Light as Therapy for Sleep Disorders and Depression in Older Adults

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Introduction

Proper lighting is necessary for vision and to carry out one's daily activities. This aspect of light – light for vision – is well known by the general public and health professionals. What is less well appreciated is the large and growing body of scientific literature on light as a therapeutic agent. Indeed, although much has been documented over the past decades about its therapeutic uses, light is rarely prescribed by physicians and other health care providers. In part this is because much is yet to be understood about the optimum characteristics of light affecting our health and well-being. Published research studies have employed a wide range of light sources, quantities, spectra, and delivery schedules, without yielding a consensus as to how to optimally provide this treatment. However, under-use of light as therapy is also due to the fact that light is naturally available and thus un-patentable, making it unappealing as a research or marketing venue for industries.[1]

Sleep disorders and depression are extremely common in older persons, and in research trials, light therapy has shown some benefits for treating these disorders. Although drug treatments are available for both conditions, in each case the available drugs fail to work a significant proportion of the time and carry with them considerable risk of adverse effects. Therefore, health care providers treating older persons would benefit from considering light therapy as an alternative for selected patients with sleep disorders or depression. In this paper we review the physiology, scientific evidence, therapeutic uses, and cautions regarding light as a therapeutic agent for these common geriatric conditions, and provide recommendations for clinicians.

Physiology of Light as Therapy

The physiological foundation of light as therapy for sleep/wake cycle disturbances is based on the understanding that living organisms have adapted to the daily rotation of the earth by developing biological rhythms that repeat at approximately 24-hour intervals (i.e., circadian rhythms); the most prominent physiological manifestations of these are the sleep/wake cycle and diurnal variations in melatonin secretion, cortisol, and core body temperature. The regulation of melatonin and temperature is controlled by the suprachiasmatic nucleus (SCN) in the hypothalamus of the brain, which fluctuates cyclically but needs an external stimulus to maintain a consistent 24-hour cycle. That key external stimulus is variation in light and darkness over the course of the day, and, in particular, exposure to high light levels during

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the morning hours. These cyclical changes in light levels in turn synchronize the SCN to the 24-hour day, assuring that the timing of physiological rhythms, so that we are asleep during nighttime hours and awake during daytime hours.

Impairment of these SCN-mediated circadian rhythms becomes increasingly common with advancing age, diminished health, and Alzheimer's disease, thereby contributing to the high prevalence of sleep disturbances in these populations.[2–4] Older adults have shown depressed melatonin rhythm amplitudes and alterations in the body's temperature cycle, which may explain the sleep disorders commonly found in these individuals.[5] Thus, the mechanism of light therapy for sleep disorders could be via stimulation of the SCN, effectively correcting the timing and/or strengthening the amplitude body's circadian cycles.

The physiological basis by which light affects mood is less well established. Light therapy is, however, a recognized and consistently demonstrated treatment for seasonal affective disorder (SAD). Although the mechanisms associated with positive effects of light in alleviating SAD symptoms are still unknown, it is believed that the circadian system might be involved. One line of research hypothesizes that the late dawn in winter results in a delayed circadian system and that morning light is an effective treatment to maintain circadian rhythms entrained to the solar day. Another research model suggests that long nights during winter months increase melatonin production. Researchers have established that melatonin in the brain is synthesized by the pineal gland from N-acetyl-serotonin, in response to signals that reaches the SCN via the retinohypothalamic tract. The SCN's postsynaptic fibers release norepinephrine, thus it is logical to hypothesize that alterations in this cycle could affect mood by influencing the serotoninergic and/or norepinephrinergic system.[6] However, research on melatonin levels in both young and older adults has failed to identify a consistent relationship between either the amount or the timing of melatonin secretion and depression.[6–8] Therefore, although the ameliorative effects of light on seasonal depression are largely accepted, the mechanism of action is not well understood.

Clinical Effectiveness of Light Therapy in Older Persons

Over two dozen studies have evaluated the efficacy of light therapy in the treatment of circadian sleep disorders and/or depression (including SAD) in older persons. Many of the studies are small, however, and are limited by their design. In addition, wide protocol variation exists in terms of the treatment applied. For instance, in studies reviewed for this article, the duration of treatment ranged from 30 minutes to 8 hours a day; the light levels from 200 to 10,000 lux; the spectrum from polychromatic white light to nearly monochromatic green or blue light; the timing from morning to evening to all day; and the intervention length from days to weeks. Tables 2 and 3 describe each study, and in the following paragraphs we attempt to interpret the overall state of evidence.

Sleep Disorders

A large body of literature substantiates the effectiveness of light as therapy in laboratory settings using young persons as subjects. In general, these studies are conducted to better understand the underlying mechanisms through which light affects the circadian system. Although some laboratory studies have included older adults as subjects, very few studies have evaluated light as therapy for older persons in non-laboratory settings. The available literature on light as a therapy for older adults in community settings is less consistent in terms of its efficacy findings, likely due to the shortcomings described above. One Cochrane review examined the effects of light therapy on sleep, behavior, and mood in older adults with dementia. Of only five studies that met the reviewers inclusion criteria, only three were ultimately reviewed due to inappropriate study methodologies. The three articles that were reviewed did not reveal any systematic benefits of light therapy for individuals with

dementia.[9] Using less stringent inclusion criteria, we identified 21 published studies evaluating the impact of light therapy on sleep quality and efficiency in older persons (Table 1). Many involved small samples; six included 10 or fewer participants. The majority (15 studies) specifically targeted persons with dementia, and three used depression as a selection criterion. Overall, 14 identified significant improvement in one or more clinical outcomes, whereas seven did not. Improved outcomes appeared to be associated with the amount of light exposure: Of the 19 studies reporting these data, seven of nine (78%) with exposures exceeding 6,000 lux-hours had positive results, compared with five of ten (50%) with lower exposure levels. In contrast, no pattern of association was noted between clinical improvement and dementia status, depression status, or the timing of light therapy. The latter finding is particularly noteworthy, because much of the literature on circadian rhythms states that the majority of older persons are phase advanced and would benefit more from evening than morning light; however, this belief is not supported by the results of published clinical studies. In conclusion, the findings on light therapy and sleep in older persons are mixed but overall suggest a favorable effect in older persons.

Depression

There is a large body of literature on effectiveness of light therapy on SAD in younger adults, and a modest body of literature supporting its effectiveness in other depressive disorders. A 2004 Cochrane review of randomized controlled trials comparing bright light therapy to inactive placebo treatments found that, among 20 methodologically high-quality studies reviewed, SAD was alleviated to a greater extent when individuals were exposed to bright light versus placebo treatments (standardized mean difference −0.90, 95% CI −1.50 to −0.31).[10] The effects of light appear to extend beyond SAD: A review of 20 studies of light therapy for non-seasonal depression found that bright light therapy was effective in reducing non-seasonal depressive symptoms, with an average effect size of .53 (considered "moderate") across studies.[1] The findings have been more consistently positive in studies of light therapy as an adjunct to pharmaceutical treatment for non-seasonal depression in adults (although not necessarily 'older' adults).[11–13] In one randomized double-blind controlled trial, for example, participants received daily dosages of 50 mg of the selective-serotonin reuptake inhibitor (SSRI) antidepressant sertraline, combined with either bright light treatment or placebo dim light; participants in the bright light adjunct group experienced greater reductions in depressive symptoms compared to those in the placebo group (p<0.05).[11,13]

We identified seven published studies of the impact of light therapy on depressive symptoms in older persons (Table 2). Of these, three reported significant improvement with light therapy, and four did not. While the small number of studies (and the relatively modest samples in all published studies) renders any conclusions tentative, reported improvement does not appear to be associated with the total amount of light exposure or the timing of the therapy in the diurnal cycle. Of possible importance is the fact that three of the four negative studies specifically selected persons with dementia, whereas all three of the positive studies studied more general populations; if valid, this conclusion could be the result of either ineffectiveness or of insensitive measures, since depression is difficult to diagnose and measure in persons with dementia. In conclusion, existing studies are inconclusive but suggest that light may have a modest effect on depressive symptoms in older persons, particularly those who do not have dementia. In addition, the strong findings in several studies of bright light as an adjunct to pharmacotherapy, which, although not exclusively conducted in the elderly, included older persons, suggest that this role may be particularly appropriate until further data are available on light as a primary therapeutic agent.[12–15]

Dose and Application

In this section we review what is known about the influence of light levels, duration, timing, and spectrum of light therapy on clinical outcomes, and – although many questions remain – provide tentative therapeutic recommendations. In general, the optimal characteristics of light as therapy differ from those for vision. Table 3 summarizes optimal lighting characteristics for both the visual and circadian systems.

Quantity of light

The light levels required for a therapeutic effect are considerably higher than that needed for vision.[16] In general, the recommended minimum light therapy is 2,500 lux of white, broadband light at the cornea for a 2-hour exposure or as much as 10,000 lux for a 30-minute exposure. If natural light is used, a rough guideline is that 2,500 lux is equivalent to being outside on a cloudy day and 10,000 lux to being outdoors on a sunny but not excessively bright day (outdoor light levels as high as 100,000 lux have been recorded). The higher the light level provided, the more attention must be given to glare reduction. High light levels can result in discomfort, and thus, limit retinal light exposure due to squinting and gaze aversion. Studies conducted in very controlled laboratory conditions showed that much lower light levels (about 100 lux at the cornea of a 4100K fluorescent light) applied for 6.5 hours can phase shift the circadian system of humans.[17] However, no studies to date have been able to clearly demonstrate that light levels this low are enough to activate the circadian system outside laboratory conditions. More importantly, light levels used in light therapy for older persons should account for the reduced retinal illuminance due to changes in the aging eye.

Spectrum

Until recently, little was known about the spectral sensitivity of the circadian system, that is, the maximally effective light color. However, a series of recent studies have shown that blue light (peaking between 440 and 460nm) is maximally effective in suppressing melatonin.[18–22] The practical implication of these data is displayed in Table 4, which compares the ability of commercial light sources to stimulate the visual and circadian systems.

Timing of exposure

Although it is well established that timing of exposure is critical in altering circadian rhythms, the optimal timing of light therapy remains controversial. In general, light therapy should be applied in the evening to produce a phase advance, and in the morning to produce a phase delay.[21,23–24] However, results contradicting laboratory findings have been reported (e.g. morning light causing a phase delay).[25]

Duration of exposure

Duration of exposure needed to impact the circadian system is greater than that needed to impact the visual system. The visual system will respond in milliseconds, while it might take several minutes to days before one can detect the impact of light on circadian rhythms.

Light Patterns and history

Finally, vision requires simultaneous light/dark contrast across the visual field, whereas light therapy appears to require light-dark contrast across time, especially to affect circadian rhythms. Moreover, it appears that light reaching the lower retina is more effective for the circadian system than light reaching the upper retina.

Proposed Light Therapy for Clinical Applications

In the absence of consistent findings, the following as a clinical approach should be considered:

- Provide white light sources with bluish tint (i.e., 7,500 K fluorescent light bulb) that provide at least 1,000 lux at the eye during daytime hours. If these light levels are considered too high, try to use lower lux blue light delivered via a light box. In this case, the person will have to sit in front of the lights for a certain amount of time daily.

- Provide the therapy at the time that is most convenient for the patient, since consistency is important, especially in influencing circadian rhythms. If the circadian timing of the patient is not known, morning light (after wakening) should be able to at least maintain entrainment, which may be just what the patient needs.

- If convenience is not an issue, ask if the patient tends to be more tired in the morning or in the late afternoon/early evening, and provide the light therapy during that time interval.

- If feasible (e.g. by providing high light levels (at least 1,000 lux at the cornea) of environmental bluish white light), consider all-daytime (e.g., 7 a.m. – 8 p.m.) bright light, coupled with dim, warm-color light (e.g., incandescent light bulbs) at night.

  Clinical trials of individualized timing, such as that suggested here, remain to be conducted in older persons.

Available Treatment Modalities

Light boxes (Figure 1) are the most common treatment devices available on the market. They are rectangular fixtures that house several light bulbs, usually fluorescent tubes, and that require the user to sit facing them for between half an hour and two hours. In general, light boxes provide a high amount of light (from 2,500 to 10,000 lux at the cornea). The main drawbacks of such devices are the necessity to remain in one place, and the fact that some users experience discomfort from having to face in the general direction of the bright light (a drawback of all light treatments). Most experts recommend the 10,000 lux box, because the recommended duration of exposure is less.

A similar product is the high intensity desk lamp (Figure 2). If oriented properly in relation to the eyes (i.e., at the manufacturer's recommended distance and in front of the user), a desk lamp can produce up to 10,000 lux exposure at the cornea. As with other light sources, visual discomfort can result; the advantage is that the desk lamp can be less obtrusive for office or home use.

Light visors (Figure 3) provide a portable alternative to light boxes and are comprised of a head-mounted light source that resembles a tennis visor. The visor is designed to give people mobility during light sessions and portability for travel; however, it can be cumbersome for some users. Because the light source is close to the eye (and preferentially reaches the more sensitive lower portion of the retina), it requires lower intensities, with a 3,000 lux to produce benefits comparable to a 10,000 lux light box.

Until recently, all of the available light boxes, visors and desk lamps used "full-spectrum" light. More recently, however, products have become available that use a nearly monochromatic light source, the light emitting diode (LED). Some use blue LEDs, peaking at 470 nm, while others use blue/green LEDs, peaking at about 500 nm. Because the peak wavelength of the blue LEDs is close to the maximum sensitivity of the circadian system, much lower light levels can be used, though not all the manufacturers are taking advantage

of this feature. Light boxes using blue LEDs typically provide about 400 lux at the cornea; light visors using the blue/green LED emit intensities ranging from 500 and 12,000 lux.

A low-tech alternative to commercial products would be for an older person to spend 20–30 minutes outdoors daily, preferably at about the same time each morning. Even an overcast day will produce 2,500 lux at the cornea, and bright sunshine can produce exposures greater than 10,000 lux at the cornea.

The dawn simulator is marketed primarily for people with seasonal affective disorder; however, it could be useful for people who are phase delayed (i.e., have trouble getting up in the morning). These use incandescent light bulbs and are programmed to gradually increase the light levels in the morning hours, simulating the sunrise. While the evidence of effectiveness is largely anecdotal, and light intensities achieved are often below those of light boxes, lamps, or visors, dawn simulators may have therapeutic value in certain sleep disorders and/or as a supplement to other lighting treatment modalities.

An experimental, not-yet-proven method of applying light therapy is the use of even, therapeutic light intensities throughout an entire room. However, when high levels of ambient lighting are used in facility common areas, the cost can be high and the light levels can be uncomfortable to some individuals; use of skylights and/or monochromatic blue light sources may reduce these problems. Exposure of all individuals rather than targeting affected patients is also a significant drawback of light therapy in public areas; an intriguing alternative would be the design of systems for use in residential areas, such as private rooms in long-term care facilities or the living areas of private homes.

Adverse Effects

One of the advantages of light as therapy is that it appears to be relatively free of serious adverse effects. Theoretically plausible potential risks include retinal damage, the induction of mania and/or agitation, heightened photosensitivity, and general somatic and psychosomatic complaints (headache, nausea, jitteriness, anxiety). The available randomized trials indicate, however, that the prevalence of major adverse effects are virtually nil, and that minor adverse effects occur at similar or only modestly increased rates among users in comparison to matched controls.

Because exposure to direct sunlight can lead to cataracts and retinal damage, and both ultraviolet radiation and high levels of short-wavelength light can damage the lens and the retina, concern has been raised about the short- and long-term effects of light therapy on the eye.[26] To date, such concerns have only been speculative; trials of up to 10,000 lux have not documented eye damage as a result of light therapy, in part because ultraviolet radiation-blocking filters or coatings are applied to most light fixtures.[13,27–28] In spite of negative research findings, many experts recommend, as a precautionary measure, excluding patients with degenerative retinal diseases,[26,29–30] as well as those without a lens,[26] from light therapy.

Some experts are particularly concerned that blue light exposure may be a hazard, compared to full spectrum light. However, outdoor exposure to daylight and sunlight are, in general, more likely to be hazardous than short-duration exposure to blue light therapy, and thus the adverse effects of blue light do not seem significant.[22,31–32]

Although no serious eye damage has been reported as a result of light therapy, a number of transient visual symptoms have been reported in greater frequency among persons exposed to light therapy than among controls. Commonly reported ocular side effects of light therapy include eyestrain,[33–34] blurred vision,[10] seeing spots,[35] glare,[35] and eye burning/

irritation.[10,35] Nearly all studies reported fast remission of symptoms; thus, side effects may only occur early in treatment as part of an adjustment phase. Other, non-visual symptoms have also been reported in some studies of light therapy including headache,[10–11, 33,35–36] nausea,[35–36] dizziness,[33] agitation,[10] and jumpiness/jitteriness/anxiety.[33,36] These adverse events are reported to be particularly common in studies in which the light source is close to the eyes, such as with head-mounted units like visors.[36] In contrast, a recent randomized trial in two long-term care facilities identified no significant increase in the prevalence of seeing spots, problems with glare, eye burning or irritation, eye redness, jitteriness, severe agitation, skin rash on the face or arms, headache, dizziness, or nausea, when bright light (2,500 lux) was compared to standard light (500 lux).[37]

Induction of mania has been reported in a few individuals receiving light therapy for treatment of depression.[38–40] The induced mania is likely a result from effective treatment of a patient with an underlying undiagnosed bipolar disorder, as has been reported with other depression treatments.[38] Hypomania, "wiredness," and agitation have also been reported in a small proportion of persons treated for depression, which should be kept in mind, especially in treating patients with dementia.[27,34–35]

Suicide has been reported in a few depressed patients not long after initiation of light therapy;[33,41] however, the initiation of any effective antidepressant treatment is known to occasionally lead to suicidal actions in a few persons.[42] In fact, antidepressant medications have been reported to increase suicidal risk in adults, and SSRI's in particular may put elderly populations at increased risk for suicide in the early stages of treatment.[43] Thus, the possibility of suicide should be a caution but not a contraindication to light as therapy for depression.

Recommendations for Clinical Practice

High light levels of bluish white light (at least 1,000 lux at the cornea) during morning hours should be considered as a possible therapy for selected older persons with sleep problems and/or depressive symptoms. Particularly appropriate candidates for such treatment would be persons who are at high risk for adverse effects from medications and individuals who rarely go outdoors. In warm climates, half an hour of outdoor daylight exposure each morning would constitute an inexpensive, convenient first-line treatment. When outdoor exposure is impractical, one of the available modalities for indoor light therapy can be prescribed.

Patients with sleep complaints should undergo a thorough medical examination prior to initiation of light therapy. That evaluation should including screening for conditions for which specific therapies are indicated, such as obstructive sleep apnea, medication-related sleep disorders, and alcoholism. Screening for depression is also important in the evaluation of patients with sleep complaints; however, the presence of depression should by no means be a contraindication to light therapy for sleep problems. Treatment for most sleep disorders appears to be best if the light is applied in the morning; however, selected individuals may benefit more from early evening light exposure.

Light appears to have a relatively modest effect as a therapy for depression in older persons. Therefore, except in cases of SAD or of relatively mild symptoms, it is probably used as an adjunct to other treatments, such as selective serotonin reuptake inhibitors (SSRIs) and/or psychotherapy. Light therapy may be of particular complementary value due to its rapid onset of action, which has been demonstrated to occur within days, rather than the weeks required by medication. Patients should time their exposure to the most convenient time of day; if patients have flexibility, however, morning or mid-day light may be optimal.

Because of the theoretical risk of retinal damage, light therapy should likely be avoided in persons with significant retinal damage (e.g. severe macular degeneration) or who have no lens in one or both eyes. Patients initiating light therapy should be cautioned that eye discomfort may result and instructed that, if it is mild, they may continue treatment. They should also be informed that, in some patients, nonspecific symptoms such as headache, dizziness, and jitteriness are sometime observed, but that these are usually mild and may be transient. Both the patient and a family member should be cautioned that, although highly unlikely, they should be on the lookout for and report rashes in light-exposed areas, suicidal thoughts, and/or severe agitation or hypomania. Laboratory monitoring is unnecessary, but periodic follow-up visits and re-evaluations should, of course, be part of the therapeutic plan.

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Figure 1.
Light boxes are currently the most common delivery system for light therapy. They are inexpensive and can provide high dosage levels and controlled spectra of light; however, they require the patient to remain in the same location for up to two hours. Photos from http://www.bio-light.com/lightsproducts.html and http://www.outsidein.co.uk/gallery.htm. Used with permission.

Figure 2.
The high intensity desk lamp comes in a variety of shapes and styles, providing a less obtrusive alternative to the light box. Photos from http://www.outsidein.co.uk/gallery.htm. Used with permission.

Figure 3.
Portable light visors allow users to move around and travel while being exposed to therapeutic light levels. The main disadvantage, if present, is wearer discomfort. Photo from http://www.outsidein.co.uk/gallery.htm. Used with permission.

Table 1

Summary of Clinical Studies of Light Therapy for Sleep and Circadian Rhythm Disorders in Older Persons

Study	Design	Population (n; mean age; depression; circadian disorder; institutional setting; dementia)	Treatment					Control Procedure	Sleep or Circadian Rhythm Measure(s)[c]	Major Findings[a]
			Intensity (lux); Duration (hours)	Spectrum	Timing	Adjunct treatment				
Alessi et al., 2005[44]	Randomized, controlled, parallel-groups trial	62; 88; N; Y; Y; N	10,00; 0.5	Sunlight	Generally in morning	Exercise, nighttime routine, noise reduction	Usual care	Actigraphy, oximetry, observations	Reduction in nighttime awakening duration and daytime sleeping in treatment group.* No other differences between groups.
Ancoli-Israel et al., 2002[25]	Randomized, controlled, parallel-groups trial	77; 86; N; Y; Y	2,500; 2	White	9:30–11:30am or 5:30–7:30pm	-	50 lux red light or daytime sleep restriction	Actigraphy	Phase delay and increased mesor in morning light treatment group.* Phase delay in evening light treatment group. No other differences between groups.
Ancoli-Israel et al., 2003[45]	Randomized, controlled parallel-groups trial	61; 82; N; N; Y; Y	2,500; 2	'Full spectrum'	9:30–11:30 am or 5:30–7:30pm	-	<300 lux red light	Actigraphy	Increase in maximum sleep bout duration in both treatment groups. No other differences between groups.
Colenda et al., 1997[46]	Pre-post trial	5; 76; -; Y; N; Y	2,000; 2	White	Upon awakening – between 7am and 9:30am	-	-	Actigraphy	No consistent effects across subjects.
Dowling et al., 2005[47]	Randomized, controlled, parallel groups trial	70; 84; -; Y; Y; Y	2,500; 1	Sunlight or white light	9:30–10:30 am or 3:30–4:30 pm	-	Usual care	Actigraphy	Phase delay in control group.* No other differences between the morning and afternoon groups, or control group.
Fetveit et al., 2003[48]	Pre-post trial	11; 86; N; Y; Y; Y	6,000–8,000; 2	White	Between 8am and 11am	-	-	Actigraphy, Sleep-wake questionnaire	Improved sleep efficiency and sleep-wake score, reduced total wake time, sleep onset latency, and mesor in treatment group.* No other differences between groups.
Figueiro et al., 2002[32]	Controlled, crossover trial	4; -; -; -; Y; Y	30; 2	Blue	6pm–8pm	-	30 lux red light	Actigraphy, body temperature, nurse observation	Phase delay and improved sleep-wakefulness in treatment period.
Kobayashi et al., 2001[49]	Pre-post trial	10; 81; -; Y; Y; N	8,000; 1	White	11:30am –12:30pm	-	-	Nurse ratings of sleep and behavior	Improved clinical ratings of sleep-wakefulness in 80% of subjects.*
Koyama et al., 1999[50]	Baseline-intervention trial	6; 86; N; Y; Y; Y	4,000; unstated	White	Late morning	-	-	Nurse ratings of sleep and behavior	Phase advance, increased nighttime sleep, and decreased daytime sleep in 50% of subjects.
Loving et al., 2005[51]	Randomized, controlled, parallel-groups trial	41; 68; Y; -; N; Y	8,500; 1	White	Morning, mid-day, or evening	Partial sleep deprivation	10 lux red light	Urinary melatonin, actigraphy, sleep log	Phase advance in morning light treatment group and in females in all treatment groups.*[b] No other differences between groups.
Loving et al., 2005[52]	Randomized, controlled, parallel-groups trial	17; 68; Y; Y; N; Y	1,200; 1	Green	Within 1 h of waking	Partial sleep deprivation	10 lux red light	Actigraphy, sleep log	No differences between groups.
Lyketsos et al., 1999[53]	Randomized, controlled, crossover trial	15; 81; N; N; Y; Y	10,000; 1	'Full spectrum'	Morning	-	Dim, low-frequency, blinking light	Sleep log	Greater increase in sleep time in treatment period.
Martiny et al., 2004[15]	Randomized, controlled, single-blind, parallel groups trial	48; 46; Y; -; N; N	10,000; 1	White	Upon awakening, but by 10am	sertraline	50 lux dim red light + sertraline	Sleep log	Greater increase in sleep duration in control group.* Later wake-up time in treatment group.*
Mishima et al., 1998[54]	Randomized, controlled, crossover trial	22; 78; -; Y; Y; Y	5,000–8,000; 2	White	9am–11am	-	300 lux dim light	Actigraphy	Decrease in nighttime activity in treatment period.*

| Study | Design | Population (n; mean age; depression; circadian disorder; institutional setting; dementia) | Treatment | | | | | Control Procedure | Sleep or Circadian Rhythm Measure(s)[c] | Major Findings[a] |
			Intensity (lux); Duration (hours)	Spectrum	Timing	Adjunct treatment				
Mishima et al., 1994[55]	Pre-post trial	14; 75; -; Y; Y; Y	3,000–5,000; 2	'Full spectrum'	9am–11am	-	Usual care	Nurse observation, serum melatonin	Increase in total and nocturnal sleep time, and decrease in daytime sleep time, in treatment group.* No changes in acrophase.
Ouslander et al., 2006[56]	Controlled, parallel-groups trial	77; 84; N; N; Y; N	1,467; 2	'Full spectrum'	Between 5pm and 8pm	Exercise, noise reduction, nighttime routine	Usual care	Actigraphy, oximetry, observation, polysomnography	Decrease in daytime sleeping in treatment group.* No other differences between groups.
Rosenthal et al., 1990[57]	Randomized, controlled, crossover trial	20; -; N; Y; N; N	2,500; 2	'Full spectrum'	Between 6am and 9am	Dark goggles in evening	300 lux light and clear goggles in evening	Body temperature, questionnaire	Phase advance and improved morning alertness and earlier sleep time in treatment period.*
Satlin et al., 1992[58]	Pre-post trial	10; 70; -; Y; Y; Y	1,500–2,000; 2	White	7pm – 9pm	-	-	Nurse ratings of sleep-wakefulness disturbances and agitation, Actigraphy	Clinical improvement in sleep-wakefulness*, nocturnal activity*, and intradaily variability. Phase advance.
Skjerve et al., 2004[59]	Pre-post trial	10; 79; -; Y; Y; Y	5,000–8,000; 0.75	White	Between 8am and 10am	-	-	Actigraphy, SWD	Phase advance. No other differences between treatments.
Suhner et al., 2002[60]	Pre-post trial	15; 72; N; Y; N; N	4,000; 2	White	8pm–11pm	-	-	Body temperature, sleep log, sleep quality	Phase delay in treatment period*. Effect of treatment diminished post-treatment.
Van Someren et al., 1997[61]	Pre-post trial	22; 79; -; -; -; Y	1,136; continuous	White	All day	-	-	Actigraphy	Increase in interdaily stability and decrease in sleep fragmentation.*

[a] Significant differences marked with an asterisk (*)

[b] Authors point out that this data is of low-quality, due to a low number of usable cases for analysis.

[c] SWD = Short Scale for Sleep-Wake Disturbances

Table 2

Summary of Evidence of Effectiveness for Non-seasonal Depression in Older Persons

Study	Design	Population (n; mean age; depression; circadian disorder; institutional setting; dementia)	Treatment					Control Procedure	Depression Measure(s)[b,c,d,e]	Finding[a]
			Intensity (lux); Duration (hours)	Spectrum	Timing	Adjunct treatment				
Loving et al., 2005[51]	Randomized, controlled, parallel-groups trial	41;68; Y:-; N: Y	8,500: 1	White	Morning, mid-day, or evening	Partial sleep deprivation		10 lux red light	GDS, SIGH-SAD, HAM-D	No difference between treatment and control groups
Loving et al., 2005[52]	Randomized, controlled, parallel-groups trial	17; 68; Y: Y:N; Y	1,200: 1	Green	Within 1 h of waking	Partial sleep deprivation		10 lux red light	GDS, SIGH-SAD, HAM-D	No difference between treatment and control groups
Lyketsos et al., 1999[53]	Randomized, controlled, crossover trial	15; 81; N: N; Y; Y	10,000: 1	'Full spectrum'	Morning	-		Dim, low-frequency, blinking light	CSDD	No difference between treatment and control groups
Ouslander et al., 2006[56]	Controlled, parallel-groups trial	77; 84; N; N; Y; N	1,467: 2	'Full spectrum'	Between 5pm and 8pm	Exercise, noise reduction, nighttime routine		Usual care	GDS	No difference between treatment and control groups
Sumaya et al., 2001[29]	Randomized, controlled crossover trial	11; 84; Y:-; Y; N	10,000; 0.5	White	Between 9am and 12:30pm	-		300 lux light	GDS	Greater improvement in treatment group*
Tsai et al., 2004[62]	Randomized, controlled, parallel-groups trial	30; 75; Y:-; Y; N	5,000; 0.8	White	Between 9am and 12:00 pm	-		Usual care	GDS	Greater improvement in treatment group*
Yamada at al., 1995[63]	Randomized, controlled, parallel-groups trial	18; -; Y:-; Y; -	2,500; 2	White	Morning or Evening	-		500 lux light	HAM-D	Greater improvement in treatment group, irrespective of timing of treatment*

[a] Significant differences marked with an asterisk (*)

[b] GDS Geriatric Depression Scale

[c] SIGH-SAD Hamilton Depression Rating Scale – Seasonal Affective Disorder Version

[d] HAM-D Hamilton Depression Rating Scale

[e] CSDD Cornell Scale for Depression in Dementia

Table 3

Comparison and Contrast between Use of Light for Vision and for Therapy

Parameter	Light for Vision	Light as Therapy
Intensity needed for effectiveness	• In task areas: 500 lux • In non-task areas (e.g. hallways): 20–30 lux	Varies with spectrum, but typical recommendation is at least 2500 lux of full-spectrum light at the cornea
Duration required for effectiveness	Very short (eye registers visual image in less than a second)	Longer; varies by light exposure from 5 minutes (for bright sunlight to more than an hour (for typical "light box" therapy)
Wavelength (in nanometers) to which brain is sensitive	A broad range (350–750 nm) is needed for vision; peak spectral sensitivity is at mid wavelength (555 nm)	450 – 480 nm (blue light)
Timing of exposure	Unimportant	Important
Contrast needed for optimal function	Spatial contrast is important (differing light/ dark patterns at the same time)	Temporal contrast is important (contrast in amount of exposure across different times during a 24-hour day)
Evenness of illumination	Preferred for optimal vision	Not important, though one study showed that light coming from above the horizon (reaching the lower retina) is more effective in suppressing melatonin
Glare	Interferes with visual function	Interferes with treatment acceptability

Table 4

Relative Strength of Selected Common Light Sources in Stimulating the Visual and Circadian Systems

Type of Light Bulb	Relative Stimulation Per Watt	
	To the Visual System [lumens/watt]	To the Circadian System [circadian stimulus/watt]
Fluorescent 3000K	100	74
Fluorescent 7500K	100	157
Incandescent	12	12
Daylight 6500K	70	133
Clear Mercury (Hg)	45	18
Blue LED (470 nm)	8 15	223 418