

Lighting solutions for older adults are becoming mainstream within the lighting community. Indeed, guidelines for

RESEARCH RECAP



Mariana G. Figueiro, Lighting Research Center

designing lighting for older adults are already available (e.g., Figueiro, 2001 and IESNA's *Lighting and the Visual Environment for Senior Living* RP-28-98), so writing another article stating that older adults need more light and less glare would be redundant. What is important to understand is that visual changes, though well characterized, are not the only light-related changes that we go through as we age. Less well understood, but no less real, are the changes that occur to our circadian functioning, and how these changes affect our daily cycles, such as sleep/wake, core body temperature, alertness and melatonin production.

My column in the February 2003 issue of *LD+A* explained how the circadian system works, and I discussed the differences between lighting characteristics for the visual and circadian systems. A useful metaphor for the circadian system is one used by David Blask, PhD, MD, researcher at the Basset Research Institute in Cooperstown, NY. Dr. Blask—also an accomplished jazz musician—compares the circadian system with a jazz band: the master clock, or pacemaker, located in the suprachiasmatic nucleus (SCN) works like the bass player of a jazz band, setting the rhythm for the entire band. The pineal gland, which produces melatonin (the “hormone of darkness”) at night and under conditions of darkness, works like the drummer, picking up the rhythms set by the bass player and amplifying it for the entire band. Light sets the timing of the circadian clock, and helps the SCN (or the bass player) keep a synchronized rhythm with the solar day. If the rhythm is lost, the entire har-

mony of the biological jazz band is lost. As we age, circadian rhythms begin to break down, and the harmony of many biological functions is lost, resulting in disturbances in sleep quantity and quality, as well as alertness, well being and, perhaps, impacts on health.

What are the changes that we go through as we age?

Sleep disturbances increase as we age. Surveys indicate that 40 to 70 percent of the aging population suffers from chronic sleep disturbances (Van Someren, 2000). In

Light, Aging and the Circadian System: Reviving 'All that Jazz?'

general, older adults tend to go to bed earlier and wake up at an earlier time of day than younger adults. Frequent nocturnal awakenings, difficulty falling asleep, and increased number of naps taken during the day are also more common in older adults. Sleep disturbances are associated with decreased physical health, including increased cardiovascular problems, disruption of endocrine functions, and decline of immune functions (Jensen et al., 1998 and Van Cauter et al., 1998). Sleep patterns of Alzheimer's disease patients are consistent with non-demented patients, but symptoms are much more frequent and tend to be much more severe, making the caring of those with Alzheimer's disease very difficult.

Why do these changes occur?

It is believed that disruption to our circadian system is one important reason why sleep disturbances increase among older adults. The circadian timing system is com-

posed of three basic components: the circadian pacemaker, or circadian clock, located in the SCN of the brain, the entrainment pathways that provide photic (and also non-photic) information to the pacemaker and the output pathways for the expression of overt rhythms, such as core body temperature, sleep/wake cycle, alertness and melatonin production. Changes to any of these components can contribute to age-related changes in sleep timing, quantity and quality. The biological jazz band loses its rhythm.

With regard to the first component, the circadian pacemaker, studies have shown that the aging human SCN is smaller and has reduced neuronal activity, especially after the age of 80 (Swaab et al., 1985). This suggests that, at a molecular level, the SCN becomes less responsive to light stimulus. Indeed, one study showed a reduced sensitivity to the resetting effects of low light levels on physical activity in older hamsters (Zhang et al., 1996). These changes can be much more dramatic with Alzheimer's disease.

With regard to the second component, the entrainment pathways, it is hypothesized that some of the neural processes involved in entrainment might be dysfunctional or less sensitive as we age (Skene and Swaab, 2003). Light information travels from the retina to the SCN through the retino-hypothalamic tract (RHT). A dysfunction or reduced sensitivity of this pathway, amplified by the reduced light transmission of the eye, can cause disturbances of circadian rhythms and, thus, impact sleep in older adults. Degeneration of this pathway with Alzheimer's disease can be even more severe.

Finally, with regard to the third component, the output pathways for the expression of overt rhythms, changes in the amplitude and timing of melatonin and body temperature rhythms have been reported with aging in humans (Ferrari et al., 2000 and Iguichi et al., 1982). Even though our circadian system appears to still respond to light as we age (Klerman et al., 2001), its sensitivity may be reduced (Zhang et al., 1996), which means that

compared to the young circadian system, greater stimulus magnitude will be needed to achieve the same response in the aging circadian system. Here are some overt rhythms and how they may affect sleep as we age:

- Melatonin is the “hormone of darkness,” conveying information about the photoperiod to the circadian clock. Melatonin levels are high at night and low during the day. Although not well established yet, it is believed by many researchers that melatonin can help induce sleep by reducing the “wake-promoting” signal deriving from the circadian pacemaker. Melatonin rhythms may be disrupted in older adults, including in Alzheimer’s disease patients, because of a general neurodegeneration that occurs with age. These changes may, in turn, reinforce sleep disruptions typically found among older adults and Alzheimer’s disease patients.

- Core body temperature has an inverse relationship with melatonin and a close relationship with our waking and sleep times. Peak melatonin levels occur slightly before core body temperature troughs. Earlier timing of melatonin rhythms may induce earlier core body temperature troughs. Waking typically occurs about two hours after the minimum core body temperature, so the early waking times in older adults may be a result of earlier core body temperature troughs.

- Light is the main synchronizer of the circadian clock to a 24-hour cycle and sets the timing of the SCN. If sensitivity of the clock to light is reduced in older adults, or if older adults are exposed to less light due to changes in the eye and changes to their daily routine, the amount of stimulation the SCN receives is reduced. Thus, lower retinal illuminance may be associated with sleep disturbances found in older adults. This can be very important for older people in assisted living or nursing facilities, where residents might only be

exposed to light greater than 1000 lux for no more than a half hour each day (Sanchez et al., 1993).

How can lighting help?

Light sets the timing of our circadian system, the biological jazz

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band, by acting as the main synchronizer of the circadian clock to a 24-hour day/night cycle. Older adults are more likely to be exposed to less light due to both physiological and behavior changes, which, by no means, implies that they are not sensitive to light. It only means that we should be more careful when we specify the light stimulus for older “adults,” i.e., it is important to understand when, how much and for how long light should be applied in order to have a positive effect on the aging circadian system.

Studies have shown that light in the evening can delay the circadian clock and help older adults sleep better at night and be more awake during the day (Murphy and Campbell, 1996). Other studies

have shown that bright light exposure during the day can help regulate rest/activity rhythms of Alzheimer’s disease patients (Van Someren et al., 1997). Alzheimer’s disease patients have even more fragmented sleep patterns than healthy older adults, which is a burden on caregivers. We recently did a pilot study (Figueiro et al., 2001), exposing Alzheimer’s disease patients to blue and red light emitting diodes (LEDs) in the evenings. Because the sensitivity of the circadian system peaks at short wavelengths, an effect was expected to be found after exposure to blue LED only. Indeed, the subjects were more likely to be found asleep from midnight to four o’clock a.m. after exposure to blue LEDs than after exposure to red LEDs (which were used as a placebo control). Replication of these results on a larger population is on the way, but the preliminary results are very encouraging.

So, can light set the timing and help keep the biological jazz band in harmony? It sure can. Remember, however, that light regulates the SCN’s timing, so presumably light can only go so far. Light can help the bass player to help the drummer, to help the other instruments in the jazz band, but if other systems in the biological jazz band have age-related problems, light can only go so far in making music. It should be emphasized, again, that lighting characteristics important to the circadian system are different than those important to the visual system (Rea et al., 2002), so lighting solutions designed to overcome impaired visual capabilities of older adults may be counterproductive for the circadian system. For example, the peak sensitivity of the visual system occurs at 555 nm, while the peak sensitivity of the circadian system is at the short-wavelength region (420-480 nm). Importantly, timing is everything for the circadian system as it is for a jazz band. Unlike the visual system, the impacts of light exposure on the circadian system will vary depending on the timing and duration of the exposure. A new generation of lighting specifiers will have to come to grips with the timing of light and its duration as well as its quantity,

spectrum and spatial distribution to ensure a high quality luminous environment for older adults.

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