IMPLEMENTING CIRCADIAN RHYTHM LIGHTING – TWO HEALTH-CARE CASE STUDIES

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Abstract

The studies derive from two larger Danish cases, which evaluated the application of circadian rhythm lighting in sensitive health care environments and highlights the difficulties that can be experienced in the implementation of entraining, or shifting of the timing, of the biological clock through lighting design. The paper focuses on the effects of introducing new 24-hour light and dark patterns on patients and residents in the two institutions, a home for the aged with dementia and a psychiatric facility for eating disorder patients. Data was gathered through ethnographic interviews, questionnaires, mappings, and structured observations. While positive benefits for health were an intended effect of implementing 24-hour biologically attuned lighting into these two environments, its introduction was also experienced negatively by staff and patients, particularly in the early stages of implementation, by affecting the patients' everyday routines and feeling of ownership. The paper lays out the foundation for current research projects by the author, by comparing the perceived comfort and experiences of the patients with the documented laboratory effects of the design of circadian lighting system. The paper concludes with preliminary recommendations for future implementations of circadian lighting designs, including the consideration of the context, the users' adaptation of the technology, communication with staff, usability and personal control.

1. Introduction

1.1 Circadian Lighting

The application of electric lighting to adjust or entrain circadian rhythm, by maintaining biological processes and behaviors relative to the 24-hour day/night cycle, has well-reported effects on health [1], [2]. Circadian rhythm lighting (CRL) has also shown promise to be effective as an integrated part of care and treatment of dementia patients (Sander et al., 2015), seasonal affective disorders, psychiatric and long-term hospitalized patients [3]–[5]. As most of the work investigating the impact of light on health and well-being has been performed in the laboratory [1], the authors' current work prioritizes research in natural settings [6]–[8], with the objective of applying and optimizing CRL's impacts on health and well-being outside laboratory conditions. However, research in natural environments presents a larger degree of complexity when dealing with patients in sensitive situations, such as resorting to the installation of lighting equipment late at night [9]; or where an experiment indicated that in the treatment of 'sundown syndrome' among elderly with dementia, and in order to have a maximum effect of circadian lighting on the sleep-wake-cycle, relatively high levels of illuminance were needed [10]; or where Alzheimer patients have been often treated with increased lighting by sitting still in front of a light box for relatively long periods [11].

This paper focuses on how the implementation of CRL influences the everyday life, the acceptance and adaptation of the patients and residents, and well-being of patients and staff in two specific healthcare contexts. This is explored through their everyday practice of light sources, and predominantly their use of electrical lighting, since the methods used in the studies attempt to identify effects of circadian adjusted lighting, where changes in daily routines and rhythms can serve as indicators for their wellbeing. This paper does not therefore present data on the effects of the intervention on the participants' health, nor does it set out to prove or disprove effects of CRL on patients' well-being and psychological health. The aim is rather to provide descriptions of how the implementation of this welfare technology influences everyday life of staff and patients, through interviews and observations.

1.2 Case-studies in healthcare environments

1.2.1 Case 1: LIGHTEL (Albertshøj) care facility for elderly dementia patients in Albertslund, Denmark.

The sub-study derived from a larger transdisciplinary intervention control trial [6], [12](approved research protocol) and investigates the effect of the introduction of CRL in a care facility on residents with varying degrees of dementia (43% Dementia, 13% Parkinson's, 47% Apoplexy and 23 % other neurological diseases, where some patients had more than one of these afflictions).

The large intervention trial collected both medical, anthropological, and sensor-based data in a concurrent research design, where CRL (Figure 1, 2 and 3) was installed on a single floor, in residents' private rooms, common spaces, living rooms and dining room. Previous research [10], [13], [14] shows that patients with dementia often have an abrupt circadian rhythm, due to deficient exposure to daylight [15], making them an interesting target group for light exposure treatments.

As care for dementia patients encourages secure and homely environments, the sub-study examines the influence of the CRL intervention on the residents' "practice of home" [16]–[18] and their perceived reality and experiences of light, from an anthropological viewpoint. Residents were interviewed about their daily lives and routines before the installation, during the control trial and the intervention. This was carried out in order to uncover how the implementation of CRL affected the residents' acceptance of the new lighting technology and the effect on their everyday lives and well-being.

During the study, the residents and staff were encouraged to have the pre-programmed lighting on at all times, and only to turn it off (by a switch on the wall) in case of emergencies. The care facility had large window sections illuminating rooms with daylight, and besides the CRL the residents were allowed to use their own lamps brought from home.

<table>
<tr><th>Baseline</th><th>Control Period: Static lighting setting</th><th>Intervention: CRL (Dec.11th 2017 – Feb 4. 2018)</th><th>Control Period: Static lighting setting</th></tr>
<tr><td>1 week</td><td>8 weeks</td><td>8 weeks</td><td>8 weeks</td></tr>
<tr><td colspan="3">Group A</td><td></td></tr>
<tr><td colspan="2"></td><td colspan="2">Group B</td></tr>
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Table 1: Research design for case-study 1. Oct. 2017 - Marts 2018.

1.2.2 Case 2: Ballerup Psychiatric Centre, Eating Disorder Unit

Although very little lighting research has been carried out on patients suffering from eating disorders (ED), they pose an interesting case, as Anorexia Nervosa and Bulimia Nervosa can be linked to comorbidity in disorders including depression and sleep deprivation, insomnia, obesity, diabetes, bipolar disorder and seasonal affective disorder [19], [20], many of which, in other types of patients, have previously been shown to be affected by 24-hour patterns of light and dark [10], [21], [22]. The objective of this particular study was to introduce two different CRL programs, to be able to compare and investigate if exposure to the two schedules (Figure 4. and 5.) would show effects on the activity and wellbeing of the hospitalized patients, through entrainment of their circadian rhythms.

These two CRL schedules were implemented in a newly built psychiatric treatment facility for ED patients. The facility offered CRL in private patient rooms, dining room and an open office, whereas corridors, courtyards and a lounge area had access to dynamic lighting and high levels of daylight.

Data were gathered through structured ethnographic observations, interviews, questionnaires, mappings, acoustical sensors, CO2 sensors, occupancy sensors, daylight sensors, thermal sensor imaging (Figure 6.), flow data, and clinical measurements, including regular blood and urine analysis. This paper focuses on the ethnographic results gained through observations carried out during the introduction of the CRL programs during May to July 2018.

1.3 Summary

In both cases, the newly installed technology was intended to implement new standards and practices for circadian light exposure in healthcare facilities. The two facilities described in this paper are both clinical units where residents are of a vulnerable group of citizens. However, in case 1 the lighting intervention was a retrofit solution installed on the 5th floor of an existing eldercare facility, built in 2015. Whereas in case 2, the entire facility is new and was finished in 2018.

While the aim is not to make a 1:1 comparison of the two case-studies, they are examples of user experiences of situations where circadian lighting systems were installed and illustrate the heterogeneity and complexity of such health-care facilities.

2. Case 1

2.1 Circadian Light Intervention

The circadian rhythm lighting was implemented in all rooms on the single floor of Albertshøj. It followed planned lighting schedules throughout the intervention (see Figure 1. showing changes in Correlated Color Temperatures (CCT)), designed to follow the day/night cycle. The CRL (see Figure 2 and 3) is presented in concordance with the CIE S 026:2018 α-opic toolbox (International Commision on Illumination (CIE)) [23] that describes the stimulus from the CRL on each of the 5 photoreceptors in the human eye; displayed as five alpha-optic curves. Furthermore, the CRL curve has been adapted to the elderly residents based on a large randomized control study on depression and anxiety in poststroke patients [4], [5]. During the morning hours, illuminance was slowly increased adding CCT with relatively shorter wavelengths of the light spectrum, peaking at 5500 K. between noon and 2pm. At night, the light contained a maximum of 1% of the spectral energy below 520 nm to minimize impact on patients' non-visual systems. The lighting schedule was carefully designed to entrain the circadian rhythms of the residents, while supporting the daily activities in the facility. The residents were able to turn the light on and off whenever preferred. Additional 8 static light settings were installed to supplement the activities when the CRL was insufficient. During the control periods, the lighting was programmed to have a static illuminance level and 3000 K. All 180 lamps and 150 wireless wall switches were individually controlled by a central, DMX-based lighting controller that automatically coordinated the CRL and static light settings.

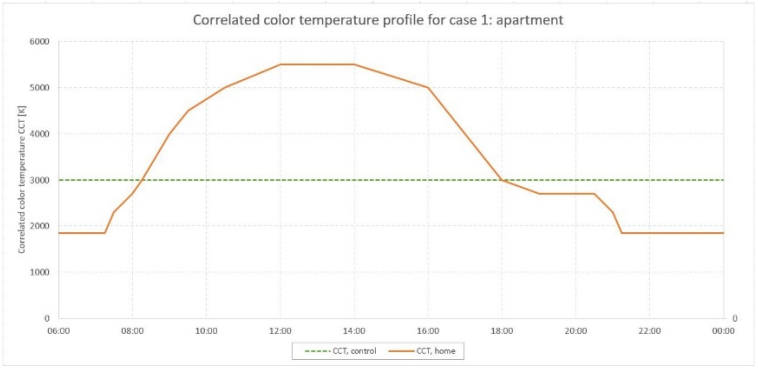

Fig. 1. CCT

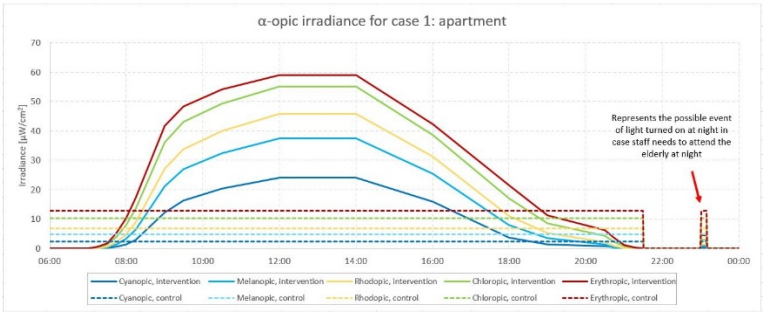

Fig. 2. Alfa-opic irradiance in apartments

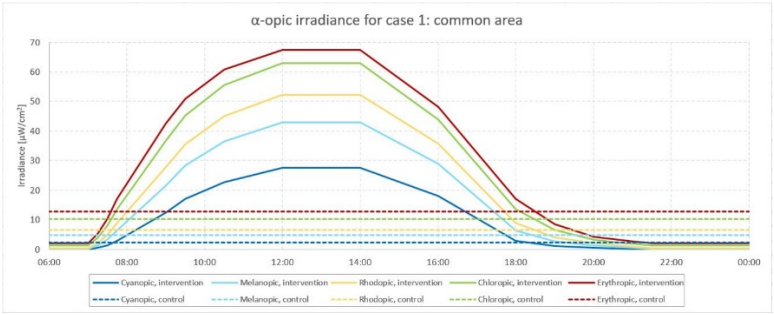

Fig. 3. Alfa-opic irradiance in common areas

2.2 Residents

Consent to participate in the intervention trial was obtained from the ethical committee VEK in 2016. IRB approval includes the interviews and observations. Seven frail elderly residents (+65) with varying degrees of dementia participated in interviews during the intervention study. Because the residents were vulnerable study-subjects, the sample size partly depended on the staff's evaluation of the resident's wellbeing, whether they were able to be

interviewed for 15 minutes or more, and able to provide a detailed account on their daily activities and experience of the lighting. These recommendations from staff reduced the participants appropriate for interviewing from 15 to 7 informants, due to severe cognitive disabilities and health-related issues. By the end of the study only 5 participants were interviewed in person about their perception of the lighting. 10 of the 15 residents, who the authors were unable to interview in person, were instead observed and surveyed through proxy interviews with staff [24].

2.3 Procedure

Interviews

Participants were given a verbal explanation of the project on the first encounter. The five participants were each interviewed 7 times over the course of 17 weeks from October 2017 to beginning of February 2018. The interviews, typically conducted after 10 am, lasted between 30-50 minutes depending on the resident's current physical and cognitive state and willingness to answer our questions. Semi-structured interview guides [25] were designed to cover themes of the residents' everyday life, relating to their routines, activities in their apartment, socially and outside the nursing home, their experience of the facility and their sleeping patterns.

The main topics during the interviews were the residents' understanding, evaluation, and practice of the installed light sources, both their own as well as the new CRL. Mappings of the light sources and perceived luminous intensity were used as a supplementary tool to communicate about the resident's perception of the lighting in their homes. The mappings (handwritten sketches) were conducted in the resident's apartment by the interviewer together with the interviewee and included noting of the arrangements of lamps in the resident's home and the perceived luminous intensity (assigned with colored stickers). The residents were asked a set of the same questions for each encounter, with small variations, to maintain consistency in the data. As more interviews were held, participants were asked about whether anything had changed in their routines: for example, relating to sleeping patterns, daily and nocturnal activities, physical health or mood. The 5 residents included in the study were also frequently reviewed with their responsible caregiver, whom they were in daily contact with, and who helped by providing their account of the situation.

Observations

Observations were gathered by two researchers, three times for control and intervention periods respectively (morning, lunch, and dinner) lasting 1,5 hours each. The meals were the central gathering point of the day for residents and staff. The notes were re-written soon after collection, and while the information was still fresh.

Analysis of data

The results transcribed by two researchers who also conducted the fieldwork, then coded into 6 themes, where this paper focuses on two of the themes: (1) Acceptance, adaptation and tolerability; (2) The impact on work environments and wellbeing of the staff. The researchers transcribed each other's interviews, and conducted a thematic analysis using NVivo software, first individually, then in collaboration to form a synthesized analysis of larger themes. The quotes used in the following text were selected to exemplify the analyzed themes, rather than attempting to generalize for a generic, elderly and institutionalized resident.

3. Case 2

In a newly built psychiatric unit for eating disorders, CRL was installed in patients' rooms, the dining room, and common areas. The lighting profile [26] was developed based on work in Case 1, the Lightel project and previous research recommendations from the field of chronobiology and cognitive research [27]. The lighting was programmed with a KNX-based lighting controller that automatically coordinated light settings to follow two CRL schedules 'L1' and 'L2' respectively for periods of 3 weeks, spread over 3 months (see Figure 4. and 5.). The CRL was validated with light measurements using an Asense TEK ALP-01 spectrometer and a Hagner EC1 luxmeter. During the test period, patients in the facility were not able to turn off the lights in their private rooms from 7am - 9pm, except during medical attention where higher light levels would be required; in these cases, staff could override the CRL.

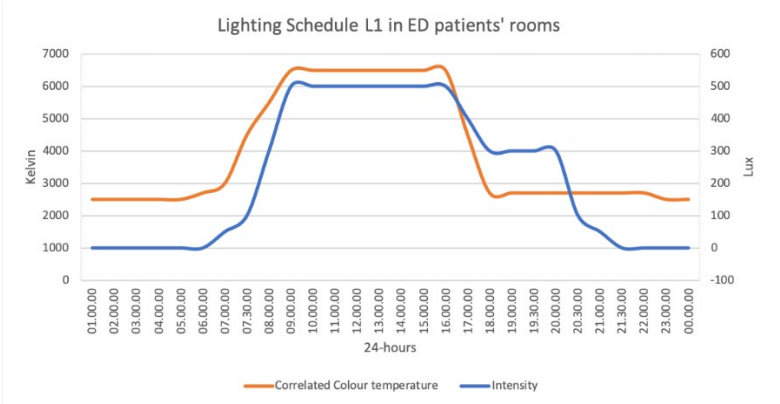

Fig. 4. Natural course of the day/night cycle

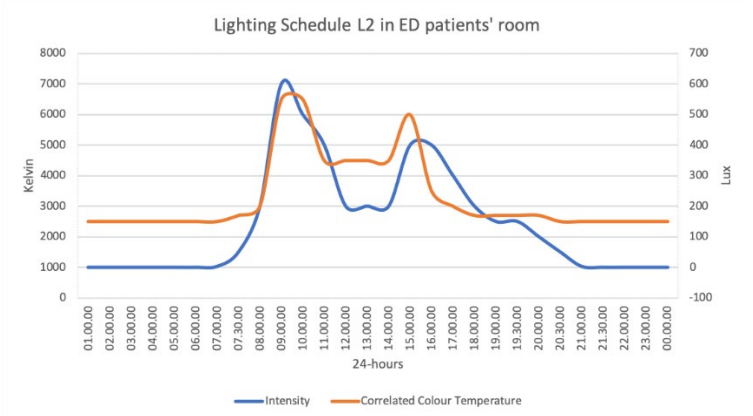

Fig. 5. Two daily 'light boosts' of higher CCT and illuminance levels

The first schedule L1 (Figure 4.) follows the natural course of the day/night cycle, with higher color temperatures and illuminances during the day than the second schedule. L2 (Figure 5.) was designed to match the strictly structured daily program applied by the medical staff in the facility and provided two daily 'light boosts' of higher CCT and illuminance levels: a strong peak in illuminance during the morning and another peak in the afternoon. The test period ran from May to July 2018 (12 weeks in total) at the Mental Health Center in Ballerup, Denmark.

3.1 Research Design

CRL Scenario	Test	L1a	L2a	L1b	L2b
Time period	6 weeks (March-April)	3 weeks (April-May)	3 weeks (May)	3 weeks (June)	3 weeks (June-July)

Table 3, research- and test design for case study 2

The experiment was based on a framework of A-B-A-B phased design, or withdrawal and reversal design [28, pp. 1-2], where each phase lasted three weeks. This design enabled a comparison of the observations and data collected from the two differing lighting programs. Each schedule was carefully designed to accompany and support the daily activities in the facility. A baseline was initially proposed prior to the data collection, but due to delays in completion of the new buildings, together with technical changes in the building, the data collected from the baseline has been discarded.

3.2 Patients

Due to the project timelines, 11 out of original 16 patients with ICD-10 diagnosis of eating disorders were exposed to both L1 and L2 and participated throughout the complete intervention period [26]. The patients were selected based on a predefined set of criteria. Inclusion criteria included: (a) Primary diagnosis of AN or BN or EDNOS; (b) (Eating Disorder Not Otherwise Specified); (c) Age ≥18 and <65. Exclusion criteria included: (a) Forced care; (b) Non-primary psychiatric disorder other than anorexia nervosa (AN), Bulimia nervosa (BN) or Eating Disorders Not

Otherwise Specified (EDNOS); (c) Binge Eating disorder; (d) somatic unstable condition; (e) High suicidal behavior or risk [26].

3.3 Staff

Psychiatric assessments by medical research assistants were carried out through interviews and questionnaires to measure and track changes in anxiety levels and wellbeing. As mentioned previously, these results will be published elsewhere. The staff are trained in assessing patients with eating disorders and have weekly internal meetings to harmonize assessments. Staff were always present in the facility. Only the night-time shift-workers had consistent work shifts, whereas the daytime (morning - afternoon) staff had rotating shifts.

3.4 Procedure

The structured observations were collected by one researcher, carried out in time slots during the period 08:30-00:30, allowing observation of the interaction patterns between patient-to-patient, staff-to-staff and patient-to-staff, at times where the electric lighting was dominant.

Figure 6. Thermal camera image of lounge area (observer seated in upper right corner)

4. Results

4.1 Adaptation and tolerability

The findings from Case 1 illustrate the difficulties for the residents in adapting to the circadian lighting. The discontent with the new lighting was exemplified by resident 1:

"Yes, you know what? When I am seated here by myself, then I let this be turned on, and it is on all the time [table lamp with green glass-shade and brass lamp base] because I like the lighting that it provides, and then no more lighting is needed. Likewise, in the bathroom you know what? I have tons of light in there, where a lamp has also been installed. It is completely insane. It is too much."

Resident 3 explains her thoughts about the process of adaptation: *"But whether I can get used to it, that I do not know. Whether I will say: 'oh, how pleasant it is', that I am afraid that I will never really do, but you never know".*

The time needed for adaptation to the CRL was generally longer than hypothesized; at the end of the intervention, all seven of the residents who underwent the complete study period, and were more independent of staff, still preferred their own lighting and daylight, rather than the circadian lighting.

Lighting controls and modern dwelling

The issues of acceptance and tolerability were not only connected to the residents' light culture but were also affected by their fear of using modern technology: "*The top switch is the new one. That one you must not touch!"* (Resident 1). Residents' insecurity towards the new CRL systems were especially revealed when it did not work: *"I thought in the beginning that it was my mistake, and I did not want to say anything".* Likewise, Resident 2 did not know how to use the lighting switches with the intention of turning the lights off in the bathroom. This resulted in distress, and decreased her feeling of autonomy and her ownership of the home:

"*It functions differently, I think. It seems to work opposite of what I have experienced my entire life where you turn it on by pressing up and you turn it off underneath. To me, it seems a bit inverted and wrong because I cannot simply turn it on and off. […] I have had some issues figuring it out and I am still fumbling with the bathroom light. To turn it on you must press up or down or how? At some point, it succeeds. […] As so many other things here in life, I will find a way to live with it, but it was also difficult for the residents to become accustomed to living in a modern dwelling."*

Resident 3 explains how she needed to get accustomed to living at the nursing home: *"Beforehand I lived for five and a half year at Aldbo (previous care facility) and now I have to get familiar with using an access card to get in and out*

and to using the elevator constantly. There is one new thing after the other in this place. Then there is this new lighting installed, I think it is a radical change."

The residents referring to their previous homes, such as the quote above, could be caused by the institutionalization and modern technology that makes it difficult to feel truly at home. Jacquelyn Frank [in 29] argues: *"Elderly persons who move into life care facilities do not automatically feel at home in their new living arrangements. Frequently, the cause for this discomfort is the physical environment: it is too institutional and too unlike their former homes"* (p. 166). Vacher [18] argues that the notion of home is strongly related to a space that residents are in control of. Thus, the loss of control characterizes a movement away from home.

This feeling of home is seen through the residents' affection towards their own lamps and lighting fixtures, as exemplified by resident 3: *"If you take my lamps from me then I will move home".* The residents' own lamps neutralize the perception of institutionalization, even though in some cases the lamps were not even connected to the electrical plug points.

Analysis of the ethnographic observations from case 2 indicates that the implementation of CRL had a self-perceived negative and disrupting effect on patients and staff, particularly for those patients who were in mid-treatment and moved into the new buildings directly from the previous facility. Patients that entered the facility later in the process had fewer negative comments and were observed to have an apparently better adaptation to the system.

Technical issues in the initial phase often resulted in negative comments related to the autonomy of the system, the lack of on/off switches and thus lack of control over their private areas. ED patients are sensitive to losing control [30] and the dynamic lighting that was "prescribed" in the entire building triggered complaints, such as some patients felt that lighting levels should be a matter of personal choice.

However, the patients were observed to become generally more positive towards living in the building and the dynamic lighting system (CRL) during the trial. Although this was empirically observed in social activities, talk and inter-group dynamics, no bio-data or questionnaires showed any positive change in anxiety levels [26].

4.3 The Influence of Staff on Residents' Acceptance

In case 1, the interviews and observations showed that the residents' attitude towards the light, and thus their process of acceptance, were affected by the staff. The interviews with the staff uncovered that as a part of their work routines they strived to maintain a positive attitude and good atmosphere, because this affected the residents' behavior. This relationship was particularly observed with those residents suffering from severe dementia. These spent most of their day in the common area and were highly dependent on the staff for daily tasks and navigation, compared to the less frail, who spent most of their day in their private spaces. Because of the staff's positive attitude and reactions towards CRL from the very beginning, it was observed that this group of residents was more tolerant of the CRL being implemented. The difference in how the lighting was accepted can thus be prescribed by the degree of autonomy, and independence from staff. In general, the staff attempted to encourage the patients to keep the lighting on as much as possible, with the exception of those patients with special needs. Despite the staff's encouragement, the frail elderly who were interviewed showed skepticism and negativity towards the lighting.

In case 2, it was observed that the patients reacted strongly to the attitudes of staff in the facility. The new digital systems and dynamic lighting were on several occasions overridden to meet the wishes of patients, for example by not having dynamic lighting in their personal rooms. When the CRL system was turned back on, this was not always supported by the staff, affecting negatively patient attitudes towards the CRL.

In spite of several introduction courses, pamphlets and informal meetings, technical errors in the initiation phase and the implementation of the CRL led to misunderstandings in the staff and patient groups, resulting in an overall negative mood in both the patient and staff group. The patients in the facility were observed to have very close relationships with some members of the staff, creating a strong connection of security and trust. For this reason, the pre-implementation education of staff is considered highly important, so that they can support patients during the transition to the CRL. Investing time and resources in informing the residents several times during the study and during changes between intervention and control period should be considered in future projects, in order to potentially reduce the negative experiences related to the implementation of the lighting.

Observations in case 2 showed a difference between the patients that moved into the new building as "first movers" and patients that entered later in the process. Where the CRL caused disruption to begin with, a more harmonious adaptation was observed later in the trial. In the first phases, where the dynamic lighting was tested and calibrated, the patients and staff were heavily affected by technical issues, creating a difficult work environment for staff, and simultaneously causing impatience and anger from patients.

Nightshifts and sleep disturbances in residents

The observations and interviews with the staff indicated that the lighting not only affected the residents but also affected their working routines. For example, the night-shift workers had observed a reduction in nocturnal activity among the residents with a severe degree of dementia between control and intervention period. Prior to the installation of CRL, the night-shift workers emphasized during interviews the frequent issue of residents' nocturnal wandering, where staff found the residents walking in the hallways or being seated in the common area at night. During the

intervention period of the CRL, nightly wandering was not reported (8 weeks in total) at all, corroborating previous research, which has shown that circadian entrainment has a significant effect on sleep quality, PSQI scores, agitation behavior, time spend out of bed, daytime napping and sleep efficiency in elder residents with moderate to late-stage of Alzheimer disease and related dementia [14], [15], [31]. Therefore, a probable effect of CRL can be found in measures of the staff / caregiver's workload and stress levels; that is, where lighting affects the residents and patients' behavior, it will also affect staff working routines and consequently their quality of work, as also indicted in a newer research study [8].

5 Conclusion

Although CRL has well documented health related effects in the laboratory, challenges can emerge during implementation of CRL programs, relating to acceptance, adaptation, and usability of the technology. These are issues, which need to be carefully addressed by lighting designers and decision makers when implementing lighting solutions that stimulate circadian rhythms. It is relevant to consider how the increasingly common inclusion of CRL in health care facilities may be perceived by the residents / patients and how disruptive effects may be minimized, in order to optimize the benefits of CRL.

While both the studies showed entrainment effects of CRL, these effects were not all positively perceived by patients and staff. When implementing CRL in facilities where the patients live permanently or for a longer period, it can be reasonably anticipated that its introduction will influence the everyday routines of patients and staff. While this influence is an intended effect of CRL – namely the entrainment of 24-hour biological rhythms, with ensuing positive benefits for health - it can also be experienced negatively as an unwanted disruption by both patients and staff. This poses the question of whether the design of luminaires and software programs for circadian entrainment should prioritize that of evidence-based practice or focus on the comfort of the occupants, including staff. This is particularly of concern in the implementation phases, where disruption effects are most likely to be experienced.

Observations from both cases indicate that the participants displayed difficulties in accepting the change of routines and habits entrained by the CRL. Firstly, the installation of the lighting affected the patients' everyday routines, as their daily routines adjusted to the automated light and dark programs. Secondly, the implementation of the lighting challenged the everyday work-routines of the staff, particularly as the automatic nature of the lighting, without the possibility of personal control, was experienced as a reduction of both staff and residents' independence. As discussed above, CRL is not only beneficial for the patients and residents but has promising effects on staff's working routines and health, as a direct circadian stimulus in reducing sleep disturbance in patients.

Communication with staff should be prioritized in future projects which implement CRL to create better transitions for the patients to the new systems and lighting conditions. Future projects need to carefully consider this challenge when implementing circadian lighting in settings such as psychiatric and elderly care facilities.

While differing in many respects from lab experiments, CRL studies in the natural environments offer new perspectives on its implementation in the context of vulnerable and frail subjects, particularly where staff actively negate effects of translocation, disorientation, and lack of control. 'Being at home' is a continuous practice built up over a longer period, where a sense of control over one's environment is an important factor. This is especially evident for the elderly, where new technologies are often a radical and confusing change, making it difficult for them to feel truly at home. The future challenge is that of moving from a 'one size fits all' approach, toward integrating circadian lighting with personalized systems that allow for individual control and interactions, while maintaining the improvements to human health and wellbeing.

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