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Schledermann, Kathrine M.; Hansen, Torben Skov; Bjørner, Thomas

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Perceived visual comfort and usefulness of a circadian lighting system implemented at a nursing home

Kathrine M. Schledermann [1] · Torben Skov Hansen [2] · Thomas Bjørner [1]

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Abstract

This study is an investigation of how staff working at a Danish nursing home experienced, perceived, and used a circadian lighting system that has been operating since 2018. The purpose of the installed circadian lighting was to improve the staff and residents' health and well-being. This paper demonstrates the importance of training and introducing the staff to the lighting system, especially operating, and maintaining a prolonged desired utilization of the system. In this study, we employed an action research methodology that included interviews, observations, and a questionnaire. We investigated 42 staff members' perceived visual comfort with, satisfaction with, perceived ease of use, and perceptions of the usefulness of the circadian lighting. Mixed methods proved valuable in the subjective assessment of light and visual comfort. We present an alternative card sorting method to study perceptions of a 24-hour lighting system. The findings revealed that the staff considered circadian light as satisfactory and a more adequate light for work than the existing lighting system. The staff considered being able to adjust the light important for maintaining visibility, setting the lighting depending on the activities, and meeting residents' needs. Furthermore, the results showed that a thought-out strategy to introduce the staff to the new lighting can be important for satisfaction and prolonged use of the lighting. Lastly, we also found that the circadian lighting system can improve the caregiver burden for night shift workers.

Keywords Circadian lighting · Visual comfort · Perceived usefulness · Action research

✉ Thomas Bjørner
tbj@create.aau.dk

Kathrine M. Schledermann
kmsc@create.aau.dk

Torben Skov Hansen
tsh@chromaviso.com

[1] Department of Architecture, Design and Media Technology, Aalborg University Copenhagen, Copenhagen, SV, Denmark

[2] Chromaviso, Health promoting Lighting, Aarhus, Denmark

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1 Introduction

The effects of environmental quality in indoor environments and occupational spaces on human well-being and health has been of increasing interest over the last decade [1, 3, 31, 40]. The growing interest in studying health-care environments, including lighting, can be explained by increased awareness of the effects that indoor environments have on staff and patients' health outcomes and psychological well-being [29]. Moreover, investments in better indoor environments and in smart welfare technologies are considered to increase quality of life and quality of care [9]. To date, studies on circadian lighting have largely focused on physiological effects and photometric measures, and they have mostly been conducted in laboratory settings, where the lighting is carefully controlled. Researchers recognize the need for field studies of well-being and health [16] in health care environments [33], where lighting potentially has significant effects. The number of field studies published in health care environments is growing steadily [7–14, 16, 17, 20, 28, 30, 31, 36, 37, 40]. However, these studies do not discuss or identify the complexity of implementing lighting systems intended to stimulate circadian rhythms in real-life environments such as hospitals and elder care facilities that involve dynamic and sometimes hectic practices, as well as a wide range of functions and patients, and where the lighting is not the staff's main priority. Nor does the previous work address long-term practices (e.g., adaptation, behavior, acceptance). The changes in the lighting practices that take place over the period of use can be valuable for informing the design of future lighting installations.

The paper aimed at shedding light on 1) staff's experiences with working in a circadian-lit environment, 2) the use of light in every practice during various times of day and as explored through perceived visual comfort. The study's research question was as follows: How do day, evening, and night shift staff experience and use a circadian lighting installation in practice? Based on research demonstrating that lighting has a significant effect on residents with dementia, it was hypothesized that night shift staff in particular would experience an improved job satisfaction. To our knowledge, previous studies on lighting for staff has to a large extent been conducted in office environments or in hospital setting [5, 8, 20, 22, 40]. Thus, the novelty of this study is the context exploited and the specific target audience of the eldercare housing staff. This paper is an extended version of the original paper that was published in the proceeding of the conference on Information Technology for Social Good [38]. This extended paper differs from the original paper by presenting 1) new graphs and illustrations that reports the lighting condition, 2) an elaboration on result and discussion section, and 3) field-notes from observations that support or illustrate findings.

2 Related work

Occupants' experience of light and space (e.g., perceived visual comfort and light appraisal, user satisfaction, lighting control) has been studied extensively in daylight conditions and office environments [7, 10, 22, 31, 40–42]. These studies found that respondents who perceived the lighting in their office space as being of higher quality rated the setting as more attractive. Respondents who reported higher satisfaction with lighting were also happier and more satisfied with their work environment [41]. Satisfaction with work environments is connected to occupants' general well-being (e.g., fatigue levels, sleep quality), productivity, performance of tasks (e.g., frequency of errors), and efficiency, in which lighting plays an

important role [8, 14, 16]. In addition, lighting systems designed to regulate the timing of circadian rhythms in humans and ensure exposure at the proper time of day have positive non-visual effects on sleep patterns, depression, anxiety, activity levels, and fatigue [17, 20]; they also reduce restlessness and alertness and exert calming effects on elderly persons with dementia [15, 16, 26, 28, 36].

Lighting systems that affect biological (non-visual), visual, and behavioral (psychological) responses are referred to by several terms. Among the most common are human-centric lighting, circadian lighting, 24-hour lighting scheme, and integrative lighting [25]. Due to its profound health-promoting effects on patients and staff with few documented side effects, circadian lighting has become increasingly popular in hospitals and elder care facilities as a welfare technology and nonpharmacological treatment option [17, 43]. However, as mentioned previously, field research studying visual comfort and user satisfaction in real-life health care environments is limited [17, 30]. The lack of research in this field could be due to the difficulty of studying lighting conditions in real-life situations in which it is challenging to isolate the variables and factors of effect [29]. Moreover, field research can be more costly and time consuming, and there can be difficulties related to access and ethical issues [6].

3 Context and light settings

The selection of the nursing home described in this paper was based on pragmatic grounds and criteria, such as availability, time, season, and physical access to the case and respondents. The Danish nursing home is located in Copenhagen and specializes in working with residents with dementia. There are 48 apartments divided among six houses (lettered A-F). Staff supervise the nursing home at all times. It is home to senior residents with various degrees of dementia, who depend on assistance from staff for daily activities such as eating, going to bed, and performing general hygiene tasks.

In 2018, Chroma Zenit (Chromaviso, Denmark) a 24-hour circadian lighting system was installed at this nursing home in the hallways, staff offices, shared bathrooms, kitchen unit, dining room, and television area. Besides the Chroma Zenit system, the common areas in the houses are illuminated by daylight entering from skylight windows and regular vertical windows. In addition, the circadian lighting was installed in four residential apartments at the same time. In this paper the lighting installation will be referred to as Chroma Zenit and Circadian Lighting.

The lighting consists of LED-based luminaires (consisting of individually controllable LEDs) that follow a dynamic lighting scheme with manual override options. Chroma Zenit is designed to regulate the circadian clock's timing for elderly residents and staff members, and it has documented positive effects on, for example, sleep, fatigue, depression, delirious behavior, and nocturnal disruptions [43]. A quasi-randomized clinical control trial including 71 apoplexy patients, of which 39 were exposed to a Chroma Zenit lighting scheme during admission to a neurorehabilitation unit at a Danish hospital, showed significant effects on post-stroke depression and anxiety and improved well-being in general, compared to the control group [43].

The Chroma Zenit lighting system operates automatically and follows a predefined scheme (Fig. 1) with sunrise at 07:00 and sunset at 22:00 (starting and ending at 1800 K). Figure 1 shows a lighting scheme of a 24-hour correlated color temperature (CCT) distribution in dining areas, offices, and hallway at the nursing home. During the morning, the light brightens

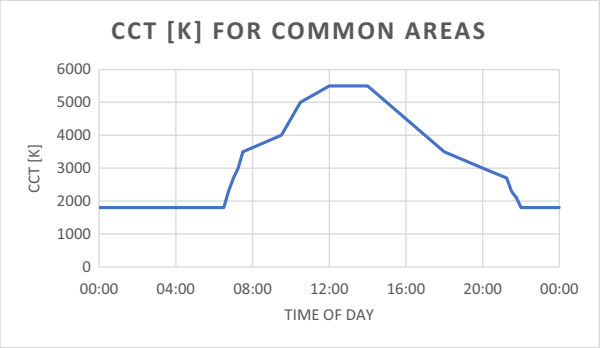

Fig. 1 Lighting scheme of a 24-hour CCT distribution for common areas

continuously in intensity and CCT (correlated color temperature) until it peaks around noon reaching 5500 K and ocular melanopic EDI at typically 323 lx.

From 14:00, it dims in intensity and CCT during the afternoon until nighttime. In the four apartments that is fitted with Chroma Zenit, after 22:00, the lighting dims down to 1800 K (Ocular melanopic EDI at typically 0.8 lx.) as default (as seen in Fig. 2), unless it is manually switched off. This is designed in case the residents want a bit of light throughout the night for e.g., wayfinding to the toilet or for reassurance. In the hallways, common areas and staff offices, the lighting remains static at 1800 K CCT (Fig. 1) throughout the night until it repeats the dynamic loop in the morning. The below Fig. 2 shows the lighting scheme of a 24-hour correlated color temperature (CCT) distribution in residents' apartments at the nursing home.

At night, the light spectrum contains less than 1% of the energy below 520 nm, which is mainly the blue wavelength domain. As a result, the light is perceived as amber (see Fig. 3). The nighttime light spectrum is designed this way to avoid disturbing the sleep and circadian rhythm, including the production of melatonin by the occupants during that period. The lighting profile at night is also designed to inform the elderly residents who is awake, that it is night. Moreover, it is designed to be perceived as comfortable for night shift staff to work in.

Besides the cyclical lighting scheme, staff can choose a set of lighting scenarios in the common areas e.g., the dining area and the television room. These lighting scenarios (Fig. 4.) are installed to enable the staff to change the lighting to support various activities such as social

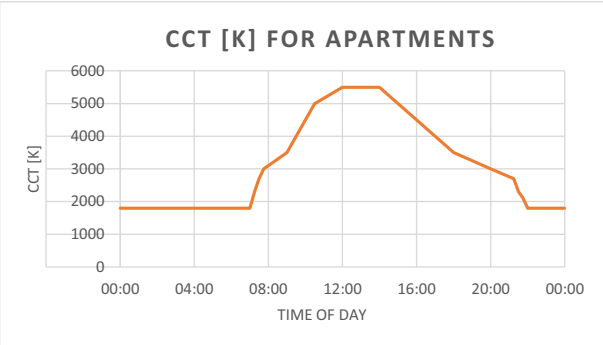

Fig. 2 Lighting scheme of a 24-hour CCT distribution for apartments

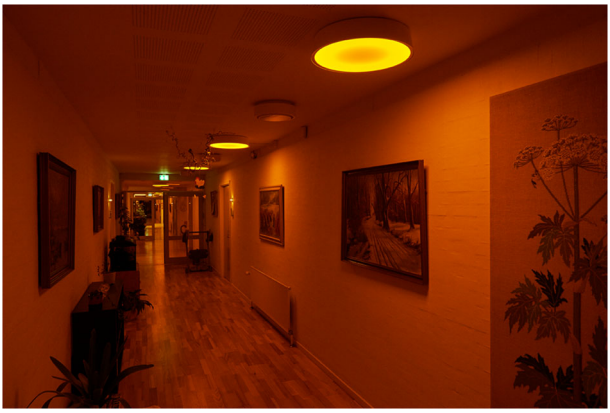

Fig. 3 Hallway (at 21:48) illuminated by Chroma Zenit

events arranged by staff or television viewing. The light control has five possible scenarios (Fig. 4): Circadian lighting (left top corner), bright light (top right corner), activity (left side mid), cozy - the Danish word "hygge" (right side mid), off (bottom left corner), and a dimmer option for illuminance level (bottom right corner).

The lighting is operated using a panel engraved with icons that symbolize the scenarios. The lighting in the hallway and in the apartments was controlled using white switches without icons to hide them from the elderly residents.

4 Methodology

This study applied an action research approach [4] to lighting. This means that we aimed to produce knowledge that can be used in practice (i.e., knowledge that can be applied when evaluating lighting installations with the aim of improving lighting conditions and work environments for occupants). Moreover, the study applies the theory of Technology Acceptance Model (TAM), that focus on predicting and explaining use of technology within four variables of perceived ease of use, perceived usefulness, behavioral intention to use, and actual

Fig. 4 Lighting control with five possible scenarios

use (TAM2) [23], and has been applied to healthcare settings. The action research was conducted from September 2020 to January 2021.

4.1 Participants and ethics

The participants consisted of 42 staff members (35 women, 6 men, and 1 other) out of 51 employed by the nursing home. Of the 42 staff members, 26 had more than three years of experience, and 32 were employed as social and health care assistants. In total, 21 staff members worked on day shifts, whereas 18 worked evening shifts, and 4 worked night shifts. The staff had fixed working schedules. Twenty-five participants reported using glasses or contact lenses.

The staff who participated in the interviews and observations were recruited by the manager of the Nursing home based on a predefined set of criteria. The manager was asked to select 10 employees: three day shift workers, three evening shift workers, and four night shift workers. The staff who were included in the study were Danish speaking full-time and part-time employees who had worked at the nursing home for more than 2 months at the time of inclusion. Excluded from the study were hourly employees and participants who worked fewer than 80% of their shifts at the nursing home. Participants with known eye diseases were also excluded.We followed the Standards for Reporting Qualitative Research (SRQR) [34]. Prior to participation, all participants completed an informed consent form that included the right to withdraw at any time, the right to refuse to answer the questions, and a guarantee of the participants' anonymity. All participants were provided with anonymized ID numbers. The participants' personal information was kept encrypted in a database that was separated from the other information used in the study. We applied special ethical considerations for access, permission, and data handling within the health care sector. This study received ethical approval (ID2021–020-00540) by an ethics committee at Aalborg University.

4.2 Materials and procedure

A mixed method approach was used consisting of interviews (n = 10), go-along observations (n = 5), and a questionnaire (n = 42). Ten staff members were recruited for interviews, which had a duration of approximately 45 minutes. These were conducted in a meeting space equipped with the circadian lighting system. The interviews were recorded using a Dictaphone [Olympus LS-P1] and stored on a secure server. During the interview one probe was introduced. First, a card sorting exercise was performed to facilitate mutual communication about lighting and visual comfort and to gain insight into how the staff perceived the lighting. Twelve laminated cards were designed with an equal number of positive and negative words. The words described different lighting attributes, and the choice of words was inspired by [19, 36] (see Fig. 5 for description of words). The participants were asked to select the cards they thought best described the current lighting in their workspace (i.e., the current lighting situation during the interview). They were instructed to pick as many of the cards as they wanted. Once they had chosen the cards, the participants were asked to place them in front of themselves on the table. Thereafter, the interviewer asked why they had chosen the specific cards and which cards they would select if it were another time of day, such as evening compared to early afternoon. The cards' arrangement was photographed and labeled with an ID number. The cards as shuffled between each interview, and the words displayed on the cards were first revealed when the instructions for the exercise were given.

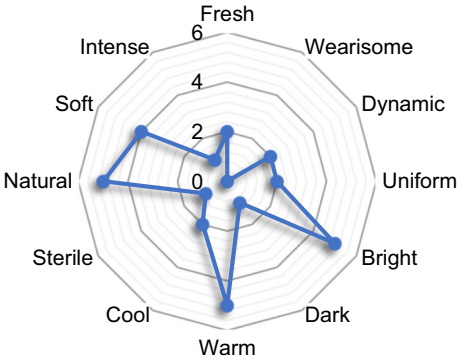

Fig. 5 Perception of the circadian lighting, interview card sorting (n = 10)

Five go-along observations were collected during the period of study: one morning observation, two evening observations, and two-night observations. It was agreed beforehand based on convenience whom the researcher should shadow while working. The focus of the observations was to capture the interactions and use of light. The observer focused on the events that occurred and did not note any personal information about the residents. One observation was collected prior to the first interview to inform the interview guide. The observer was careful to avoid being intrusive in the work and maintained a passive level of involvement [4].

Questionnaires in printed format was distributed on January 26, 2021. The questionnaire was distributed after a sales representative of Chromaviso held a follow-up introduction about the lighting application. The questionnaire was inspired by TAM and prior questionnaires on visual comfort and satisfaction (i.e., [2, 29]) and included the following topics: implementation, usefulness, usability, and experience of the lighting. The questionnaire consisted of 30 items and a used five-point Likert scale.

4.3 Data analysis

The questionnaires were analyzed using cumulative frequency. The interviews were analyzed using traditional coding [4] via the following four steps: organizing, recognizing, coding, and interpretation. The interviews were transcribed verbatim to be organized and prepared for data analysis. The transcripts were read several times by two researchers to recognize the concepts and themes, which also included a general sense of the information and an opportunity to reflect on its overall meaning. The researchers then coded and labeled the data in categories and subcategories using Nvivo12, followed by interpretation.

5 Findings

5.1 Light practice

Staff members were asked how often they use the circadian lighting settings. Eighteen participants replied "weekly", 15 replied "daily", 6 replied "monthly", 2 replied "rarely", and none replied "never". In the apartments equipped the circadian lighting, the researcher observed how staff changed the lighting during wake-up time. While performing his work, a staff member explained that when he wakes up elderly persons, he sets the soft lighting on to

gently indicate that it is time to wake up. Thereafter, however, he switches it to a brighter light to indicate that it is time to get up and to ensure that he can see what he is doing. In addition, almost all staff members perceived it as very important to be able to adjust the circadian lighting according to different activities:

> "I adjust it [the light] so I can see the resident. As I explained, it is important to have some light here so I can see if there is something wrong with the resident. To be able to see them is probably important to me, so I know if there is something I need to react to, or that I might have missed if the light wasn't turned on. In this way, it is very important for me to see the resident. Umm…also, when I need to help the resident to the toilet, so to speak, the lighting gives them some extra security, which also helps them to see properly." (ID 5, night shift)

On one hand, being able to have proper lighting for performing work assignments, providing care, and having visibility for inspecting residents was important to the staff. On the other hand, the ability to adjust the illuminance and CCT according to the desired atmosphere during activities such as watching television in the living room, doing creative tasks at the tables, or participating in seasonal activities was also important. This was especially articulated by evening staff:

> "Because you could say that it is this time [evening] when, until they [the residents] need to go to bed, they are seated in the living or dining area. It becomes homely when we can dim the lights and set some cozy lights." (ID 9, evening shift).

5.2 Subjective lighting assessment

The words chosen most often to describe the circadian lighting were "naturalistic," "warm," and "bright". Each was chosen five times during the card-sorting exercise (Fig. 5). The second most chosen term was the word "soft," which was selected by four respondents.

The word "naturalistic" related to diurnal changes in illuminance and correlated color temperature. As expected, "warm" was used in relation to "soft" to explain the lighting during the early morning hours, late evening, and night. For instance, a night shift worker referred to visual comfort while explaining her choice of "warm" as follows:

> "I think it is warm because it [the lighting] changes to a warmer yellow color, not that white, sharp one. Thus, I also find it soft, like, you know, for the eyes. You don't get discomfort in your eyes by looking at it, and it is pleasant to be in." (ID 4, night shift)

These choices were also evident in the questionnaire, in which 22 of 40 respondents rated the lighting as natural (Q1, Table 1, SD = 1.53; M = 2.35). In addition, independent of shift type, the staff seemed to agree that the lighting was not artificial (17 = no extent and 13 = low extent, Table 1), and only one staff member perceived the lighting as sterile (Table 1).

The lighting was not perceived as wearisome or boring. However, when asked about the color temperature (e.g., cold, or warm) in the questionnaire (Table 1), the respondents exhibited no clear tendency in their answers. For warm color temperatures, a broad dispersion in answers was evident (SD 1.74; M = 3.03)(Q5, Table 1). This might have occurred because the staff members work at different times of day. Negative words such as "wearisome," "sterile," "dark," and "uniform" were chosen only 0, 1, 1, and 2 times, respectively. However, the interviews revealed that the words could have a double meaning. For example, the

Table 1 Perception of the circadian lighting from the questionnaire (n = 42)

1=No extent. 2=low extent. 3=Neutral. 4=Moderate extent 5=Greater extent	1	2	3	4	5	Total	Mean	SD
1. The lighting is natural	2	4	6	22	6	40	2.35	1.53
2. The lighting is artificial	17	13	7	2	3	42	3.93	1.98
3. The lighting is invigorating	2	8	13	9	7	39	2.72	1.65
4. The lighting is boring	23	8	5	2	3	41	4.12	2.03
5. The lighting is warm	8	4	8	11	4	35	3.03	1.74
6. The lighting is cold	22	3	6	4	1	36	4.14	2.03
7. The lighting is powerful	12	6	13	5	2	38	3.55	1.88
8. The lighting is weak	19	4	8	3	1	35	4.06	2.01

interviews showed that the respondents used the word "bright" both positively and negatively. They connected brightness to visibility and being able to perform tasks. One respondent, when asked in the interview whether she used the word negatively or positively, stated,

> "No, I think it is good. It is bright—that is, you can see what you write on the computer or on a piece of paper." (ID 8, evening shift)

However, "bright" was also used negatively. ID10 connected it to seasonal changes:

> "At this time of season, for example, it does not match the darkness of the season, and I think it glares. I think it is too bright. It is difficult to make certain spaces cozy, like in the television room in the evening." (ID10, evening shift)

Furthermore, three out of four interviewed evening staff members expressed a dissonance between the time when the lighting starts to dim and transit from evening to night light and the time when the residents go to bed. Observations of their evening showed their meal started at a fix time at 18:00, where the residents were gathered the common area. And most of the residents were assisted back to their home for a night's sleep at 20:00 and no later than 22:00. The staff all expressed a need for the lighting to dim at the beginning of the evening. As ID10 stated, "They [residents] have not experienced when it dims, and especially not at this time of year, where the light dims right or becomes darker." Here, ID 10 refers to the shortening of the daylight minutes during the winter.

5.3 Light satisfaction

The staff at the nursing home perceived a very high satisfaction with the new implemented circadian lighting at their workplace (Q 2.1-Q2.6) Q2.1: SD = 2.01; M = 4.05 (Table 2). Twenty-two participants agreed that the lighting was comfortable to work in, and 19 strongly agreed when asked whether they perceived the circadian lighting to be valuable for them and the residents living at the nursing home (Q2.2, Table 2). Further, there was also high perceived satisfaction for doing specific work tasks in circadian lighting (Q3.1-Q3.3, Table 2). An interesting part of these positive assessments is that previous studies reported that staff workers who perceive lighting positively, also recognize visual comfort and perceive the atmosphere as more attractive [5, 42]. The positive perception of the lighting also led to better mood, higher work satisfaction, and greater overall engagement in their work [5, 42]. In spite that we have positive feedback for well-being scorings (Q41.-4.4, Table 2), we do not have evidence for the causality to the implemented circadian lighting system.

Table 2 Cumulative frequency of answers from questionnaire (n = 42)

1=Strongly Disagree. 2=Disagree. 3=Neither or disagree. 4=Agree. 5=Strongly agree	1	2	3	4	5	Total	Mean	SD
1. Before/ After the introduction								
Q1.1: Before the introduction I knew how the circadian lighting works	3	4	7	15	11	40	3.68	1.92
Q1.2: After the introduction I know how the circadian lighting works	1	0	5	16	19	41	4.27	2.07
Q1.3: It makes sense for me when and where the circadian lighting can be used	0	2	6	18	15	41	4.12	2.03
2. Workplace								
Q2.1: In general, I am satisfied with the circadian lighting at my workplace	2	2	4	17	16	41	4.03	2.01
Q2.2: I perceive values in the circadian lighting for both me and the residents	1	2	3	17	19	42	4.21	2.05
Q2.3: The circadian lighting is easy to use	0	1	5	21	15	42	4.19	2.05
Q2.4: It is comfortable to be and work in the circadian lighting	0	0	6	22	14	42	4.19	2.05
Q2.5: It is important that the circadian lighting is adjustable according to different work situations	0	1	7	18	16	42	4.17	2.04
Q2.6: I perceive the circadian lighting as a normal part in my everyday work	1	1	4	23	13	42	4.10	2.02
3. Perceived circadian lighting experiences								
Q3.1: I can read, write, and perform tasks in the current lighting	2	0	4	27	9	42	3.98	1.99
Q3.2: The lighting is suited for computer work	3	1	4	26	8	42	3.62	1.90
Q3.3: I often experience that the lighting does not work as it should	1	10	5	14	12	42	3.62	1.90
4. Well-being								
Q4.1: I feel sleepy and tired during my shift	9	16	10	3	4	42	2.45	1.57
Q4.2: I have difficulties being concentrated during my work	12	22	3	1	4	42	2.12	1.46
Q4.3: I have difficulties remembering work related tasks	12	19	5	2	4	42	2.21	1.49
Q4.4: I have tired eyes and eye irritations when I get home from work	0	4	5	6	7	22	3.73	1.93

The staff also appraised the circadian lighting clearly in the interviews. For instance, they expressed higher satisfaction with the circadian lighting compared to the dimmable white lighting installed in the residents' apartments:

> "It is much better than the light they have in their apartments […] the lamps on the walls, and the like. They are not really good for working, not for cases where you need to inspect a wound or something else up close." (ID 10, evening shift)

As ID 10 exemplified, the staff found the lighting inadequate for work tasks that required inspection of a small area, and the evening staff's satisfaction was linked to the visibility the lighting provided. In addition, the staff spent excessive downtime finding the right level of light in the apartments that were not fitted with circadian lighting. This problem was exemplified during a night shift (starting at 04:15) when a staff member had to change a resident's diaper. We walked into the apartment, where the staff member turned on the light using the switch to the left of the main door. The light turned on dimly. Then she walked to the bathroom, turned on the lighting, found the items she needed (e.g., diapers, washcloths), moved to the resident's bed, put down the items, and walked back to the main door, where she adjusted the light again. She said she needed more light. She pressed the switch a couple of times and held it down for a while. The lighting dimmed, increased in intensity, and then dimmed again. She said that she was trying to find the right setting that was not too sharp and was comfortable for the resident. She gave up and continued her work.

The staff also expressed their satisfaction when asked to describe the lighting that was installed prior to the circadian lighting.

> "It was more, like, powerful [referring to the old light]. You know, I have never had issues with light and never had a headache though after the new [light] arrived that, like, could change color, I thought it was terrific for the eyes also. The other [light] was really such a white, much sharper light, you know." (ID 4, night shift).

5.4 Perceived ease-of-use and usefulness of Chroma Zenit

The new lighting system was perceived as easy to use (Q2.3, Table 2), and with no major differences within different shift work (Fig. 6).

Overall, the questionnaire results revealed that the circadian lighting was perceived as easy to use, however it was repeatedly observed by the researcher during the period of study that at night, that the lighting where set to different settings of the common hallway that connected all residents' houses (Fig. 7).

This resulted in the middle section of the hallway were lit more brightly, whereas the rest were lit in the warm 1800 K night light. When asked about this, the staff who worked night expressed no knowledge about how to control the lighting in the hallway. This might be a result of blank lighting controls, and a substantial substitution in staff since the installation and introduction to the circadian lighting initially took place in 2018.

5.5 Workload and nocturnal activity

Satisfaction with the lighting was also visible in the workload described by the staff, as the lighting has an indirect effect on the residents' nocturnal activity. Four night staff and two

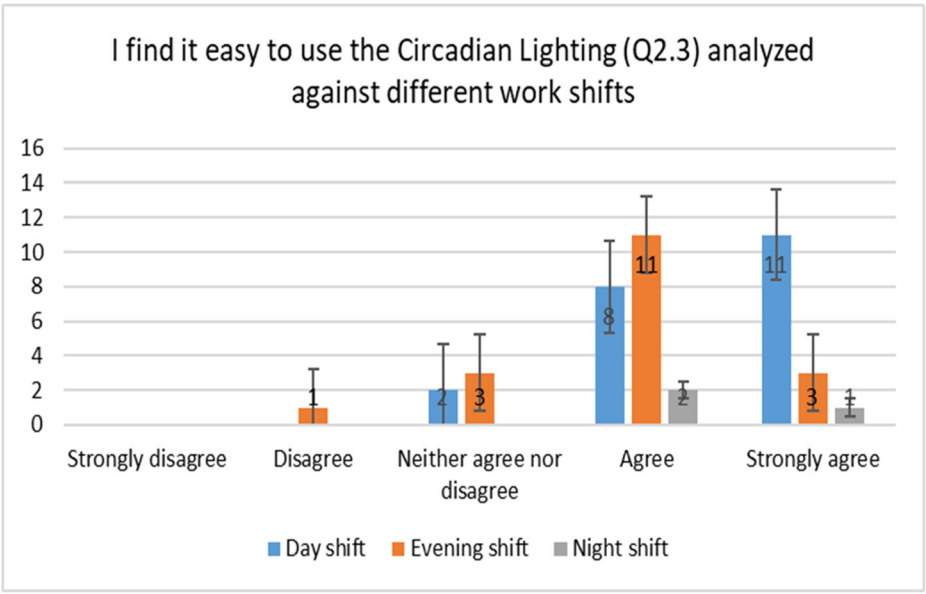

Fig. 6 Perceived ease of use of the circadian lighting for different work shifts (n = 42)

Fig. 7 Observed light phenomenon in the main hallway at night, where the lighting is set to two different settings

evening staff articulated their observations on nocturnal activity. Two members (ID 8 and ID 5) explained how the circadian lighting, compared to the past lighting system, does not invite the residents to wander away from their apartments:

> "It is clear that if somebody wakes up and looks outside, then it is of course bright, and this might invite to them to walk out. Today, when some of our residents look out, then it is dark, and they might think, 'Huh, it is dark,' then turn around and walk back inside." (ID 8, evening shift)

All four staff who were permanent night shift workers stated they had experienced a significant reduction in nocturnal activity compared to before circadian lighting was installed:

> "We experienced, prior to circadian lighting, a lot of nocturnal activities among the residents, but after circadian lighting was installed, it steadily decreased. It was not, how should I put it, obscene that we on a regular night had fourteen people who were awake

at some point during the night. […] It was a lot of walking around to find them, but after the circadian lighting it is calm and steady, with only one regular night wanderer" (ID 5, night shift).

Elderly with dementia, such as the residents in this care home, are known to have disturbances in their sleeping pattern causing e.g. nocturnal wandering and sundown syndrome, where previous studies have reported a positive effect on sleep when employing dynamic lighting (e.g. lighting that imitates the natural daylight) as a nonpharmacological treatment [12, 13, 27, 28, 35]. Similar to the experiences of the staff that was reported in this study, previous studies have addressed how reduction in nocturnal activity can decrease the caregivers' burden and workload, which in turn can increase job satisfaction [16, 18, 28].

6 Strengths and limitations of the study

In this Danish nursing home, most of staff had knowledge about the system before, as Chromaviso held a presentation shortly after the installation of the lighting in 2018, instructing the staff on how to use the new lighting. This can explain the high number of staff that knew how the system works before the second instruction in January 2021 (that was based on input from this study), but also the higher number of staff that knew how the system works after the introduction; and already at this early stage of implementation made sense of how to use it. This study demonstrated that qualitative methods can be useful to identify what factors of the lighting were important for the participants. The interviews showed how card sorting, as a method to assess the lighting situation, was useful to understand the respondents' perception of the light. We can conclude that card sorting can be valuable to uncover similarities and diversities in end users' experience of the lighting. Furthermore, structured qualitative card sorting is a valuable method for encouraging participants to talk about the rather abstract topic of a circadian lighting system's usefulness within the context and experiences of their work environment. These experiences would otherwise be difficult to capture in a laboratory setting. However, card sorting is not a stand-alone method and should be supported by other methods to uncover the participants' underlying perceptions of the attribute (e.g., positive, or negative) and why the participants experienced it in a particular way. Previous studies have addressed the challenge of collecting subjective data of a luminated environment [2, 10, 19, 22, 37, 39, 41]. Houser and Tiller [24] stressed the important to give clear and detailed instructions about the judgement of rating scales when conducting e.g., semantic differential scale with participants. In our study, the participants were informed that they could choose as many cards as they found matched their experience of the light. Although this gave a broad variety of answers, it also resulted in inconsistency related to number of cards chosen. Moreover, we noticed that participants sometimes asked if they could choose more cards after the first card had been selected. To mitigate this, future work should consider whether a fixed number of cards to choose from would be more ideal. We conclude that, the method has potential to be developed and tested further within lighting conditions. For example, it would be interesting to compare the light attributes with different types of shifts and across multiple cases. Future work is needed to create significant evidence of and insight into eldercare housing staff's comfort and well-being with their use of the circadian lighting system. These factors should be considered in relation to non-image forming (NIF) effects including light spectrum, the intensity, timing, and duration [25]. First, researchers need to include a much larger number

of nurses across hospital wards and/or nursing homes. Second, they need to collect additional identifying details about the nurses with a potential focus on evening and night shift workers. Third, there is a need for longitudinal studies that include well-defined data obtained through repeated measurements over time. This study demonstrates how light is experienced and used two years after its installation, thus it would be interesting to replicate the study in an intervention study with a baseline or control group or comparing it to another lighting system (such as [30]). This would enable tracking of the experience over time and to investigate how the circadian light system is adopted by the users from the beginning.

However, when researchers perform evaluations in very specific contexts with real users in a field context, it can be difficult to conduct a perfect research evaluation. Logistics, time constraints, gatekeepers, legislation, lack of a proper posttest, technical issues, and lack of resources can be barriers that prevent perfect evaluations. In addition, randomization is often impractical for evaluating a circadian lighting system in a fieldwork context.

This study included day, evening, and night shift workers, as this sample provided a general idea of the staff's experiences and needs at various times of day. Previous studies have frequently included night shift workers, as they are at the most risk of developing long-term illness, such as fatigue [20]. In this study, our participants had fixed shifts; therefore, researchers should consider rotating shift schedules in future studies. Last, using action research, we identified experiences that can be considered and applied in optimization and adjustment of circadian lighting design.

7 Discussion and conclusion

We set out to investigate staff's perception and experience of working with a 24-hour lighting schedule installed in a Danish nursing home. In general, the staff was very satisfied with the new circadian lighting system, and a vast majority agreed the circadian lighting to be valuable for them and the residents living at the nursing home. We concluded that staff expressed high satisfaction with the circadian lighting system in their workspace and comfort working with it, compared to the rooms without circadian lighting. Although we did not document circadian lighting's effects on residents, the staff's perceived improvement in the residents' sleeping patterns indicated a potential positive spillover effect on the staff's well-being and job satisfaction.

The participants reported to be highly satisfied with the circadian lighting; though, being able to adjust the lighting was perceived as important for the staff in this study when the circadian lighting was considered inadequate for the activities taking place. Having control of the lit environment has also been reported in other studies [10, 21], with the same conclusion as within this study, and with the important perceived interrelation between the participants' satisfaction with the lit environment and access to lighting controls.

When implementing a new circadian lighting system, there could be gaps between the inherent value of the technology and the user's ability to put it to work effectively. Implementing technological change into an organization like a Danish nursing home, it presents a different set of challenges to both the management, and for the staff and residents that is going to use the new circadian lighting system in their everyday work life, such as the importance of having circadian lighting on as much of the day as possible to gain the beneficial health effects [37]. For instance, the staff expressed in the interviews, that they were not always keen to have circadian lighting switched on when the resident's watched television, as it was very bright,

and not very cozy. Therefore, a very important part of implementing this new circadian lighting system is to have a detailed and thought-out strategy (as demonstrated in this case) for how to introduce and teach the staff how to use the new system, to initiate acceptance and adaptation of the lighting. Including a strategy for introducing potential new staff members to the system after the installation has been in use. The circadian lighting is simple to operate once proper introduction and training is given on how to use it, and this could be an influential key to a successful implementation [37]. It is important not to underestimate potential confusion, difficult behavioral changes, or resistance from the users [32]. In the introduction it is important to provide not only the management, but also the staff with evidence-based knowledge about the technology, and to be very honest and transparent of what the technology can do (at the current stage/ development) – and especially what it cannot do. In this study it can be concluded that multiple instructions and dialogues with the end-users can have a positive influence a prolonged use and satisfaction towards the technology.

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