric dummy variables (sine and cosine projections on 6 am and 12 am, respectively), which were used as simultaneous independent variables in a least squares multiple regression. The resulting within-subject coefficient estimates were then transformed to compute standard interpretive cosinor parameters (e.g. amplitude, acrophase) as well as a goodness of fit index for the model (*r*-square). These within-subject cosinor summary parameters then became variables in the across-subject analyses. Repeated measures analysis of variance (three groups by two time-points design) was used to test the study hypotheses of potential treatment group differences in intra-individual change from baseline (week 1) to the end of the intervention (week 11) in the summary variables.

RESULTS

Compliance with actigraphy

Subjects tolerated the Actiwatches well, with 84% never removing the device during the 6 days and 7 nights at baseline and 4 days and 5 nights at the end of the intervention. On average, there were 153 hours of valid data for the baseline week (SD = 7, range 125–156) and 105 hours for the intervention week (SD = 7, range 69–108), with no significant differences between the groups.

Exposure to light treatment

Attendance and approximate percent of the intervention missed (e.g. eyes closed/sleeping, toileting time, etc.) were recorded for each subject. The percentage (dose) of intervention received was calculated by dividing the hours of intervention received by the total possible number of intervention hours (50 hours over the 10-week intervention period). The mean percentage of intervention received was 76% (SD = 17, range 28–100) and there was no significant difference in dose between the experimental groups.

Sleep and wake

Mean values for these variables by group are presented in Table 1. Repeated measures analysis of variance revealed no significant differences in nighttime or daytime sleep or activity variables between the groups.

Rest-activity rhythm

Mean values for these variables by group are presented in Table 2. Cosinor analysis of baseline data revealed relatively low *r*-square values indicating a poor goodness of fit of the model with the data as has been reported elsewhere for subjects with severe AD (Harper *et al.*, 2004). Goodness of fit (*r*-square) was used as a covariate in the subsequent acrophase analyses. Repeated measures analysis of variance revealed no significant differences in *r*-square or amplitude between the three groups. There was, however, a significant ($p < 0.04$) main effect of treatment for acrophase with relative stability in both morning and afternoon light experimental groups, but a mean shift in excess of two hours in the control group. The average peak of the rest-activity rhythm delayed 131 minutes in the control group (from 13:33 to 15:44) and advanced slightly in the morning (17 minutes) and afternoon (1 minute) groups. When we compared all subjects who received light (either morning or afternoon) to the control subjects, repeated measures analysis of variance revealed an even more significant result ($p < 0.01$).

DISCUSSION

Overall, bright light exposure in the morning or afternoon did not improve the majority of measures of sleep-wake or rest-activity compared to control subjects. These findings are different from those reported by others (e.g. Satlin *et al.*, 1992; Ancoli-Israel *et al.*, 2003) where subjects evidenced improvement in sleep-wake and/or circadian parameters. Due to institutional staffing constraints, subjects in the experimental conditions were only exposed to bright light Monday through Friday. It is possible that light exposure every day of the week, exposure of longer duration each day, or higher intensity would have produced a stronger effect. The old age, severity of dementia, and large inter-individual differences in our sample may also explain, in part, the lack of treatment effects. It is possible that subjects respond to light differently across the lifespan and range of cognitive impairment (Yamadera *et al.*, 2000; Ancoli-Israel *et al.*, 2002). Since 96% of our sample scored in the moderate or severe range of MMSE scores, subjects may have had only a weak sensitivity to the light exposure as suggested by Yamadera *et al.* (2000).

Subjects in this study exhibited severely disrupted rest-activity rhythms, as reflected by low values for *r*-square at baseline. Since the light treatments were administered to all subjects at the same times of the day, it is possible that some subjects received light during a sensitive region of their individual phase response curve while others did not. In future studies, it might be more effective to individualize the timing of light exposure for each subject based on their endogenous rhythm.

While we found no statistically significant differences between the groups on the circadian parameters of goodness of fit or amplitude, our results indicate that the experimental groups, as a whole, received sufficient light to prevent their rest-activity rhythm acrophase from shifting. In contrast, the tendency in the control group was to phase delay, perhaps because their overall light exposure was not sufficient to maintain their entrainment to the 24-hour day. Thus, exposure to one-hour of bright light in either the morning or afternoon may provide sufficient additional input to the circadian pacemaker to facilitate entrainment, but not enough to impact other circadian or sleep parameters. This finding has the potential to be clinically significant for the delivery of care since it may be easier for caregivers across settings to provide care to patients with socially acceptable rest-activity patterns (i.e. active during the day and

asleep at night). Finally, bright light alone was not sufficient to impact sleep and circadian parameters in this population but might produce a more robust effect if combined with other treatments, for example, melatonin.

CONCLUSION

One hour of bright light, administered to institutionalized subjects with AD either in the morning or afternoon, did not improve nighttime sleep or daytime wake parameters compared to a control group of similar patients. Subjects who received the bright light did, however, evidence a stability of their rest-activity rhythms that was not evidenced in subjects who received only light of usual institutional intensity. Bright light remains a potentially promising and practical intervention in the long term care environment. Further studies are needed to assess whether daily and longer duration of light exposure could produce more robust effects.

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References

Ancoli-Israel S, Clopton P, Klauber MR, Fell R, Mason W. Use of wrist activity for monitoring sleep/wake in demented nursing-home patients. Sleep 1997;20:24–27. [PubMed: 9130330]

Ancoli-Israel S, Gehrman P, Martin JL, et al. Increased light exposure consolidates sleep and strengthens circadian rhythms in severe Alzheimer's disease patients. Behavioral Sleep Med 2003;1:22–36.

Ancoli-Israel S, Martin JL, Kripke DF, Marler M, Klauber MR. Effect of light treatment on sleep and circadian rhythms in demented nursing home patients. J Am Geriatr Soc 2002;50:282–289. [PubMed: 12028210]

Bliwise DL, Hughes M, McMahon PM, Kutner N. Observed sleep/wakefulness and severity of dementia in an Alzheimer disease special care unit. J Gerontol A Biol Sci Med Sci 1995;50A:M303–M306. [PubMed: 7583801]

Campbell SA, Kripke DF, Gillin JC, Hrubovcak JC. Exposure to light in healthy elderly subjects and Alzheimer's patients. Physiol Behav 1988;42:141–144. [PubMed: 3368532]

Castor D, Woods D, Pigott K, Hemmes R. Effect of sunlight on sleep patterns of the elderly. JAAPA 1991;4:321–326.

Dowling GA, Hubbard EM, Mastick J, Luxenberg JS, Burr RL, Van Someren EJW. Effect of morning bright light treatment for rest-activity disruption in institutionalized patients with severe Alzheimer's disease. Int Psychogeriatr. In pressin press

Fetveit A, Skjerve A, Bjorvatn B. Bright light treatment improves sleep in institutionalized elderly—an open trial. Int J Geriatr Psychiatry 2003;18:520–526. [PubMed: 12789673]

Folstein MF, Folstein SE, McHugh PR. 'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician. J Psychiatr Res 1975;12:189–198. [PubMed: 1202204]

Harper DG, Stopa EG, McKee AC, Satlin A, Fish D, Volicer L. Dementia severity and Lewy bodies affect circadian rhythms in Alzheimer disease. Neurobiol Aging 2004;25:771–781. [PubMed: 15165702]

Hoban TM, Lewy AJ, Sack RI, Singer CM. The effects of shifting sleep two hours within a fixed photoperiod. J Neural Transm Gen Sect 1991;85:61–68. [PubMed: 1867839]

Hope T, Keene J, Gedling K, Fairburn CG, Jacoby R. Predictors of institutionalization for people with dementia living at home with a carer. Int J Geriatr Psychiatry 1998;13:682–690. [PubMed: 9818303]

Lyketsos CG, Veiel LL, Baker A, Steele C. A randomized, controlled trial of bright light therapy for agitated behaviors in dementia patients residiing in long-term care. Int J of Geriatr Psychiatry 1999;14:520–525. [PubMed: 10440971]

McCurry SM, Ancoli-Israel S. Sleep dysfunction in Alzheimer's disease and other dementias. Curr Treat Options Neurol 2003;5:261–272. [PubMed: 12670415]

McKhann G, Drachman D, Folstein M, Katzman R, Price D, Stadlan EM. Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA work group under the auspices of Department of Health and Human Services task force on Alzheimer's disease. Neurology 1984;34:939–944. [PubMed: 6610841]

Refinetti, R. Circadian Physiology. CRC Press LLC; Boca Raton, Florida: 2000.

Satlin A, Volicer L, Ross V, Herz L, Campbell S. Bright light treatment of behavioral and sleep disturbances in patients with Alzheimer's disease. Am J Psychiatry 1992;149:1028–1032. [PubMed: 1353313]

Shochat T, Martin J, Marler M, Ancoli-Israel S. Illumination levels in nursing home patients: effects on sleep and activity rhythms. J Sleep Res 2000;9:373–379. [PubMed: 11386204]

Yaffe K, Fox P, Newcomer R, et al. Patient and caregiver characteristics and nursing home placement in patients with dementia. JAMA 2002;287:2090–2097. [PubMed: 11966383]

Yamadera H, Ito T, Suzuki H, Asayama K, Ito R, Endo S. Effects of bright light on cognitive and sleep-wake (circadian) rhythm disturbances in Alzheimer-type dementia. Psychiatry Clin Neurosci 2000;54:352–353. [PubMed: 11186110]

Yesavage JA, Friedman L, Ancoli-Israel S, et al. Development of diagnostic criteria for defining sleep disturbance in Alzheimer's disease. J Geriatr Psychiatry Neurol 2003;16:131–139. [PubMed: 12967054]

Table 1

Actigraphy variable analyses, means and standard deviations, $n = 70$ (17 control, 29 am light, 24 pm light)

Nighttime variables (8 pm–8 am)	Baseline	End of intervention
Sleep Efficiency (%)		
Control	66.88 (19.24)	71.14 (16.78)
am light	63.02 (19.57)	66.64 (15.85)
pm light	72.70 (13.58)	72.68 (13.65)
Sleep Time (hh:mm)		
Control	8:01 (2:18)	8:32 (2:00)
am light	7:33 (2:20)	7:59 (1:54)
pm light	8:43 (1:38)	8:42 (1:38)
Wake Time (hh:mm)		
Control	3:58 (2:18)	3:27 (2:00)
am light	4:25 (2:20)	3:59 (1:54)
pm light	3:16 (1:37)	3:16 (1:38)
Number of Awakenings		
Control	34.88 (13.65)	37.99 (11.65)
am light	41.56 (16.03)	42.88 (37.99)
pm light	32.08 (11.76)	33.61 (11.63)
Duration of Awakenings (mm:ss)		
Control	8:11 (6:11)	5:58 (3:48)
am light	7:14 (4:43)	6:14 (4:26)
pm light	6:39 (3:54)	6:14 (3:12)
Mean Activity Score		
Control	55249 (147365)	45538 (51428)
am light	79516 (147365)	88327 (227063)
pm light	41608 (31086)	41608 (31086)
Daytime Variables (8 am–8 pm)		
Wake Time (hh:mm)		
Control	7:21 (2:43)	6:34 (2:50)
am light	6:36 (2:30)	6:24 (2:38)
pm light	6:27 (3:03)	6:23 (2:55)
Mean Activity Score		
Control	94573 (70061)	83513 (67641)
am light	110853 (171174)	133564 (305546)
pm light	89176 (74548)	84094 (74949)

Table 2

Circadian rhythm cosinor analyses, means and standard deviations, $n = 70$ (17 control, 29 am light, 24 pm light)

	Baseline	End of intervention
R^2		
Control	0.17 (0.14)	0.16 (0.13)
am light	0.09 (0.09)	0.11 (0.09)
pm light	0.17 (0.14)	0.17 (0.15)
Amplitude		
Control	1.32 (0.83)	1.20 (0.79)
am light	0.89 (0.56)	1.05 (0.70)
pm light	1.29 (0.83)	1.28 (0.88)
Acrophase (hh:mm)		
Control	13:33 (3:26)	15:44 (3:39)
am light	15:28 (3:19)	15:11 (3:40)
pm light	14:34 (2:05)	14:33 (2:21)