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Brief morning light treatment for sleep/wake disturbances in older memory- impaired individuals and their caregivers

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Abstract

Background—Scheduled exposure to bright light (phototherapy) has been used, with varying degrees of success, to treat sleep disruption in older individuals. Most of these studies have been done in institutional settings and have used several hours of daily light exposure. Such a regimen in the home setting may be untenable, especially when the individual with the sleep disruption has memory impairment and is being cared for by a family member. As such, we examined the effectiveness of a "user-friendly" phototherapy protocol that would be readily usable in the home environment.

Methods—We exposed a group of 54 older caregiver/care recipient dyads, in which the care recipient had a memory impairment, to two weeks of morning bright light phototherapy. Dyads were exposed to either bright white (~4,200 lux) or dim red (~90 lux) light for 30 minutes every day, starting within 30 minutes of arising. All subjects also received sleep hygiene therapy. Objective (actigraphy) and subjective measures of sleep and mood were obtained at baseline and at the end of the two weeks of phototherapy.

Results—In care recipients, actigraphy- and log-determined time in bed and total sleep time declined in the active condition ($p<0.05$, ANOVA); there was no corresponding change in subjective insomnia symptoms ($p's>0.37$, ANOVA). The decrease in time in bed was associated with an earlier out of bed time in the morning ($p<0.001$, Pearson correlation). The decrease in total sleep time was associated with a decrease in sleep efficiency ($p<0.001$, Pearson correlation) and an increase in wake after sleep onset ($p<0.001$, Pearson correlation). In caregivers, there were no differential changes in actigraphic measures of sleep ($p's>0.05$, ANOVA). Actigraphy-measured wake after sleep onset and sleep efficiency did, however, improve in both conditions, as did sleepiness, insomnia symptoms, and depressive symptomatology ($p's<0.05$, ANOVA).

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Conclusions—Exposure to this regimen of phototherapy diminished sleep in older individuals with memory impairments. Their caregivers, however, experienced an improvement in sleep and mood that appeared independent of the phototherapy and likely due to participation in this protocol or the sleep hygiene therapy.

Keywords

sleep; Alzheimer's; phototherapy; light; caregiver; circadian; clinical trial

Introduction

Scheduled bright light has been used to treat sleep disorders with chronobiological etiology for more than 30 years [1]. It has been hypothesized that the sleep disruption frequently associated with Alzheimer's disease (AD) may have a chronobiological etiology secondary to a diminution of the amplitude of the circadian oscillation [2]. It has been further hypothesized that bright light could help increase the amplitude of the circadian system in older individuals, secondarily improving sleep [3].

Clinical trials of the effects of bright light on sleep problems in older individuals with memory problems of varying etiologies, however, have had mixed results [4–9]. Setting (home, institution), timing (morning, evening), and duration (1–16 hours) have all varied among studies, potentially contributing to the heterogeneity of findings regarding the efficacy of the treatment. Most studies of bright light treatment have been administered in institutional settings. Even if we were to suppose that bright light is a therapy practical for translation into wide use, current delivery regimens typically require several hours of bright light exposure, which is not feasible for most adults, especially those with memory problems in whom compliance might be an issue. Thus, although potentially efficacious, there are significant effectiveness questions regarding the delivery of bright light treatment for individuals with memory impairment.

We developed a "user friendly" protocol that investigated whether a brief (30-minute) daily exposure to bright light delivered at home by caregivers would be sufficient to improve sleep in individuals with memory problems. Two conditions (bright white light and dim red light) were studied, both of which included an identical program of sleep hygiene for ethical reasons and to support the believability of the placebo condition. Caregivers themselves also received both elements of the treatment and were responsible for the completion of study measures as well as the delivery of the light treatment to the care recipient. Given the caregivers' participation, we examined the effects of the light therapy and the sleep hygiene component on both the sleep and psychological status of the caregivers as well as the care recipients.

Methods

Participants

Participants (care recipient/caregiver dyads) were enlisted from the surrounding community through flyers, informational presentations, senior newsletters, local newspaper and radio advertisements, and referral from the Alzheimer's Disease Research Center of California at the VA Palo Alto Health Care System. All care recipients were required to have a diagnosis of mild cognitive impairment (MCI), AD, other dementia, or diagnosable memory impairment (California Department of Health Services Alzheimer's Research Centers of California, IHA-UCSF Version 07/01/99 criteria). Because sleep disturbances are prevalent among older adults with memory problems [10], and care recipient sleep disturbance does not necessarily affect caregiver sleep [11], we did not assume that caregivers would be

reliable informants regarding care recipient sleep, and therefore recruited without a requirement of a complaint about care recipient sleep. Both caregivers and care recipients were required to obtain documented approval from a licensed optometrist or ophthalmologist to participate in the protocol. Exclusion criteria included history of mania or bipolar disorder, prior bright light treatment, irregular or non-24 hour sleep/wake cycle, Parkinson's disease, and indications of restless legs syndrome or periodic limb movement disorder as indicated by responses to relevant items on the Global Sleep Assessment Questionnaire, GSAQ [12]). All procedures described below were approved by the Stanford University Institutional Review Board and were consistent with the principles outlined in the Declaration of Helsinki.

Design

The study design was a parallel group two week-study of an in-home light treatment. There were two conditions: BRIGHT and DIM. In both conditions, caregivers and care recipients received the same experimental light exposure and were positioned side by side in front of the light boxes for 30 minutes, beginning within 30 minutes of the care recipient's arising for the day. Rise time was based on the information collected in seven days of sleep reports prior to the intervention, as well as on discussion with the dyad as to feasibility. In both experimental conditions light exposure was scheduled to take place once daily and was introduced gradually, starting with 10 min on Day 1, increasing to 20 min on Day 2, and finally to 30 min on Day 3, where it remained until the end of treatment (Day 14). Taking into account participants' living arrangements and convenience, light boxes of the same size (12" x 6" opening) and manufacture (SunBox Co., Gaithersburg, MD) were placed in a dedicated area of the home so that light exposure was maximally convenient while adhering to the constraints of the targeted light exposure (see below). After optimal light conditions were obtained, a research assistant collected ten readings of illuminance at all participants' outer canthi (Spectra Professional IV-A photometer, Spectra Cine, Burbank CA) with the light sensor positioned in the direction of the participant's gaze. These measurements were repeated at the end of the treatment. In BRIGHT, light boxes produced 4,200 ± 1,600 lux full spectrum white light at the corneal level. In DIM, red filters reduced lamp output such that ambient illumination was 90 ± 96 lux, which was slightly higher (by 37 ± 66 lux, $p<0.001$, paired *t*-test) than the ambient illumination already present (56 ± 88 lux). All light boxes had a plastic filter that blocked ultraviolet (UV-A, UV-B) radiation. Participants were instructed to avoid looking directly at the light boxes and to read, watch television, or conduct any sedentary activity that could be accomplished by staying in one location for the allotted 30 minutes.

On the first day of light treatment, all patient/caregiver dyads received sleep hygiene treatment administered by an experienced sleep therapist (LF) in a telephone session lasting approximately 50 minutes. The intent of this session was to bolster participants' understanding of and compliance with the protocol through a brief, simplified explanation of the factors underlying sleep regulation as well as the basics of sleep hygiene. Participants were given a manualized set of instructions to follow, which included suggestions for: regular scheduling of meals and into and out of bed times; a sleep environment that was dark yet safe, quiet (no radio/TV), comfortable, and separate from other activities; and limitation of caffeine (two cups no later than lunch) and alcohol (one drink no later than dinner). Increased daytime activity was encouraged and napping discouraged; looking at the clock on waking during the night was also discouraged. The therapist provided the rationale for each instruction and discussed possible solutions for any that were problematic for specific individuals. There was a follow-up sleep hygiene telephone session at the end of the first week of light treatment. In this session the sleep hygiene components were reviewed and caregivers and care recipients discussed practices they had been trying to change, problems

that interfered with change, and solutions that could be used to deal with these problems. Care recipients were encouraged to participate in these discussions.

Measures

Sleep reports and actigraphy—Daily sleep reports and wrist actigraphy (small motion-detecting devices that resemble a wrist watch in appearance) (Octogon Basic Actigraph, Ambulatory Monitoring Inc, Ardsley, NY) were collected for both members of the dyad during a baseline week (Week 0) prior to intervention and during the second (final) week of intervention (Week 2). Information on the daily sleep reports was completed by caregivers and included into- and out-of-bed times. Both participants also wore wrist actigraphs that were used to collect three-dimensional arm movement data for estimating sleep/wake in participants' home environments (Ancoli-Israel et al., 2003). Actigraphs were set to collect data in 60-second epochs and were later scored (Action 4, Ambulatory Monitoring Inc.) and averaged across nights. The sleep parameters of interest were number of minutes of wake after sleep onset (WASO), time in bed (TIB, determined from sleep logs), total sleep time (TST), and sleep efficiency (SE, equal to TST/TIB).

Questionnaires—At Weeks 0 and 2, study questionnaires were also administered. Questionnaires included the Epworth Sleepiness Scale [13] (ESS, daytime sleepiness), a 20-item modification of the Blake-Gomez Sleep Hygiene Questionnaire [14] (sleep hygiene-related behaviors), and the Beck Depression Inventory [15] (BDI, depressive symptomatology). The Mini-Mental State Examination [16] (MMSE) and the CERAD Word List Memory test [17] were administered at baseline as measures of global cognition and memory, respectively. The first four questions of the GSAQ were analyzed for subjective assessment of symptoms of insomnia (q1) and daytime sleepiness (q2-4). In all cases where care recipients wished to complete questionnaires, responses were checked by caregivers.

Statistical Analyses

Data were analyzed with two-way repeated measure analysis of variance (ANOVA) using *post-hoc* paired t-tests as appropriate (SAS 9.1.3, SAS Institute, Cary NC). Correlational examinations were conducted using Pearson correlation (Origin, OriginLab Corporation, Northampton MA). All data are presented as average ± SD.

Results

Of 1056 initial recruitment responses and referrals, 959 individuals were either not interested in participation or did not meet inclusion/exclusion criteria, (e.g., not having a caregiver living in the home willing to participate in the study). Of the 97 caregiver-care recipient dyads passing initial screening, 21 were ineligible and another 17 were not interested in continuing participation. A total of 59 dyads were randomized to treatment; three dyads dropped out during treatment and two additional dyads were not included in the analyses because a change from their initial diagnosis made them ineligible. The memory-impaired participants (23 female/31 male) were 77.9 ± 8.1 years old, had 15.2 ± 2.3 years of education, MMSE scores of 22.1 ± 4.7 (range, 10–28), and CERAD recall scores of 1.26 ± 1.82 (range, 0–8). Their caregivers (36 female/18 male) were 68.8 ± 12.7 years old and had 15.6 ± 2.2 yrs of education, MMSE scores of 29.2 ± 1.1, and CERAD recall scores of 6.57 ± 2.29 (range, 0–10). The 54 completed dyads were randomized as 31 in BRIGHT and 23 in DIM. The imbalance in BRIGHT vs. DIM was due to obtaining a lower recruitment number than was originally expected and upon which the randomization scheme was based. There was no difference in age, sex ratio, or years of education within caregivers or care recipients randomized to BRIGHT or DIM (p's>0.15; t's<|1.45|, df = 52, *t*-tests or χ^{2}'s<0.60, df = 1, X^2 test, as appropriate). Caregivers in BRIGHT had a slightly higher MMSE than caregivers

in DIM at baseline (29.5 ± 0.85 versus 28.7 ± 1.24, $p<0.05$, $t = 2.52$, $df = 51$, *t*-test), but there was no significant difference in baseline MMSE for care recipients randomized to either condition ($p=0.057$, $t = 1.97$, $df = 33.3$, *t*-test).

In care recipients, TIB and TST significantly declined in BRIGHT as compared to DIM (Table 1). WASO and SE were unchanged in both BRIGHT and DIM (Table 1). The TIB decrease in BRIGHT was associated with an earlier out of bed time ($p<0.001$, $r=0.89$, Pearson correlation), but time into bed ($p=0.19$, $r= -0.25$, Pearson correlation) did not change. The decline in TST was associated with a decrease in SE ($p<0.001$, $r=0.78$, Pearson correlation) and an increase in WASO ($p<0.001$, $r= -0.66$, Pearson correlation), even though SE and WASO were not, independently, changed by BRIGHT. Thus, care recipients exposed to BRIGHT got out of bed earlier than usual, and this was associated with a worsening of their sleep. There was, however, no significant change in GSAQ-rated subjective insomnia symptoms or sleepiness as perceived by the caregivers (p's>0.37, $F's_{(1,52)}<0.81$, ANOVAs).

In caregivers exposed to either BRIGHT or DIM, actigraphy indicated a decline in WASO, an improvement in SE, and no change in TIB and TST (Table 1). Regardless of treatment condition, GSAQ-rated insomnia symptoms (q1) were also improved ($p<0.01$, $F_{(1,52)} = 11.02$, ANOVA). Because we observed improvements in WASO, SE, and GSAQ in caregivers under *both* BRIGHT and DIM, the results could be ascribed to a participation effect or the common intervention (sleep hygiene). After two weeks of study participation, independent of treatment condition, caregivers also had significant improvements in their Blake-Gomez scores (1.7 ± 2.2 in BRIGHT, 1.5 ± 1.7 in DIM; $p<0.0001$, $F_{(1,40)} = 25.27$, ANOVA), BDI scores (−3.9 ± 3.7 in BRIGHT, −2.9 ± 4.1 in DIM; $p<0.0001$, $F_{(1,52)} = 40.63$, ANOVA), and ESS scores (−1.8 ± 2.8 in BRIGHT, −0.80 ± 2.1 in DIM; $p<0.05$, $F_{(1,26)} = 6.58$, ANOVA). The changes in WASO and GSAQ (q1) were not, however, correlated with the changes in BDI, Blake-Gomez, or ESS (p's>0.06, r's<|0.3|, Pearson correlations). The change in SE, while not correlated with Blake-Gomez or ESS (p's>0.19, r's<|0.26|, Pearson correlations), was correlated with change in BDI score ($p<0.05$, $r= -0.32$, Pearson correlation). The change in BDI score was itself correlated with a change in the Blake-Gomez ($p<0.05$, $r= -0.34$, Pearson correlation).

Discussion

These results suggest that a brief, 30-minute exposure to bright light in the morning was not sufficient for improving sleep in older individuals with memory problems or their caregivers. If anything, the requirements of the study may have curtailed the sleep time of the care recipients such that they got less sleep during the intervention. We observed this in those individuals exposed to BRIGHT as compared to DIM, implying that the dyad might have been more motivated to participate in the BRIGHT condition and gotten up earlier than necessarily desired. It should be noted, however, that time in bed still remained at more than nine hours at the end of the study. As reducing time in bed can be a useful treatment of sleep disruption, sleep restriction as an adjunct to phototherapy should be explored in future studies. Issues of timing and duration of light exposure may well have influenced the outcome of this effectiveness study. The efficacy of morning versus evening exposure for the treatment of sleep disruption in older individuals is equivocal. We chose to provide morning exposure to ease caregivers' burden in keeping care recipients awake during the light exposure. Again to ease caregiver burden, the length of the exposure was limited to 30 minutes, which may have been too brief.

In the caregivers, we found that sleep improved in both the DIM and BRIGHT conditions, implying that the improvement was likely due either to a participation effect or the common

intervention, sleep hygiene. Behaviors related to sleep hygiene, as measured by the modified Blake-Gomez questionnaire, did improve in all caregivers. While the changes in sleep hygiene were not correlated with any of the sleep improvements we observed, they were correlated with changes in depressive symptomatology in both BRIGHT and DIM. Mood disorders such as depression occur at a higher incidence among caregivers than among their age-matched non-caregiving cohorts [18] and such depression in caregivers is often correlated with their sleep problems [19–21]. Further testing of sleep hygiene against an appropriate control is needed to determine if changes in sleep-related behaviors alone are sufficient to improve depressive symptomatology in caregivers or if mere participation in a research study (i.e., having their problems heard) is sufficient to improve mood.

In a previous study, a large, carefully controlled clinical trial, we found that bright light in older, non-demented adults was ineffective in the treatment of their primary insomnia [22]. It may be that an increase in bright light exposure is only effective in older adults with a specific deficit in their circadian system. As our study population consisted of sleep disruptions of various etiologies, it is possible that a selection of specific types of sleep/wake disruptions would yield more positive results. We have shown recently that the motor pattern present in individuals who have both apathy and Alzheimer's disease is consistent with a specific deficit in the circadian system [23]. Thus, memory-impaired individuals with both apathy and a disruption in their sleep/wake pattern might be responsive to light therapy, though this remains to be formally tested.

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Table 1

Comparison of actigraphic sleep parameters in care recipients and caregivers in BRIGHT and DIM conditions at baseline and after two weeks of treatment (EndTx).

	BRIGHT		DIM	
	Baseline	**EndTx**	**Baseline**	**EndTx**
Care recipients				
Time in bed (min)	604 ± 102	557 ± 100 *	579 ± 87.2	556 ± 65.2
Total sleep time (min)	434 ± 106	393 ± 127 *	428 ± 105	420 ± 125
Wake after sleep onset (min)	124 ± 98.1	124 ± 111	108 ± 102	107 ± 110
Sleep efficiency (%)	72.9 ± 17.0	71.7 ± 21.2	75.1 ± 17.8	75.8 ± 20.8
Caregivers				
Time in bed (min)	511 ± 78.1	492 ± 57.1	503 ± 56.8	501 ± 63.5
Total sleep time (min)	386 ± 77.4	398 ± 65.4	392 ± 101	409 ± 84.9
Wake after sleep onset (min)	88.8 ± 74.9	63.4 ± 60.0 ¥	77.1 ± 77.9	61.0 ± 64.8 ¥
Sleep efficiency (%)	76.4 ± 14.9	81.3 ± 13.1 ¥	78.0 ± 18.7	82.0 ± 15.0 ¥

Note:

* $p<0.05$ vs. DIM, $F_{(1,49)}>4.12$, (two-way repeated measures ANOVA with post-hoc *t*-tests);

¥ $p<0.05$ vs. BL, $F_{(1,49)}>4.44$, (two-way repeated measures ANOVA with post-hoc *t*-tests)