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Impact of Tuned Lighting on Skilled Nursing Center Residents' Sleep

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ABSTRACT

The Problem: Sleep disturbance is common among nursing center residents and places them at risk for poor health outcomes. Lighting that changes in color and intensity over the course of the day and night may improve sleep and other outcomes, such as dementia behaviors, but has not been rigorously evaluated under real-world conditions.

The Resolution: The results of this single-facility study show that facility-level tuned lighting is feasible to implement and evaluate in a nursing center. Researchers randomly assigned three corridors to one of two lighting conditions, then the other. Residents experienced half as many sleep disturbances while exposed to tuned vs. static lighting. There was no effect on behaviors.

Tips for Success: Tuned lighting is a low-risk intervention that could be used in new construction or when retrofitting fixtures in existing buildings.

Keywords: Nursing home, long-term care, lighting, sleep, behaviors

INTRODUCTION

Sleep disturbance, which is common among skilled nursing center residents (Martin & Ancoli-Israel, 2008), places older adults at higher risk for physical and cognitive decline (McCrae et al., 2008; Song, Blackwell, et al., 2015; Song, Dzierzewski, et al., 2015; Suh et al., 2018), as well as depression, frailty, morbidity, and mortality (da Silva et al., 2016; Dam et al., 2008; Livingston, Blizard, & Mann, 1993; Miner & Kryger, 2017; St George, Delbaere, Williams, & Lord, 2009; Stenholm et al., 2019). There are many potential causes of sleep disturbance, including environmental stimuli involving both daytime and nighttime light exposure (Schnelle, Alessi, Al Samarrai, Fricker, & Ouslander, 1999; Schnelle et al., 1998; Schnelle, Ouslander, Simmons, Alessi, & Gravel, 1993). Although bright light during the day and darkness at night are among the most powerful cues for healthy circadian rhythm (Klein, Moore, & Reppert, 1991; Van Someren & Riemersma-Van Der Lek, 2007; Wehr, 1991), most residents in institutional care settings, such as nursing centers, have little daily exposure to bright light or daylight and also experience nighttime light exposure (Konis, 2018; Noell-Waggoner, 2006). Few facilities are designed to optimize residents' exposure to natural light or to use artificial lighting that is sufficiently bright during the day and dim at night (Noell-Waggoner, 2002).

Interventions involving changes in light exposure have improved sleep among nursing center residents (Capezuti et al., 2018; Shang et al., 2019), and advances in technologies hold additional, untested promise. Fixtures that tune lighting color and intensity throughout the day, mimicking natural day and night lighting, are among the new technologies and because such "tuned" lighting is low risk, it can be implemented automatically without requiring staff time or attention and may improve circadian rhythm and sleep. While prior studies focused on tuned lighting, including some in nursing centers, and demonstrated some improvement in sleep and other outcomes, most had methodological limitations (Tähkämö, Partonen, & Pesonen, 2019) or did not use the latest technology. There is a growing need to evaluate the impact of automated tuned lighting on sleep under real-world nursing center conditions, so that results can inform policy and practice in the industry.

The goal of our evaluation was to test the feasibility of automated tuned lighting in a nursing center and establish preliminary efficacy data. We hypothesized that the tuned lighting would improve residents' sleep. This is the first evaluation, to our knowledge, of automated tuned lighting in which the nursing home staff was responsible for implementing the lighting, as would occur if such lighting were widely adopted in the industry.

METHODS

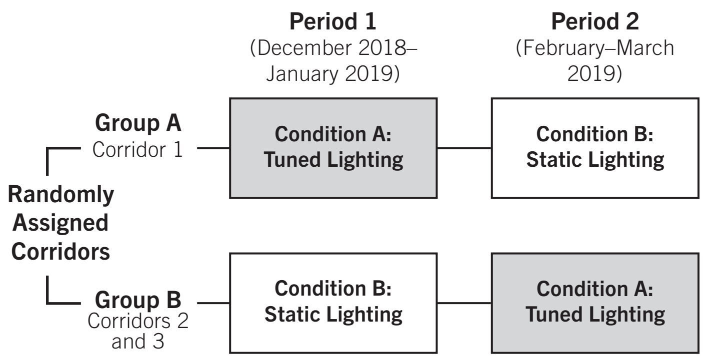
Setting and Participants

The study involved a 99-bed nursing center in Sacramento, California. In 2015, leaders from this nursing center collaborated with the Sacramento Municipal Utility District to install and pilot test tuned lighting in several locations within their facility. In 2018, they expanded installation of these lights to all five of their corridors; lighting did not change in residents' rooms, which had motion sensor–activated night lights but no tuned lighting. To participate in the project, facility leaders agreed (1) to implement the protocol we designed as a quality improvement (QI) project delivered to all residents residing on the three corridors that house long-term care residents, (2) to allow staff to participate in interviews, (3) to provide the research team with resident-level data, and (4) not to add or change any concurrent lighting programs during the project. In addition to installing tunable fixtures, the nursing center had an existing QI program focused on targeted daylight exposure for residents with sleep disturbances; that program began before this work and continued uninterrupted, affecting residents equally during both time periods in this evaluation. Residents in that program were included in this analysis.

Study Design

During time period 1 (December 1, 2018, through January 31, 2019), one long-stay corridor was randomly assigned to the tuned lighting condition (intervention) and two were assigned to the static lighting condition (control). During time period 2 (February 1, 2019, through March 31, 2019), the conditions were switched. The **Appendix** details the lighting protocol; the tuned condition involved lighting that changed in color and intensity over the course of the day and night, and the static condition was programmed to mimic the fluorescent lighting in place at the facility prior to installation of the tunable fixtures. We chose 2-month time periods because we believed the potential effects of the lights to be relatively immediate, within 1 to 2 weeks of initial exposure. The crossover design allowed for evaluation of within-person changes over time and control of any sequence effects (**Figure**).

Figure. Period 1 and Period 2 Random Assignments



Implementation

Nursing center staff implemented the tunable lighting as a QI project that affected all residents on the facility's three long-term care corridors. We excluded one corridor housing short-term post-acute care patients. The corridors' light fixtures were programmed to use either the tunable or static settings, and (for the tuned settings) to change color and intensity settings automatically during the course of the day and night.

Data Sources

We collected the following data to characterize the participating nursing center, assess lighting levels, and examine resident outcomes.

Facility characteristics. We used secondary data from LTCfocus.org (Brown University School of Public Health, n.d.) and Nursing Home Compare (Medicare.gov, n.d.) to characterize the participating nursing center. LTCfocus.org is a website managed by Brown University that contains aggregated, nursing center–level data from federally mandated assessments and state inspections. Nursing Home Compare is a Centers for Medicare & Medicaid Services website that publishes quality measures and ratings for nursing centers. Both datasets are publicly available.

Lighting levels. Two research team members used meters to capture spectral power distribution data on site at the nursing center at three times: (1) prior to the intervention (baseline), (2) during the first time period, and (3) during the second time period. We used these data to assess the corridors' adherence to the lighting protocol and characterize typical light exposure for residents over the course of a 24-hour day; the results are published elsewhere (Miller, 2019).

Resident outcomes. Two research team members collected resident sleep and behavior data by interviewing staff members on site at two time points: at the end of time period 1 (January 2019) and at the end of time period 2 (March 2019).

Sleep disturbances. The Neuropsychiatric Inventory (NPI) (Hatoum et al., 2005) was originally developed to evaluate 10 types of common behavioral disturbances in community-dwelling persons living with dementia, including delusions, hallucinations, depression, agitation, anxiety, elation, disinhibition, irritability, apathy, and wandering/repeated behaviors. In 2000, the tool was modified for administration to nursing center staff, with reported moderate correlations between staff reports and those of gold standard–trained observers (Wood et al., 2000). Clinically significant changes in total score and scores on subscales were identified (Iverson, Hopp, DeWolfe, & Solomons, 2002), and the NPI-Nursing Home Version (NPI-NH) is now commonly used to evaluate behavioral and drug interventions in this setting (Appelhof et al., 2019; Ballard et al., 2018). In addition to behavioral disturbances, the NPI-NH measures sleep and eating disturbances, common neurodegenerative changes in dementia. The Sleep Disorders Inventory (SDI) is an expanded version of the NPI-NH sleep domain, which has been used to independently evaluate the frequency and severity of sleep disturbances in people with dementia (Kinnunen et al., 2018; Livingston et al., 2019; Okuda et al., 2019; Tractenberg, Singer, Cummings, & Thal, 2003).

We interviewed night staff about all 63 long-term care residents' nighttime sleep disturbances using the SDI (Tractenberg et al., 2003). The SDI asks eight questions about sleep behaviors and then about the frequency and severity of each behavior in the past 2 weeks. Frequency is assessed as not present (0), less than once per week (1), one to two times per week (2), several times per week but less than every day (3), or every night (4).

Severity is assessed as mild (1), moderate (2), or severe (3). A total score is derived by summing the products of the frequency and severity ratings for each behavior. Higher scores indicate more problems with sleep.

Agitated and aggressive behaviors. Although the primary focus of this intervention was on improving sleep, we also were interested in measuring agitated behaviors among residents with dementia. We interviewed day staff about the behaviors of all 35 residents living with dementia by using the Cohen-Mansfield Agitation Inventory (CMAI) (Cohen-Mansfield, Marx, & Rosenthal, 1989). The CMAI asks about 29 verbally and physically agitated and aggressive behaviors, such as yelling, cursing, kicking, hitting, or calling out. Staff members were asked how often each of these behaviors occurred in the past 2 weeks: not applicable (0), never (1), less than once a week (2), once or twice a week (3), several times a week (4), once or twice a day (5), several times a day (6), or several times an hour (7). A total score is derived by summing the reported frequencies for all behaviors. Higher scores indicate more agitated behaviors. The CMAI has been widely used in nursing homes (Figueiro et al., 2019; Surr et al., 2020; Veleva et al., 2020) and has very good reported interrater reliability (Cohen-Mansfield et al., 1989).

Statistical Analysis

We calculated mean SDI and CMAI scores for residents under each lighting condition: tuned and static. We described the significance of within-person changes using paired *t*-tests. All analyses were conducted using Stata 14 (StataCorp, College Station, Texas).

RESULTS

Table 1 presents descriptive characteristics for the 99-bed nursing center in this study. The facility is not-for-profit and rated as 5 Stars (the highest rating) by the Centers for Medicare & Medicaid Services. Medicaid is the payer for more than half the residents (54.2%), and staff provide an average of more than 4 hours of direct care per resident per day. The mean age of residents is 88.3 years, and they are predominantly female (71.4%) and non-White (79.8%).

Table 2 presents resident nighttime sleep disturbances and agitated behaviors under the tuned and static lighting conditions. On average, the 63 residents living on the three long-term care corridors experienced half as many nighttime sleep disturbances with tuned versus static lighting (1.8 vs. 3.6 disturbances, respectively). The sleep disturbance data were highly skewed: Residents commonly had either no sleep disturbances or many severe disturbances. This is reflected in the relatively low mean, but large standard deviation (or variance) around that mean. Questions regarding agitated behaviors were asked only for the subset of residents living with Alzheimer's disease and related dementias ($N = 35$). We did not observe significant differences in agitated behaviors between the static and tuned lighting conditions (36.9 vs. 36.2 behaviors, respectively).

Table 1. Characteristics of the Participating Skilled Nursing Center

Facility Characteristics	
Total beds, *n*	99
Not-for-profit	Yes
Payer mix, %	
Medicare	18.8
Medicaid	54.2
Private pay	27.0
Staffing, hours/resident/day	4.15
5-Star Nursing Home Compare rating (range, 1–5)	5
Mean age, years	88.3
Female sex, %	71.4
Non-White, %	79.8

Sources. Publicly available data from Brown University School of Public Health (n.d.) and Medicare.gov (n.d.).

Table 2. Resident Nighttime Sleep Disturbances and Agitated Behaviors, by Lighting Condition

Resident Outcome	Static Lighting	Tuned Lighting	Mean decrease
	Mean *(SD)*		
Nighttime sleep disturbances ($N = 63$)[a]	3.6 (7.2)	1.8 (3.8)	-1.8*
Agitated behaviors ($N = 35$)[b]	36.9 (9.2)	36.2 (7.71)	-0.7

[a]Higher scores indicate worse sleep (possible range, 0–12, frequency only).

[b]Higher scores indicate more agitation (possible range, 29–203).

*$p < .05$.

DISCUSSION

In this single-facility pilot study, we found that long-stay skilled nursing center residents experienced fewer nighttime sleep disturbances when exposed to a tuned lighting condition than when the same residents were exposed to a static lighting condition. Among residents with dementia, we did not observe any difference in agitated behaviors between the two lighting conditions. While we focused on nursing center residents, sleep disturbance, as noted earlier, is common among older adults in all seniors housing settings and places them at higher risk for a wide range of poor health outcomes, from physical and cognitive decline to depression, frailty, morbidity, and mortality (da Silva et al., 2016; Dam et al., 2008; Livingston et al., 1993; McCrae et al., 2008; Miner & Kryger, 2017; Song, Blackwell, et al., 2015; Song, Dzierzewski, et al., 2015; St George et al., 2009; Stenholm et al., 2019; Suh et al., 2018). Tuned lighting may be a low-risk intervention to improve sleep and should be considered by seniors housing leaders when undertaking new construction or retrofitting LED fixtures in existing buildings, as many are already doing for energy savings.

Research into the connection between light and health began in the 1980s with examination of seasonal affective disorder (Skwerer et al., 1988); by the 1990s, it evolved into exploration of the application of light to improve the mood and health of older adults, including those in nursing homes (Riemersma-Van Der Lek et al., 2008). While several systematic reviews highlight evidence suggesting that bright lighting or tuned lighting may improve circadian rhythm, sleep, and other outcomes (Capezuti et al., 2018; Shang et al., 2019; Tähkämö et al., 2019), this is the first study, to our knowledge, to implement programmable, tunable LED lighting in nursing homes under real-world conditions. Prior research has varied widely, but many interventions involve light delivered to individuals, exposing participants to lighting in a particular spectrum and brightness for short intervals, such as 2 hours daily, and measuring biological responses rather than assessing the impact of lighting for sustained periods. Incorporating lighting into the built environment is a distinct and important next phase of research.

In our study, the nursing center adopted a lighting protocol that exposed all long-stay residents to tuned and static conditions during time period 1 or time period 2. The protocol involved not only brighter daytime corridor lighting, but also dimmer nighttime corridor lighting. Earlier research has found that nursing center residents likely receive too little light during the day and too much at night; our measurements confirmed our ability to decrease nighttime lighting levels, but we could only increase daytime lighting to the fixtures' maximum output. The lighting experts on our team cautioned that this might not be sufficiently bright to optimally affect circadian rhythm to achieve our goals regarding agitated behavior, so we made sleep disturbance our primary outcome. The fact that the sleep data were highly skewed is likely due to the fact that the intervention reduced sleep disturbances among residents with severe sleep disturbances, in a setting in which many residents share rooms of two or as many as four people. Other research supports the fact that roommates' sleep habits can have a big impact on residents' sleep patterns (Neikrug & Ancoli-Israel, 2010); improving sleep among even a few residents whose sleep is very disturbed may therefore have a ripple effect on roommates and others located nearby.

We also measured agitated behaviors among the subset of residents with Alzheimer's disease and related dementias ($N = 35$). Previous research has highlighted the potential for changes in lighting to improve the behaviors and psychological symptoms of dementia, such as agitation and aggression (Dowling, Graf, Hubbard, & Luxenberg, 2007; Lovell, Ancoli-Israel, & Gevirtz, 1995; Riemersma-Van Der Lek et al., 2008; Van Someren, Kessler, Mirmiran, & Swaab, 1997). For example, Lovell, Ancoli-Israel, and Gevirtz (1995) found that nursing center residents exhibited less agitation on days when they were exposed to 2 hours of bright light compared with days without the light treatment (Lovell et al., 1995). Although we did not observe significant longer-term changes in behaviors in the small sample of residents with dementia, it is important to remember that this is a pilot study, not a full-scale efficacy study. We did not conduct a priori power calculations to determine sample size, and our results should not be interpreted as a definitive conclusion that LED lighting works to improve sleep or does not work to reduce agitation (Leon, Davis, & Kraemer, 2011); further, the study should not be used as the basis of power calculations in future studies (Kraemer, Mintz, Noda, Tinklenberg, & Yesavage, 2006). Rather, this study establishes a best-practice lighting protocol for this setting, acceptability and feasibility of the protocol's delivery, and a setting-specific assessment strategy (Kistin & Silverstein, 2015).

We chose commonly used and validated tools to assess sleep and behaviors. However, there are several limitations to this assessment strategy. One involved a language barrier: Several of the residents spoke only Chinese and staff communicated with them through single words or gestures. Staff members found it difficult to respond to questions about verbal behaviors that require awareness of what residents are saying, because some of the items on the CMAI are language dependent, such as whether residents are repeating the same sentence or questions. Another limitation of the measurement strategy is its reliance on memory. The existing measurement tools rely on staff members to remember and report sleep disturbances and agitated behaviors during the past week. Agitated behaviors are often normalized, making it difficult for staff to recall behavioral frequency. Future research could leverage emerging technology, such as individual light, sleep, and activity monitors, to measure outcomes more accurately. Such technology could offer resident-specific light delivery data and potentially lead to real-time clinical intervention for sleep and, if demonstrated to be effective, agitated behaviors.

CONCLUSION

This evaluation adds to the evidence that automated tuned LED lighting, which changes in color and intensity throughout the day, mimicking natural day and night lighting is feasible and acceptable for older adults in residential care settings. Findings suggest that a potential effect on sleep may be actionable for builders and owners making decisions about new construction or retrofitting fixtures into existing buildings. The next step for this research should be a full-scale efficacy study. Strategies to automate interventions that improve experience and outcomes for residents in these settings are also likely to be increasingly important as the long-term care industry continues to focus staff time and resources on recovering from the coronavirus pandemic in the coming months and years.

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APPENDIX: LIGHTING PROTOCOL

Static Lighting

Color spectrum and light output are fixed. A gradual output change over a 30-minute period is scheduled to begin 30 minutes before the next output time.

These settings were designed to mimic the previous static fluorescent lighting system, which delivered a 4100K light spectrum 24 hours a day, but with every other light being shut off during nighttime hours. This setting is simulated with the LED system, set to 4100K, but with every luminaire dimmed to 50% output at night.

Time	Color Temperature	Light Output
7 a.m. to 8 p.m.	4100K	100%
8 p.m. to 7 a.m.	4100K	50%

Tuned Lighting

The color spectrum and light output are tuned. A gradual color and output change occurs over a 30-minute period beginning 30 minutes before the next color spectrum and output time.

Time	Color Temperature	Light Output
7 a.m. to 4 p.m.	6500K	100%
4 p.m. to 8 p.m.	4100K	100%
8 p.m. to 7 a.m.	2700K	20% or less of maximum output

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