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# An Explorative Investigation of the Effect of Naturalistic Light on Agitation-Associated Behavior in Nursing Home Residents With Dementia: A Pilot Study

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## Abstract

**Aim:** To study the effect of naturalistic light, programmed to replicate the spectrum distribution of natural light from dusk to dawn, on agitation measured with a Cohen-Mansfield Agitation Inventory–inspired score of nursing home residents with dementia. **Background:** Though the effects of different types of light on the sleep-wake patterns of senior adults and people with dementia have been examined in several studies, the effects of naturalistic light systems, as a possible nonpharmacological intervention to improve sleep and reduce agitation, have yet to be extensively evaluated due to the relative novelty of the technology. **Methods:** The study was designed as a 6-month pilot study of a prospective interventional longitudinal cohort study, with five participants recruited from a single department of a Danish nursing home. The effect of naturalistic lighting on agitation-associated behaviors was recorded over a 3-day period pre- and postintervention. Results: An overall 71.2% reduction in the frequency of agitation-associated behaviors was recorded, with the frequency of some behaviors even reduced by 100%. **Conclusions:** This pilot study estimates that naturalistic lighting may be a promising nonpharmacological intervention to improve the overall agitation of nursing home residents with dementia, with a possible added benefit of an improved work environment for the staff. This study, therefore, finds indication for the performance of a randomized controlled trial with the same intervention and a larger cohort.

## Keywords

natural light, dementia, environment of care, experimental

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## Introduction

Sunlight appears to be an important, if not the main, regulator for the circadian rhythm and the sleep-wake cycle. It is also widely accepted that sleep disturbances affect people with dementia negatively, and the effects of different types of light on the sleep-wake patterns of senior adults and people with dementia have increasingly been a topic of research over the last 3 decades in particular (Figueiro, 2017).

The neuroanatomical regulation of the circadian rhythm by light is primarily based on the connection between the retina, the light sensitive layer of the eye, and a cluster of neurons at the base of the of the brain where the optic nerves cross; more specifically the suprachiasmatic nucleus (SCN) and the melanopsin-positive retinal ganglion cells of the retina which are found to have a spectral sensitivity to short-wavelength blue light (Blume et al., 2019; Thapan et al., 2001; van Lieshout-van Dal et al., 2019).

In general, people with neurodegenerative diseases have disturbances in the sleep-wake cycle and damage to the circadian-rhythm regulating regions of the brain. The damage is possibly caused by a combination of accumulating pathogenic proteins, neuroinflammation, and synaptic damage (Figueiro, 2017; Malhotra, 2018; Musiek & Holtzman, 2016). Nonetheless, factors such as medication side effects, indoor light exposure, and neuropsychiatric disturbances may also play a role in the circadian disturbance.

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Naturalistic light systems, programmed to dynamically replicate the spectrum distribution of natural light from dusk to dawn, are now commercially available and there are many thoughts and opinions about the beneficial effect of this nonpharmacological intervention. Most of the evidence is obtained from a few small studies performed in healthy individuals in controlled laboratories with only bright lighting without a naturalistic light component (Hjetland et al., 2020). More studies investigating the effect of naturalistic light are therefore needed to support the significant additional cost of installation.

Thus, with this pilot study, the effect of naturalistic light on agitation of nursing home residents with dementia was studied.

The aim of this pilot study was to investigate an indication for a larger trial, by evaluating if naturalistic lighting improves the overall agitation of a small cohort of nursing home residents with dementia.

## Method

### *Design*

The study was designed as a pilot study of a prospective interventional longitudinal cohort study, comparing the frequency of agitation-associated behaviors in residents at a nursing home department for people with dementia before and after the installation of lamps with naturalistic light.

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Pre- and postimplementation data on the same five nursing home residents was collected by certified nursing assistants (CNAs) in end of June 2018—an unspecified amount of time after the staff training and follow-up at the end of February 2019, resulting in an intervention period of almost 6 months.

The original Cohen-Mansfield Agitation Inventory (CMAI) score is a validated proxy informant interview that rates 29 agitation-associated behaviors and their frequencies through the day, commonly over a 14-day period. According to frequency, each behavior is rated on a 7-point scale from *never* to *several times per hour*, with total scores ranging between 29 and 203 (Finkel et al., 1992; Griffiths et al., 2020; Kupeli et al., 2018). The behaviors can be grouped into (1) aggressive behavior, (2) nonaggressive behavior, and (3) verbal agitation (which may

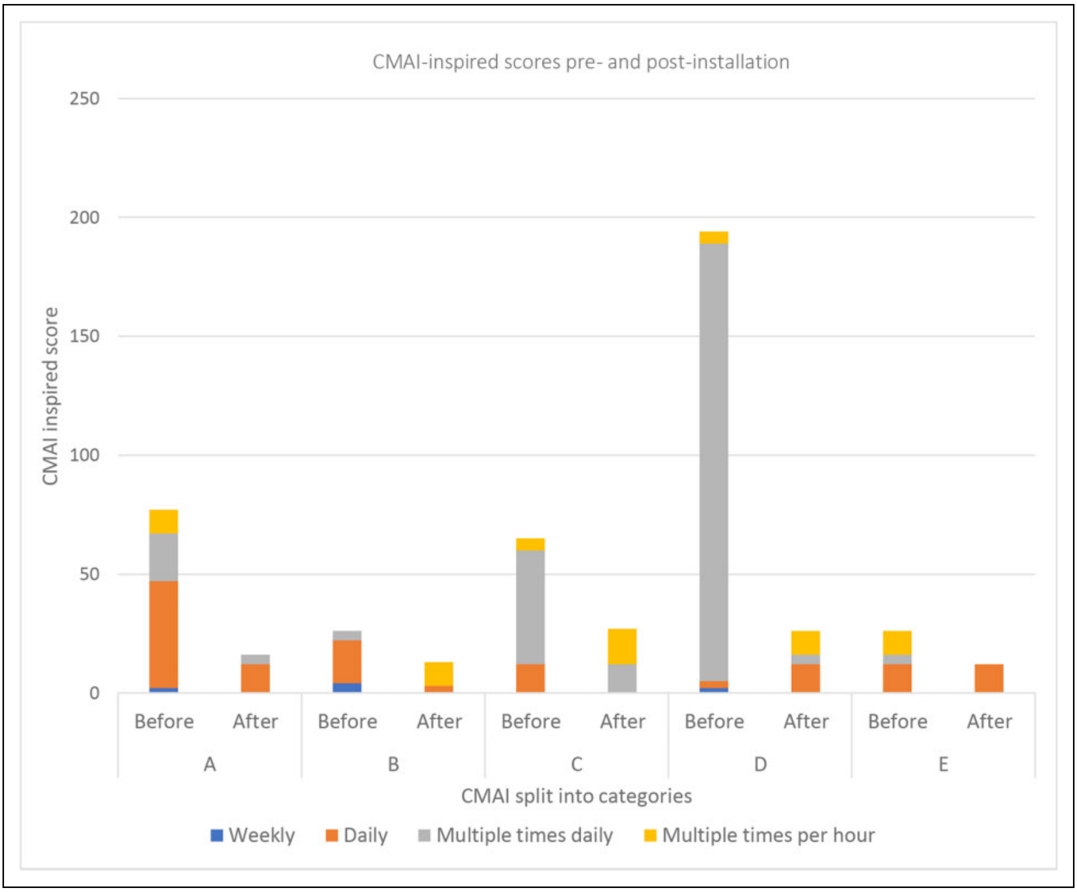


**Figure 1.** Cohen-Mansfield Agitation Inventory–inspired scores pre- and postinstallation of naturalistic light for Participants A–E, showing the proportion of the score relating to each observational frequency. Weekly = over 3 days.

further be divided into aggressive and nonaggressive verbal agitation).

In this pilot study, due to logistical challenges, a CMAI-inspired score was self-administered by the CNAs over a 3-day period pre- and postintervention, instead of a 14-day period. The participants were scored 4 times per day, in the morning, midday, afternoon, and night over a 3-day period at time of inclusion and again at follow-up over a period of 6 months (end of June 2018 to end of February 2019). Points were given at the time of *each* scoring. The 29 agitation-associated behaviors and their frequencies were evaluated on a 5-point scale. Behaviors were scored in a period at the start of the study and again after a period by following algorithm: *never* = 0 point, *weekly* = 2 points (i.e., maximum score of 2 points over the 3-day period), *daily* = 3 points (i.e., maximum score of 3 points per day and maximum score of 9 [3 × 3] points over the 3-day period), *several times daily* = 4 points (i.e., maximum score of 48 [4 × 4 × 3] points over the 3-day period), and *several times per hour* = 5 points (i.e., maximum score of 60 [5 × 4 × 3] points over a 3-day period). Based on the algorithm, total scores ranging between 0 and 1,740 points. The points awarded are shown in Figure 1.

All observed behaviors and the total number of each registered behavior pre- and postintervention were also registered.

## *Sample*

Five participants were recruited from a single department of a Danish nursing home, which had a reported high number of residents with dementia and agitated nighttime behavior. There was no selection, as it was the five residents who lived in that wing at the time. No exclusion criteria were made, and no demographic data regarding the residents were collected.

### Intervention

Light installations were changed from normal nondynamic indoor lighting to naturalistic lighting and implemented across the department in May–June 2018. The CNAs received 1 day of training in the use of the system by the manufacturer. Two lamps were installed in the staff office, eight in the communal area and kitchen, six in every hall, and three in every resident's apartment—in the bathroom, bedroom, and living room. The intervention was turned on in September 2018.

Every lamp followed a circadian rhythm protocol, automated to simulate the natural development of light intensity and color during the day. Every apartment and communal area was fitted with individual switches with preprogrammed scenarios, and a master control was placed in the staff office, allowing possible deviation from protocol when needed.

In all areas of the nursing home, the lighting design was implemented with both fully automated naturalistic lighting as one light setting and then additional static light settings that could be used whenever lighting is needed for a specific task or activity. The automated naturalistic light setting overrode all other light settings every morning to ensure most use of it. It followed a design of spectral distribution according to West et al. ( 2017) which in turn followed the light description after Lucas et al. (2014). Compared to West et al., the light in this study was adapted to the tasks, timing, and visual environment of a nursing home. The naturalistic lighting was dim, 1,800 K correlated color temperature (CCT) during nighttime. Around the time of shift change, the light smoothly changed toward higher CCT and increased simultaneously in intensity. The smooth change continued toward noon where it reached the highest intensity and 5,500 K CCT for maximum circadian stimulus.

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In the afternoon, it changed smoothly toward lower illuminance and CCT levels reaching 2,700 K around dinner. During the evening, it continued to dim in preparation for the coming sleep for the nursing home residents.

Regarding the timing of the naturalistic lighting, the project layout was divided into communal areas and apartments. In the communal areas, the naturalistic lighting had a fixed timing, where the dim, biological darkness at night extended from 22.00 to 7.00 the following day, as a bedtime cue for any residents walking in the communal areas at night.

## Results

As the CMAI-inspired scores are not normally distributed variables, Wilcoxon signed-rank test was used to calculate the difference between before and after intervention (Table 1). Data were expressed as median and interquartile range. Hedges's $g$ test was also included as the test does not consider the number of participants and can be used by <20 participants and therefore only looks at the effect of intervention between the groups (Table 2). Hedges's $g$ uses pooled weighted standard deviations (instead of pooled standard deviations). A calculated scores above 0.8 is estimated as large effect of the intervention. Nonparametric analyses were made in Statistical Analysis System (SAS Inst. Inc., Version 9.4, Cary, NC). A $p$ value .05 was considered significant.

The scores pre- and postintervention were divided into three different types of scores, determined as number of affected observed behaviors over the 3-day period *for all items in each participant* (*the sum of affected observed behaviors, individual, i.e., all observations minus the*

**Table 1.** Difference in CMAI-Inspired Scores Before and After Intervention by Naturalistic light.

| CMAI Analysis | Score Before Intervention Median | Score After Intervention Median | Differences in Scores Median (IQR) | *p* Value |
|---|---|---|---|---|
| Observed behaviors, individual | 18 | 5 | −12 (14.0) | .075 |
| Total score | 65 | 16 | −38 (47.0) | .090 |
| Observed behaviors, items | 9 | 1 | −6.5 (10.5) | **.002** |

*Note.* CMAI-inspired scores did not display a parametric distribution, thus median with IQR is presented. Wilcoxon signed-rank test was used to calculate the statistical difference. Cohen-Mansfield Agitation Inventory = CMAI; IQR = interquartile range. Statistical significance is marked as bold.

**Table 2.** Difference in Cohen-Mansfield Agitation Inventory (CMAI)–Inspired Scores Before and After Intervention With Naturalistic Light Calculated by a Hedges's *g* Test Comparison.

| CMAI | Hedges's *g* Test |
|---|---|
| Observed behaviors, individual | 1.19 |
| Total score | 1.08 |
| Observed behaviors, items | 1.05 |

*"never" observations*), over the *Total Score* (representing the calculated CMAI-inspired score) (Figure 1), and over the sum of positive affected observed behaviors for each item (the sum for each item for all five resident pre- and postintervention are compared) over the 3-day period (*observed behaviors, items*; Table 3).

There was an observed large effect of naturalistic lighting by a Hedges's *g* test in "*observed behaviors, individual*" and "*total score*." Wilcoxon signed-rank test showed a *p* value at .075 and .090 (Table 1) in these scores indicating a trend toward a large reduction in the observed behaviors in each participant by the intervention, also illustrated by a Hedges's $g > 0.8$ (Table 2).

In the "*observed behaviors, items*," a significant effect by a *p* value of .002 (Table 1) with a Hedges's *g* test at 1.05 (Table 2) was found indicating that the intervention reduced the frequency of agitation-associated behaviors in the entire study group as well.

An overall 71.2% reduction in the frequency of agitation-associated behaviors was recorded, where five behaviors were reduced by 100% and two behaviors were increased by 100% (Table 3).

## Discussion

In summary, reduced agitated behavior and nighttime activity was observed among the participants following implementation of naturalistic lighting.

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The physiological explanation behind the effect of light is complex since the involved brain areas and networks in relation to CMAI scores overlap between cognitive areas and areas responsible for arousal and sleep.

Networks in relation to arousal and wakefulness are mediated by several transmitters, but one of the essential elements to achieve wakefulness is maintained by the orexin-containing neurons in the lateral hypothalamus; these neurons provide excitatory input to the nuclear in brainstem-related areas involved in the ascending arousal system (ARAS), as well as to the entire cerebral cortex. Orexin-containing neurons are activated by light through SCN connections, making SCN an important stimulator of the ARAS. Suppression of neural drive from SCN could therefore underlie the feeling of sleepiness and fatigue because of reduced energy levels and impaired mental concentration (Cohen & Albers, 1991), which may reduce agitation and promote sleep in people with dementia. The explanation behind this is that projections from SCN reach both the wake-promoting neurons and the sleep-promoting systems by both direct and indirect routes, relayed through the dorsomedial hypothalamus and the

**Table 3.** Data Collected by CNAs Regarding Types of Affected Agitation-Associated Behaviors Among Residents and Their Frequency Before and After Intervention.

| Type of Affected Agitation-Associated Behavior | Number of Observed Behaviors Before Intervention | Numberof Observed Behaviors After Intervention | Decline in % |
|---|---|---|---|
| 1. Pacing and aimless wandering | 15 | 2 | 86.7 |
| 2. Inappropriate dressing or disrobing | 1 | 0 | 100.0 |
| 3. Spitting (including while feeding) | 0 | 1 | −100.0 |
| 5. Constant unwarranted request for attention or help | 17 | 10 | 41.2 |
| 6. Repetitive sentences or questions | 21 | 10 | 52.4 |
| 12. Making strange noises | 10 | 4 | 60.0 |
| 15. Scratching | 4 | 0 | 100.0 |
| 16.Trying to get to a different place | 8 | 0 | 100.0 |
| 18. Complaining | 1 | 0 | 100.0 |
| 22. Handling things inappropriately | 0 | 1 | −100.0 |
| 26. Performing repetitious mannerisms | 12 | 0 | 100.0 |
| 29. General restlessness | 15 | 2 | 86.7 |
| Total | 104 | 30 | |
| Total decline in % | | | 71.2 |

*Note*. Nonobserved behaviors have been omitted.

ventral subparaventricular zone. The function of SCN is therefore to increase wakefulness and cognitive function during the active period and increase sleep during the inactive period (Harrington, 2012), which may explain the effect that light has in this study and other studies mentioned above, especially in people where cognitive understanding of time is lacking.

There is no unique correspondence between color and light spectrum in human color perception, since several different spectral distributions can be seen as the same color as the tint of white. Therefore, to specify lighting in detail, it was necessary to specify the light spectrum—that is, the quantity of each wavelength within the visible range of the electromagnetic radiation for each state of daylight or discrete color. The light spectrum analysis was used in this project as CCT and lux are not exact measures for the human nonvisual response to light.

## Limitations

A possible limitation of the study is that no vision test was performed on the participants, and it is possible that eye diseases such as cataracts or macular degeneration may have reduced the effect of the light on the agitation-associated behaviors. Also, no devices recording the physical location or individual light exposure of each participant were available, thus limiting the ability to evaluate if the participants were exposed to the naturalistic lighting system as intended. However, as described in the Method section, the naturalistic lighting system was installed in all areas of the nursing home, thus we presumed that any variation in naturalistic lighting among participants would be negligible. No information was given about controversies between the installation process and the residents. Measurements from another study revealed only limited influence of the natural light due to the often cloudy weather during the intervention period in Denmark and the fact that modern windows only allow a small amount of blue light spectrum pass through, which end up with only a small amount of natural blue light that can be measured in the resident rooms (West et al., 2017).

Another possible limitation is that no data regarding neuropsychiatric comorbidities, disease stages, and pharmacological treatment were included, which may possibly have influenced the scores.

Since the department houses residents with dementia and reported high agitation levels, it is also possible that the day-to-day interactions between the residents may have influenced the scores. In addition, prescribed medication may have affected data, however, indication for medication distribution is estimated to be the same throughout the period.

Furthermore, multiple other variables may have influenced the data, and this should be taken into consideration during more comprehensive studies in the future.

A 3-day observation period pre- and postintervention was chosen instead of a 14-day period, thus limiting the ability to sufficiently quantify the weekly frequency of the agitation-associated behaviors, which made it necessary to also convert the original CMAI 7-point scale to a CMAI-inspired 5-point scale. Thus, the category "weekly" reflects that a behavior has been registered over a 3-day period. Another conflict could be the large difference in points scoring between low scores ("weekly", "daily") and high scores ("several times daily", "several times per hour") in the CMAI-inspired score, as participants with agitated behavior will quickly gain many points compared to the normal CMAI scoring system. However, the authors do not suspect that the altered measuring period has a significant impact on the reported effects of naturalistic lighting, since a measuring period of 3-days was used both pre- and postintervention. The use of a CMAI-inspired scoring could also limit the possibility to compare this pilot study with other studies, but the results still give an accurate impression to the purpose of a pilot study.

The use of the CNAs as proxies to collect data regarding the participants may possibly have introduced some bias, since no CNAs were blinded regarding the installation and implementation of the naturalistic lighting. However, using self-reported data would be impractical due to the dementia of the participants.

It is possible that the supplementary use of further evaluation tools such as the neuropsychiatric inventory—nursing home edition (NPI-NH) and the behavior rating scale for dementia (BRSD)—could have strengthened our findings, as these are also widely used assessment tools (Ballard et al., 2018; Cohen-Mansfield & Golander, n.d.). However, the addition of other assessment tools, of which some may require specific training such as with the BRSD, might have reduced the feasibility of this pilot study due to resource limitations.

Furthermore, this pilot study included five participants and no control group which reduces the evidence level; however it is likely, that a higher number of included participants would increase the evidence for the benefit of the light due to the high Hedges's $g$ score.

Overall, this pilot study adds to an increasing amount of evidence regarding the importance of light as a regulator for human behavior and the use of lighting as a nonpharmacological aid with no reported negative side effects in the treatment and care of people with neurodegenerative disease.

## Note of Interest

An informal focus-group interview with members of staff (CNAs) was conducted at the end of the project. The collected data do not support any conclusions and have thus been omitted from the results. However, the authors have decided to note that this anecdotal data revealed certain interesting informal observations that may inspire questions for further studies to elucidate.

The staff noted an increased well-being among the nursing home residents. The residents stayed longer in the communal areas and increased their food-intake during meals. The staff also observed an increased level of daytime activity with reduced tendency to sleeping around early evening and less nighttime activity among the residents in general.

The staff also noted an increased general well-being for themselves, with a sense of feeling more energetic during the day, reduced tendency for headaches, and with a more pleasant work environment during the night compared to other departments of the nursing home without naturalistic lighting.

Previous studies have assessed the effect of lighting on worker performance (Figueiro et al., 2016; Graves et al., 2021) but the possible added benefit of naturalistic lighting on staff health and productivity remains to be explored and could be taken into consideration when evaluating the costs and benefits of the installation of naturalistic lighting. It is feasible to improve current facilities with naturalistic lighting, thus improving the living spaces of nursing home residents with otherwise limited exposure to natural lighting due to factors such as reduced mobility or reduced capability to leave indoor facilities.

It might be interesting for future studies to explore the effect of naturalistic lighting on agitation, depressive symptoms, or rehabilitation in larger groups of participants with neurodegenerative disease and compare these with groups of participants with stroke or other neurological diseases.

We speculate that the implementation of naturalistic lighting may become an integral part of the design of future hospital and care facilities, as well as the improvement of existing facilities, and even possibly at a broader societal level in regions with a low annual sunshine duration.

## Conclusion

This pilot study indicates that naturalistic lighting may be an effective nonpharmacological intervention in nursing home settings to improve the overall agitation of residents with dementia. This study therefore finds indication for conducting a randomized controlled trial with the same intervention and larger cohort.

## Implications for Practice

- Indoor naturalistic lighting systems (light that imitates the sunlight rhythm throughout the day) may improve agitation-associated behaviors in nursing home residents with dementia.
- Correct use and description of spectrum distribution is essential during the installation of dynamic lighting systems and research in this area.
- Larger studies investigating on the effect of naturalistic light are needed, and these may benefit from the use of a combination of validated neuropsychiatric assessment tools.

### Authors' Note

None of the authors have ethical conflicts to disclose. This study did not require an Institutional Review Board (IRB) statement.

### Declaration of Conflicting Interests

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