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Exploring the use of dawn and dusk simulation for better sleep and daily functioning among nursing home residents with dementia

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Exploring the use of dawn and dusk simulation for better sleep and daily functioning among nursing home residents with dementia

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Abstract

The current pilot study explored the use of dawn and dusk simulation (DDS) in order to improve the sleep patterns and the daily functioning of nursing home residents suffering from dementia. Dementia is a group of diseases that impairs mental functioning. As a side effect, this also influences the circadian rhythms of the elderly. The use of DDS was investigated to try to alleviate these symptoms, as well as the applicability of the used methods. The methods that were used in this study were DDS as the lighting manipulation, actigraphy to measure sleep/wake patterns of the participants and daily questionnaires filled in by the nursing staff to investigate daily functioning. The data gathered from the actigraphy and the daily questionnaires was analyzed qualitatively. The results showed that there were some small influences of the light manipulation on both the actigraphy variables and the daily questionnaire variables, but that the direction and the magnitude of the effect varied a lot between participants. Additionally, it was found that the use of DDS, actigraphy and daily questionnaires for this particular research population has some problems. The DDS was found to be difficult to set at the right times due to fragmented sleeping patterns of the participants, actigraphy was found to be relatively inaccurate due to false positives of sleep and the daily questionnaires were found to be too much to do next to the nursing staff's normal workload. These results provide a good insight on the use of DDS for this particular research population and which problems should be overcome in future studies.

Keywords: actigraphy, circadian rhythms, dawn dusk simulation, dementia

Introduction

Dementia is a group of diseases with a wide range of symptoms associated with cognitive decline ("basics of Alzheimer's disease", 2017; "Dementia", 2017). The core mental functions that could be impaired by dementia consist of memory, communication and language, ability to focus and pay attention, reasoning and judgement and visual perception. At least two core mental functions must be significantly impaired to consider dementia. Most types of dementia are progressive, meaning that the severity of the symptoms will get worse over time. The cause of dementia is the damaging of brain cells which interferes with the communication between other brain cells. The most prevalent type of dementia is Alzheimer's disease which accounts for 60% to 80% of cases (Fratiglioni and Rocca, 2001). Alzheimer's disease usually starts with difficulty remembering newly learned information. As it advances, the symptoms include but are not limited to mood and behavior changes, more serious memory loss and difficulty communicating. The second most prevalent type is vascular dementia which occurs after a stroke. In vascular dementia, the most common symptoms are confusion, disorientation, trouble speaking or understanding speech and vision loss ("basics of Alzheimer's disease", 2017; "Dementia", 2017). The symptoms caused by dementia are often accompanied with other problems such as sleep disturbances, changes in mood and changes in performance on activities of daily living (González-Salvador et al., 2000; Lee & Lyketsos, 2003; Purandare, Burns, Craig, Faragher, & Scott, 2001). At this moment, there is no cure for dementia. Because of this, it is important to find ways to alleviate the symptoms of dementia through other ways. In this study, we focus on the use of light to positively influence daytime functioning and circadian functions in demented elderly. Before we discuss the influences of light found on dementia thus far, we will start with a discussion of the influences of light on healthy humans in general.

The Influence of Light

The influence of light on humans can be roughly divided into two overarching categories, namely effects via image forming processes and the effects via non-image forming processes. These processes start when light enters the eye through the cornea, which is the transparent layer in front of the pupil of the eye. The amount of light that enters the eye is influenced by the size of the pupil. In bright light, the pupil contracts and becomes smaller, while at lower light intensities the pupil will become larger in order to let more light in. After the light has passed through the transparent vitreous humor, the jelly-like substance inside the eye, it will reach the retina. The retina is the location where light is absorbed and converted to electrical signals ('transduction') with the help of three different kinds of photoreceptors. These photoreceptors are the rods, cones and intrinsically

photosensitive retinal ganglion cells (ipRGC's). Each of these photoreceptors plays a different role in visual functioning, which will be discussed below.

The image forming processes are used to enable vision and let us see and experience the environment. This is done through the two classical photoreceptors, which are the rods and cones. Under dim light conditions, only the rods will be activated (scotopic vision). When the light becomes brighter, the cones will also be activated (photopic vision). This enables us to see color and see more detail. The cones are again divided into three different groups, each group enabling vision for a different color. These three groups consist of the short wavelength-cones (S-cones), the medium wavelength cones (M-cones) and the long wavelength cones (L-cones). These cones are sensitive to short, medium and long wavelengths, respectively (Boyce, 2003).

Image forming effects.

Image forming photoreception using the rods and cones has been shown to have an influence on both visual experience and visual performance. Sekuler & Blake (2002) found that lighting influences the ability of humans to detect and discern between, for example, fore- and background and between colors. In addition, Boyce (2003) and Rea (2002) found that a minimum light intensity, spectral composition and uniformity of light are needed in order to be able to recognize colors. Lighting could also cause people to experience a room differently. Boyce & Cuttle (1990) and Vogels & Bronckers (2009) have found that a room is viewed as brighter when a higher illuminance is used and that a lower correlated color temperature (CCT) could cause people to view the room as warmer and more relaxed. In addition to these influences, lighting also has an effect on visual comfort or discomfort. For example, low lighting will cause visual discomfort because it will prohibit people from seeing the environment correctly (Rea, 2000). Too high illuminances will also cause visual discomfort because of glare, which will also result in people not being able to perceive their environment correctly (Boyce, 2003; Rea, 2000). Next to the problems in perceiving the environment, too high illuminances could also have a negative effect on health. It could for example cause fatigue or induce a headache (Rea, 2000).

Non-image forming effects.

In contrast to influencing individuals' everyday functioning through the visual pathway, there are non-image forming (NIF) effects as well. These can influence a persons' mental and affective state, physiology and behavior. These effects are mostly regulated by a third photoreceptor that communicates with different parts of the brain compared to the rods and cones, along with a lower contribution by the rods and cones. This third photoreceptor is the ipRGC (Berson, Dunn & Takao, 2002; David-Gray, Janssen, DeGrip, Nevo & Foster, 1998; Foster et al., 1991; Freedman et al., 1999; Hattar, Liao, Takoa, Berson & Yau, 2002; Lucas, Douglas & Foster, 2001; Lucas, Freedman, Muñoz,

Garcia-Fernandez & Foster, 1999; Soni, Philp, Knox & Foster, 1998). These photoreceptors communicate with areas in the brain such as the suprachiasmatic nucleus (SCN; the biological clock) and the intergeniculate leaflet (IGL), which are connected to the regulation of sleep, alertness and mood (Gooley, Lu, Fischer & Saper, 2003; Hattar, Liao, Takoa, Berson & Yau, 2002; Hattar et al., 2006; Lucas, 2013; Schmidt, Chen & Hattar, 2011; Vandewalle, Maquet & Dijk, 2009). The ipRGCs are also most sensitive to a different part in the light spectrum than the rods and cones, namely to mainly blue light with a wavelength of around 460-480 nm (Dacey et al., 2005; Hattar, Liao, Takoa, Berson & Yau., 2002; Hankins, Peirson & Foster, 2008; Provencio et al., 2000). The sensitivity to this specific wavelength is caused by the photopigment melanopsin, which is present in the ipRGCs (Brainard et al. 2001; Wright, Lack and Kennaway, 2004). Compared to the classical photoreceptors, the receptive field is also larger and they require a higher light intensity in order to be activated (Berson, Dunn & Takao, 2002; Berson, 2003; Dacey et al., 2005; Hattar, Liao, Takoa, Berson & Yau, 2002). These non-image forming effects can again be divided in two parts, namely the acute effects and effects on the circadian rhythm.

Acute effects.

Acute effects may arise both during the day and during the night. Early research showed that a higher illuminance during the night suppresses melatonin production (Lewy, Wehr, Goodwin, Newsome & Markey, 1980; McIntyre, Norman, Burrows & Armstrong, 1989). In addition, later studies found that higher illuminances also have an effect on other physiological measures. When exposed to a higher light intensity, core body temperature and heart rate were found to be increased (Badia, Myerse, Boecker & Culpepper, 1991; Dawson & Campbell, 1991; Myers & Badia, 1993; Rüger, Gordijn, Beersma, de Vries & Daan, 2006). Next to these physiological functions, Subjective sleepiness, sustained attention and cognitive performance were also found to be increased when the subjects were exposed to a higher light intensity (Badia, Myerse, Boecker & Culpepper, 1991; Boyce, Beckstead, Eklund, Strobel & Rea, 1997; Cajochen, Zeitzer, Czeisler & Dijk, 2000; Dawson & Campbell, 1991; McIntyre, Norman, Burrows & Armstrong, 1989; Myers & Badia, 1993; Rüger, Gordijn, Beersma, de Vries & Daan, 2006; Yokoi, Aoki, Shiomura, Iwanaga & Katsuura, 2003). Moreover, the spectral composition of the light also plays an important role at night. Lockley et al. (2006) found that monochromatic blue light at a wavelength of 460 nm decreased sleepiness, improved reaction times and decreased lapses in a simple reaction time task compared to a wavelength of 550 nm. Other effects of short-wavelength light are on self-reported alertness, melatonin suppression, heart rate and body temperature (Brainard et al., 2001; Cajochen et al., 2005; Revell, Arendt, Fogg & Skene, 2006; Thapan, Arendt & Skene, 2001; Wood, Rea, Plitnick & Figuerio, 2013).

During daytime, similar effects as those during nighttime were found. It was discovered that light intensity decreased sleepiness and fatigue, while also increasing energy of participants who were sleep deprived prior to the lighting manipulation (Phipps-Nelson, Redman, Dijk & Rajaratman, 2003; Rüger, Gordijn, Beersma, de Vries & Daan, 2006; Vandewalle et al., 2006). Again, the spectral composition was also found to have an effect during daytime. It has been shown that when exposing someone to light with a wavelength of 420 nm, compared to 470 nm and 600 nm, subjective alertness and subjective mood can be increased (Revell, Arendt, Fogg & Skene, 2006).

However, Souman, Tinga, te Pas, van Ee and Vlaskamp (2017) reviewed the literature about acute alerting effects of light. They found that the acute effects of light exposure are not as straightforward as it seems. While polychromatic white light has been found to increase subjective alertness in many studies, it has to be noted that a substantial portion of studies failed to find a significant effect. This could be because, in the studies that did not reach significance, they used too high baseline light intensities. Another reason could be the low statistical power because of low sample sizes. The low sample sizes also makes it difficult to draw correct conclusions from the studies that investigated other kinds of lighting manipulation such as light with a higher color temperature or monochromatic light exposure. The review showed that a higher color temperature (having a larger contribution of the blue part of the spectrum) has been found to increase subjective alertness in some studies, but at the same time no effect was found when the short wavelength part of the spectrum was filtered out. Similarly, monochromatic light exposure did not show a clear effect of blue light versus longer wavelengths on subjective alertness. Far fewer studies included in the review investigated objective alerting effects of light. Again, very few found a positive effect of either increased light intensity or increase color temperature. Again, sample sizes were found to be too low to allow for high statistical power.

Effects on the circadian rhythm.

In addition to inducing acute effects on state wellbeing, light also has an influence on a persons' circadian rhythm. Circadian rhythms are rhythms of about 24 hours that cause systematic changes in physiology, mood, cognition and behavior over time under free-running circumstances (Czeisler & Wright, 1999; Duffy & Czeisler, 2009). This rhythm is generated by the suprachiasmatic nucleus (SCN), which is located in the anterior hypothalamus (Schibler & Sassone-Corsi, 2002). Almost all of the processes in humans show these circadian rhythms, such as body temperature and hormone secretion such as melatonin and cortisol. Additionally, behavioral factors such as mood and cognition also show a circadian rhythm. One of the most observable behavioral circadian rhythm is the sleep-wake cycle, which is different for each person and dependent on an individuals' chronotype. Chronotypes can be divided into three types, namely the early, normal and late

chronotype. The chronotype of a person is generally measured with the use of the Munich Chronotype Questionnaire (MCTQ; Roenneberg, Wirz-Justice & Merrow, 2003) or the Morningness-Eveningness Questionnaire (MEQ; Horne & Ostberg, 1976). If someone has an early chronotype, this means that their preferred sleep time will be early in the evening and their preferred wake time early in the morning. On the other hand, if someone has a late chronotype, they prefer to go to bed later in the evening and wake up later in the morning. These chronotypes are also called "larks" and "owls", respectively (Natale, Adan & Chotai, 2002; Roenneberg, Wirz-Justice & Merrow, 2003).

If these circadian rhythms are not aligned to the local clock time, the circadian time will 'free-run' (Czeisler et al., 1999). In order for a circadian rhythm to run in phase with local clock time, it needs to be entrained to the external 24-hour rhythm on a daily basis (Zee & Turek, 1999). The internal clock of a human can be entrained by rhythmic environmental stimuli, so called zeitgebers ('time-givers'). Various kinds of zeitgebers exist such as light, exogenous melatonin and even physical and social activity (Baehr et al., 2003; Barger, Wright, Huges & Czeisler, 2004; Goel, 2005), with light being the strongest and most important one by far. The effects of these zeitgebers on one's circadian rhythm depend on the timing of exposure to them. For example, light can cause the circadian rhythm in organisms to shift in phase, which could cause entrainment to or misalignment with the external clock. The direction in and extent to which the phase is shifted depends on the amount of light exposure, spectral composition of the light and the timing of the exposure (Czeisler & Wright, 1999). Multiple studies have shown that exposure to light in the early morning could lead to a phase advance, while light exposure during the early night could result in a phase delay (Boivin, Duffy, Kronauer, & Czeisler, 1996; Zeitzer, Dijk, Kronauer, Brown, & Czeisler, 2000).

Circadian misalignment.

Misalignment of the internal circadian rhythms with the internal clock means that for example the sleep/wake cycle of a human does not correspond with the natural 24-h cycle of a day. There are several ways in which the internal and external time of a person could be misaligned. One way is daylight savings time. In daylight savings time the external clock will be moved back or ahead one hour, which will cause our internal clock to be misaligned with the external clock for one hour as well (Kantermann, Juda, Merrow & Roenneberg, 2007). For daylight saving time, it has been found by multiple studies that the 1-hour phase advance during spring increases the risk of myocardial infarction during the first two days after the change (Janzky et al., 2012; Janzky & Ljung, 2008). This result has also been found for stroke occurrence (Foerch, Korf, Steinmetz & Sitzer, 2008). On the other hand, no relationship between psychiatric disturbance and daylight saving time has been found in existing studies (Lahti, Haukka, Lonnqvist & Partonen, 2008; Shapiro, Blake, Fossey & Adams, 1990).

In addition to the daylight savings time, jet lag could also cause circadian misalignment. When someone travels across time zones too fast, the internal clock cannot keep up with the changes in time. This causes misalignment between the internal and external clocks, for example when your internal clock is at 11:00 AM, the external clock could be at 04:00 AM if you have travelled to the west. Because of this fast travelling between time zones, your normal sleep and wake times does not correspond with the local clock times anymore. Symptoms of this kind of misalignment can range from gastrointestinal upset, impaired daytime function, excessive daytime sleepiness, difficulty sleeping and general malaise (Boulos et al., 1995).

A more frequently occurring misalignment is when someone does a lot of shift work. Because of this, their sleep/wake cycle does not align with their internal time, or with the natural light/dark cycle. The most common symptom of shift work is the loss of one to four hours of sleep per day (Akerstedt, 1995; Knauth et al., 1980). Doing a lot of shift work could cause an employee to suffer from shift work sleep disorder (SWD), which has been estimated to afflict 10% of the shift working population (Drake, Roehrs, Richardson, Walsh & Roth, 2004). People suffering from SWD have been found to have a shorter sleep duration, worse sleep quality, worse performance on memory tasks and greater prevalence of gastric ulcers and depressive symptoms than workers without SWD (Drake, Roehrs, Richardson, Walsh & Roth, 2004; Gumenyuk et al., 2010, Gumenyuk, Howard, Roth, Korzyukov & Drake, 2014).

Another cause of circadian misalignment is social jetlag, which occurs more frequently than both jet lag and shift work misalignment. Social jetlag occurs when your preferred wake or sleep time, defined by your chronotype, does not correspond with the time you are forced to get up or go to sleep due to social obligations such as work or school hours. For example when a person has a late chronotype and his or her preferred waking up time is 11:00 AM, but has to get up at 08:00 AM, this will cause a misalignment between their preferred sleep/wake rhythm and their internal clock. The sleep debt created this way has been found to decrease attention, performance, mood (Dinges et al., 1997) and memory consolidation (Karni & Sagi, 1993). This, in turn, could potentially cause car accidents because of the lower vigilance and increased sleep inertia (Bonnet & Arand, 1995) or even learning deficits in adolescents because of disturbed sleep patterns (Carskadon, Acebo & Seifer, 2001).

Circadian misalignment could also be a consequence of diseases such as dementia. This is believed to be a result of progressive deterioration and decrease in the number of neurons in the SCN (Deschenes & McCurry, 2009). For example, a study by Ancoli-Isreal et al. (1997) compared two groups of patients, namely a Severe Dementia Group (SDG) and a composite group of Moderate, Mild, or No Dementia Group (MMNDG). They found that, when comparing both groups, that sleep

was extremely fragmented in both groups. However, the group of severely demented patients slept more both at night and during the day, with a lower average activity, a more blunted circadian rhythm amplitude and larger phase delays.

Uses of Light Therapy

The effects of circadian misalignment show that it is very important to have zeitgebers that align the circadian rhythm to the external clock. Normally, this will be done through daylight exposure during the day. However, exposure to daylight throughout the day is not always sufficient or even possible. In these cases, light therapy could be used to replace the normal daylight exposure. The most common way of employing light therapy is by using bright light. Bright light has three major effects on the circadian system, namely that it increases the amplitude of the rhythm, it shifts the phase of the rhythm (depending on the timing of light exposure) and in turn modifies the phase relationship between sleep and the external clock (Wirz-Justice, 2006). Bright light therapy was originally used to decrease depressive symptoms in people suffering from Seasonal Affect Disorder (SAD), which is a disorder that causes people to become depressed due to decreased light exposure as the days shorten but recover again as the days get longer and light exposure increases again in spring (Partonen & Pandi-Perumal, 2010). However, light therapy has also been found to be an effective treatment for non-seasonal types of depression. Benedetti et al. (2003) have shown that morning light therapy was superior to placebo in augmenting the antidepressant effect of citalopram in individuals suffering from non-seasonal depression. In the study, all participants suffered from non-seasonal depression and were treated with an antidepressant for the duration of the study. They compared two conditions. These were the experimental condition, in which participants had morning light therapy for a duration of 30 minutes, and a placebo condition. The morning light therapy consisted of exposure to light with an intensity of 400 lux and a spectrum ranging from 485-515 nm. The results showed that depression scores were significantly lowered for participants in the experimental condition, compared to the placebo condition. Similarly, Martiny (2004) also investigated the effect of bright light on individuals suffering from non-seasonal depression. Participants were randomly assigned to either daily bright white light treatment for 1 hour (experimental condition) or daily dim red light treatment for 30 minutes (placebo condition) for 5 weeks. For both conditions, all participants also took an anti-depressant for the duration of the study. They found that the bright light treatment, as an adjunct treatment to antidepressants, was an effective way of decreasing depression in individuals suffering from non-seasonal depression.

While these bright light treatments are often found to be effective, they could also be quite annoying for the users since they are exposed to a very high brightness and they have to sit in front of these lights for the duration of the exposure. Therefore, an alternative to this treatment has been

investigated, namely naturalistic dawn simulation. In naturalistic dawn simulation, the dawn of a day is simulated by a light that starts at a low level and increases to a higher level over the course of a set time period. This simulation starts before the habitual wake-up time of the person. Similarly to bright light therapy, dawn simulation has been found to provoke an antidepressant response and normalization of abnormal sleeping patterns (Terman et al., 1989; Avery et al., 1993, 1994, 2001). This has also been shown in a large controlled study by Terman & Terman (2006). They compared the effects of naturalistic dawn simulation, dawn pulse, bright light, negative air ionization with a high flow rate and negative air ionization with a low flow rate on people suffering from SAD. In the naturalistic dawn simulation condition, the light started at <1 lux 90 minutes before the habitual wake up time of the participant and increased to 250 lux over the course of those 90 minutes. As a control for the naturalistic dawn simulation, they used a dawn pulse of 250 lux for 13 minutes before wake up time in the dawn pulse condition. For the bright light condition they used a bright light box, exposing the participants to 10,000 lux white light for 30 minutes within 10 minutes of rising. The negative air ionization was done by using a negative air ion generator directed towards the pillow of the participant. The results showed that naturalistic dawn simulation, dawn pulse, bright light and negative air ionization with a high flow rate were similarly superior to negative air ionization with a low flow rate, with all four of the superior methods showing similar magnitudes of improvement on depression scores. This shows that naturalistic dawn simulation could be used as a replacement for bright light exposure during the day as a treatment for SAD.

Effects of bright light on dementia.

In elderly suffering from dementia, depressive symptoms are often a problem as well. In addition, studies suggest that 25% to 35% of people that suffer from Alzheimer's disease have problems with sleeping (Dauvilliers, 2007)) such as nighttime sleep fragmentation, increased sleep latency, decreased slow-wave sleep and increased daytime napping. Another common problem found is "sundowning" which is an increase in confusion, wandering and agitation in the late afternoon and the evening (Wu & Swaab, 2007). These symptoms are believed to be caused by progressive deterioration and decrease in the number of neurons in the SCN, the brain area to which the ipRGCs communicate (Wu & Swaab, 2007).

Attempts have been made to decrease depressive symptoms and sleep disturbances in dementia patients with the help of bright light. One of these studies was done by Riemersma et al. (2008). They investigated the effects of bright light and melatonin on cognitive and non-cognitive functions in elderly residents of group care facilities, all suffering from dementia. The participants were assigned to one of four different conditions. These conditions were light exposure only, melatonin administration only, combined light exposure and melatonin administration and neither

light or melatonin (the control condition). A large number of ceiling mounted fixtures were installed in the living room for the light exposure. These were turned on between approximately 9 AM and 6 PM, with an average exposure of ±1000 lux on the eye. Melatonin was administered daily, 1 hour before bed time to allow it to dissolve completely. Six weeks before the study started, neuropsychiatric symptoms of the participants were assessed. The participants were then followed for up to 3.5 years, although this varied greatly. This was primarily due to logistical reasons such as renovations, moving and staff limitations. Follow-up assessments were made 6 weeks after the start and after that every 6 months. At these times, several outcome measures were assessed. The actigraphy measures were averaged over blocks of two weeks. The used outcome measures can be found in Table 5 in appendix A.

The results show that exposure to the light decreased cognitive decline for a fixed amount at all time points. It was also found to ameliorate depressive symptoms. No significant treatment effect was found for the behavioral expressions of negative and positive mood or on the outcome of the NPI-Q. It was, however, found that the combination of light and melatonin decreased agitated behavior. For the sleep variables, the results yielded that combined treatment of light and melatonin ameliorated nocturnal restlessness with an effect that decreased over time. Sleep efficiency was also increased by the combined treatment. In addition, melatonin shortened sleep onset latency and increased sleep duration. Regarding the sleep structure, it was found that the combined treatment reduced the average duration of awakenings during the night. Melatonin was also found to increase the average duration of uninterrupted sleep periods.

Effects of dawn-dusk simulation on dementia.

Next to the effects of bright light during the day, the influence of dawn-dusk simulation (DDS) on demented elderly was also investigated by Gasio et al. (2002). In their study, they recruited patients suffering from dementia from two nursing homes in Switzerland. Thirteen participants were randomly assigned to either the DDS or the placebo condition. The experiment lasted 9 weeks in total, 3 weeks of baseline, 3 weeks of treatment and finally 3 weeks of follow-up. The manipulation they used for the simulation of dawn and dusk was as follows. First, they determined two dates/latitudes to provide dawn and dusk parameters. These parameters consisted of the duration of dawn, dusk and the dark period between dawn and dusk. For the light, they used a computer algorithm that drove an electronic controller connected to an overhead halogen lamp, which was placed behind a diffusing membrane behind the subject's bed (Terman, Schlager, Fairhurst & Perlman, 1989). This light provided an intensity starting at 0.001 lux and gradually increasing over 30 minutes to ~210 lux at the level of the participants' pillow. The post-dawn signal remained on for another 15 minutes after reaching the maximum light intensity. Pre-dusk, the light was turned on 45

minutes before starting to decrease the light intensity to give the patients time to go to bed. In the placebo condition, the same simulation parameters were used, but instead of white light, a 15 W red-light bulb yielding < 5 lux was used. In order to determine the effects of the DDS, they employed several questionnaires, which were administered in each of the three-week blocks. In addition to these questionnaires, they also used an activity monitor (Actiwatch®, Cambridge Neurotechnologies, UK) worn on the non-dominant wrist. Mean activity and light exposure was determined by averaging the data in 1 h bins over the 24 h cycle and then averaging for each 3-week period. Last, using a sleep analysis program, sleep logs were analyzed to find effects on 32 actimetry-derived sleep variables. These actimetry-derived sleep variables consist of measures such as time in bed, sleep latency and sleep efficiency. A more detailed list of the used outcome measures can be found in Table 5 in appendix A.

The results of the study showed no significant effect of either condition on the neuropsychological evaluations (CERAD, MMSE, NPI and GDS). Mean activity during 24 hours was also not significantly influenced by the DDS treatment, while mean light exposure tended to be decreased during the night (i.e. patients or caregivers turned the lights on less often or for a shorter time), but not during the day. None of the circadian stability or amplitude characteristics (IS, IV and RA) were found to be significantly modified by either treatment. However, the onset of the least active 5 hours showed an advance in the DDS condition compared to the dim red light condition. No significant difference of the effect on circadian phase was found for both treatments. However, it was found that 3 out of 9 participants showed a phase advance of both rise and fall of activity after DDS, compared to baseline. Additionally, amount of motor activity in the evening for 4 out of 9 participants was significantly decreased both during and after DDS treatment. There was no significant effect found on the 32 actimetry derived sleep variables, although a tendency of amelioration on these variables was found in the DDS condition while the situation worsened in the red light condition. The DDS treatment tended to increase assumed sleep duration, sleep quality and the amount of immobile phases. It was also found to shorten sleep latency. It should be noted, however, that the amount of participants in this study was fairly low, with only 13 people participating. In addition, the experimental and placebo condition were not balanced, having only 9 and 4 participants, respectively. This means that the results found in this study are speculative at best, since it is hard to find such small effects with such a small research population.

Our Study

Based on the studies focusing on lighting interventions for elderly suffering from dementia, we see that the effects are still unclear. In the study by Riemersma et al., the results they found were largely inconclusive. With bright light therapy having significant effects on some of the outcome

measures while insignificant on others. In the study by Gasio et al., they also did not find clear effects of DDS on elderly suffering from dementia, with none of the outcome measures significantly modified by the treatment. Again, it should be noted that the amount of participants that participated in the study by Gasio et al. was small as well as unbalanced. In addition to the unclear results, the studies show a large difference in the used outcome measures. Aside from the use of actigraphy, which was used in a different way in the two studies, almost none of the questionnaires are used in both studies.

In our explorative study, we will try to find out how elderly patients suffering from dementia experience a personalized lighting scenario, tuned to support their sleep/wake patterns as well as their daytime functioning. In the nursing home, the current lighting system does not provide enough light to be adequate for this population. In order to improve the situation, we will design a personalized lighting system which will perform DDS based on the sleep/wake rhythm of the participants. We will investigate which problems arise when using this system and if the used outcome measures are suitable for measuring the effects of light on this particular research population. In addition, we will qualitatively explore the effects of the personalized system on the sleep-wake rhythm, behavior and mood of the participants. If we are able to answer these questions, a follow-up study investigating the effects of the system qualitatively would become much more feasible.

This study will contribute to the field by exploring how well a personalized lighting system, providing DDS, will work for elderly suffering from dementia. This will be done by giving more insight into the effects of DDS on dementia and the applicability of the methods that will be employed in the study. These methods consist of the use of DDS, actigraphy and daily questionnaires. We expect this personalized lighting system to improve both the sleep/wake patterns as well as the daytime functioning of the participants.

Method

Current Lighting Situation

Before we started the experiment, we have investigated the current situation in the nursing home. This was done by employing two measurement protocols, one for measuring the daylight contribution and one for measuring the electrical light contribution. The daylight measurements were done with an overcast sky at two points during the day, namely at approximately 10:00 in the morning and 14:00 in the afternoon. This was to map possible changes in the daylight contribution. During the daylight measurements the electrical light was turned off. We also compared daylight contribution through the windows with and without luminance screening to determine the effect of the screening. The measurements for the electrical light were done in the evening when the sun had gone down. This was to ensure that there was no daylight contribution anymore so we could solely measure the contribution of the electrical light.

First, we defined the grid points on which the measurements were to be done. The grid points for the daylight contribution were based on the daylight protocol for the daylight contribution (Velds & Christoffersen, 2001) and the grid points for the electrical light contribution were based on the NEN-EN 12464 standard. Then, for each grid point, we determined the lux value on that point with the help of a portable lux meter (LMT pocket-lux). For both the daylight and the electrical light measurements, this was done vertically at eye level (height 1.20 m).

Design

In this experiment, we used a 2x1 within-subject design. All participants were assigned to the dawn-dusk simulation condition. Half of the group experienced the DDS in the first week but not in the second, and vice versa for the other half. The order of the exposure to DDS was counterbalanced. In the DDS condition we manipulated the light settings in the apartment of the client living in the care facility. The light settings were manipulated with the help of a standing lamp from Vitaallicht. With this lamp, we provided dawn and dusk simulation relative to the normal times the clients would normally wake up and go to bed. These habitual wake and sleep times were recorded a week in advance.

For the dawn simulation, the light increased from an output of ~40 lux at the eye to about 250 lux at the eye over a course of 45 minutes in the morning, in blocks of 15 minutes. After the light had reached the top illuminance, it remained on for another 45 minutes at this level. For the dusk simulation, the light decreased from 250 lux to ~40 lux over the course of 45 minutes, in blocks of 15 minutes. Before the dusk simulation started, the light was already on at a level of 250 lux in order to give the participant time to go to bed. At the end of these time periods, the lights turned off.

Participants

The participants consisted of 7 clients, all under the care of nursing home “Buurstede”, which is located in Oosterhout, the Netherlands. “Buurstede” is part of organization “De Riethorst Stromenland”. All residents of the nursing home have their own apartment where they can sleep and retreat. During the daytime they can also spend their time in two common living rooms which are supervised by caregivers. Before enrolling the clients in the study, their relatives/caregivers were asked to provide informed consent. Inclusion criteria were that the clients have been diagnosed of dementia, while clients were excluded if they had severely impaired sight. The diagnosis for dementia in all cases was done before they came to the nursing home. The diagnosis was done with the “Dementie Onderzoek West Brabant” (DOWB) protocol, which consists of a combination of various neuropsychological tests.

Setting & Apparatus

The apartment of the client consisted of a small open kitchen adjacent to the personal living space. In addition, each client had their own bathroom which includes a sink, toilet and shower. The standard furniture in a room consisted of a bed, a small table and a chair. The bed of the clients was placed in the personal living space beneath the lamp. The clients were allowed to use their own furniture in the rooms as well. More detailed descriptions of the clients’ apartments can be found in appendix B.

The lighting system providing the DDS was realized using a free-standing luminaire from Vitaallicht (Vitaallicht, Eindhoven, Netherlands). The free-standing luminaire stood either next to the bed or at the foot end of the bed of the client, depending on the setup of the apartment. This luminaire consisted of two types of light strips, one for cool white light (LED Lighting Acrich White, Cool 6500K) and warm white light (LED Lighting Acrich White, Warm 2700K). Two different kinds of Vitaallicht lamps were used, namely the first generation lamp and the second generation lamp. The first generation lamp consisted of 4 warm white light strips and 8 cool white light strips, while the second generation lamp consisted of 5 warm white light strips and 10 cool white light strips. This luminaire could be configured to provide the lighting described in the design section. For this we set the first generation lamp to increase from 4% output to 45% output and vice versa, and the second generation lamp to increase from 4% output to 30% output and vice versa. We measured light intensity, CCT, color rendering index (CRI) and spectral irradiance at eye level (while in bed facing the light). This was measured using a calibrated spectroradiometer (JETI Specbos 1201). The CRI of the lamp was $R_a = 88$. The spectral irradiance is shown in Figure 1.

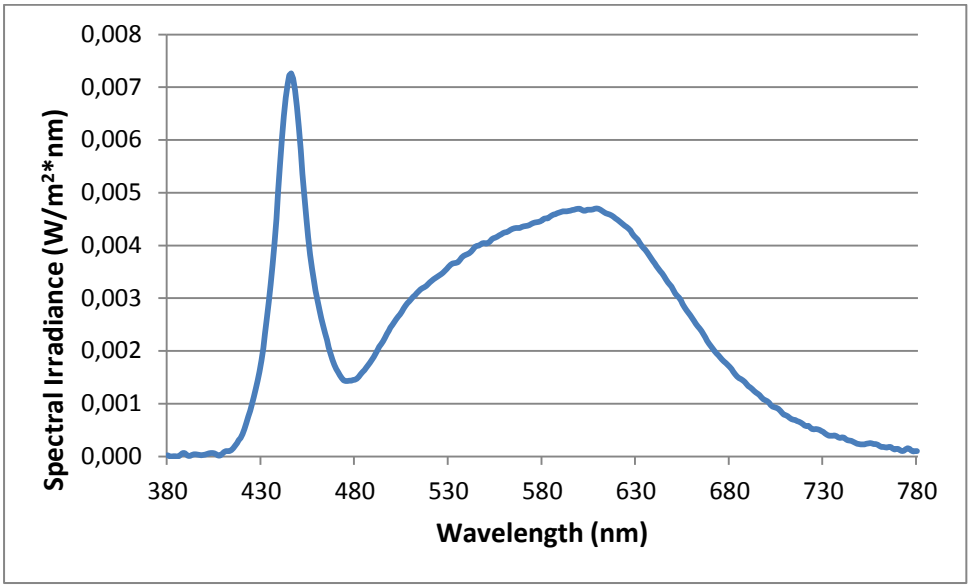

Figure 1: Spectral irradiance of the light used for the DDS.

Procedure

Before the start of the study, relatives of the clients were instructed on what the study encompassed. They were then asked to sign an informed consent form on behalf of the client. For the clients that were enrolled into the study, we determined what the normal sleep and wake times were for the participating clients. This was done so that we were able to align the times of the DDS with their actual sleep/wake rhythm. For this we employed actigraphy, which gave us an insight on the times the clients fell asleep and when they woke up. In addition, we spoke to the nurses of the facility to get a better insight in their sleep/wake rhythm. The actigraphy was also employed during the study to map the sleep/wake rhythm and physical activity of the participants.

Next to actigraphy, caregivers were asked to fill in daily questionnaires about the enrolled clients. These questionnaires were filled in on three different times during the day. These times were in the morning after the client woke up, during lunch and during dinner. In addition to the daily questionnaire, the caregivers were asked to fill in the Nijmegen Observer-Rated Depression scale (NORD; Leontjevas et al., 2011). This had to be done twice by the same caregiver, once just before the study started and once just after the study.

After the study ended, the relatives of the clients were debriefed and thanked for their relatives' participation. We then invited a number of the nurses for a semi-structured interview.

Measurements

Actiwatch.

Every client wore the actiwatch a week before the study started in order to map the normal sleep/wake rhythm of the client. During the experiment, the actiwatch was also worn on the wrist. With these actiwatches we recorded several variables. These were the sleep onset, sleep offset, sleep duration, sleep latency, sleep efficiency and the wake after sleep onset. The wake after sleep onset was defined as the number of minutes of wake detected by the Actiware Software after the participant initially fell asleep.

Daily questionnaires.

The daily questionnaire consisted of 6 items which compared the current situation with the normal situation. The items were “how well did the client cooperate?”, “How talkative is the client?”, “How friendly is the client?”, “How cheerful is the client?”, “How awake is the client?” and “How calm is the client?”. In the lunch and dinner questionnaires, the question “How is the appetite of the client?” was added. The caregivers were asked to score these items based on their regular daily observations. The items were rated on a scale from 1 (much less than normal) to 7 (much more than normal). At the end of each questionnaire the caregivers were asked to write down any notable occurrences. The daily questionnaires can be found in appendix C.

Nijmegen Observer-Rated Depression scale (NORD).

The NORD was filled in by twice by the nurses, once before the start of the study and once just after. The NORD is a questionnaire developed in order to measure depression. It consisted of 5 items, which are answered with either a “yes” or a “no”. The items in the questionnaire were “Does the client often have a sad, gloomy or despondent impression?”, “Does the client cry a lot or is he/she often emotional?”, “Is a positive reaction to social contacts or happy events often missing for the client?”, “Does the client need a lot of encouragement to be active or to take part in joint activities?” and “Are there often problems with sleeping (falling asleep, sleep continuity, waking up) or with appetite (no appetite, unusual high appetite)?”. The NORD can be found in appendix C.

Interview.

After the study ended, three employees of the nursing staff were invited to an interview. In this semi-structured interview we discussed their experiences with the personalized lighting system, the actiwatches, the filling in of the daily questionnaires and other notable observations. In addition, we asked some nurses to fill in a questionnaire with the same topics as the interview.

Analysis

Since we did not have enough participants to perform a proper quantitative analysis, we performed qualitative analyses on the data. These analyses consisted of visual inspection of the graphs from the actiwatch, comparing scores of the daily questionnaires and a thematic analysis (Braun & Clarke, 2006) of the semi-structured interview. Because of issues regarding the planning of filling in the NORD questionnaire for the second time, we have not analyzed the results of the NORD anymore.

In order to prepare our data for the analyses, we have removed several data points. For the actiwatch data, we divided the data into three different sets. The first set was the complete raw data, the second set was a cleaned up version and in the third we also removed daytime sleep periods. The data points that were removed in second data set were highly improbable sleep periods of the participant. An example of this is when a participant was shown to have been asleep from 10:00 in the morning to 22:00 in the evening, and then going to sleep again 2 hours later. For the dataset of the daily questionnaires we removed several data points in which an external factor greatly influenced the scores for those blocks. These external factors could be identified through the notable occurrences the nursing staff had written down. Examples of these factors were when a participant had fallen down or when it was the participants' birthday.

Results

In this chapter, we will discuss the descriptive results of the study. This will be divided into several sections, namely the lighting measurement results, the actigraphy results and the results for the daily questionnaires filled in by the nursing home staff. After this we will discuss the qualitative data we gathered from the interviews.

Current Lighting Situation

Daylight.

The measurements for the daylight contribution were only done for the livings rooms and not for the apartment of one of the clients. Reason for this is that the people living in nursing home spend most of their time in the living rooms and not in their apartment. All the measurements were done under an overcast sky. The measurements were also done at two times, namely starting once in the morning at 10:00 and once in the afternoon at 14:00. In addition, they were done once with optimal luminance screening and once without any window obstruction. There were 5 measurement points for each window, with equal spacing between each point. These points started close to the windows and moved further away with each point.

Living room 1.

In the first living room we performed two measurements. The first measurement (window 1) was done at the windows located at the upper part of the room, where a large table was also positioned. The second was performed at the window near the bottom of the room, near the television corner. The results of the first measurement are shown in Figure 2. The first living room does not have a contribution of direct sunlight because the windows are also inside the building. Instead, the sunlight comes through a semi-transparent diffusing ceiling. Despite this, we see that near the window the illuminance is quite high, especially in the afternoon with values of around 1500 lux. However, this quickly declines as we go further away from the window, with values of about 300 lux on measurement point 4 and only 200 lux on measurement point 5. Because of this, it is often needed to keep the lights on in addition to the daylight to provide a high enough light intensity in the living room.

Figure 3 shows the results of the measurements for the second window in the living room. For this window only the daylight contribution during the afternoon was measured due to time constraints. We see that, similar to the first window, the light intensity starts reasonably high near the window and again quickly declines the further away from the window. This time, however, we also see quite a big difference between optimal luminance screening and no luminance screening, at

least close to the window. For measurement points 4 and 5 we see that the light intensity is below 200, which is quite low.

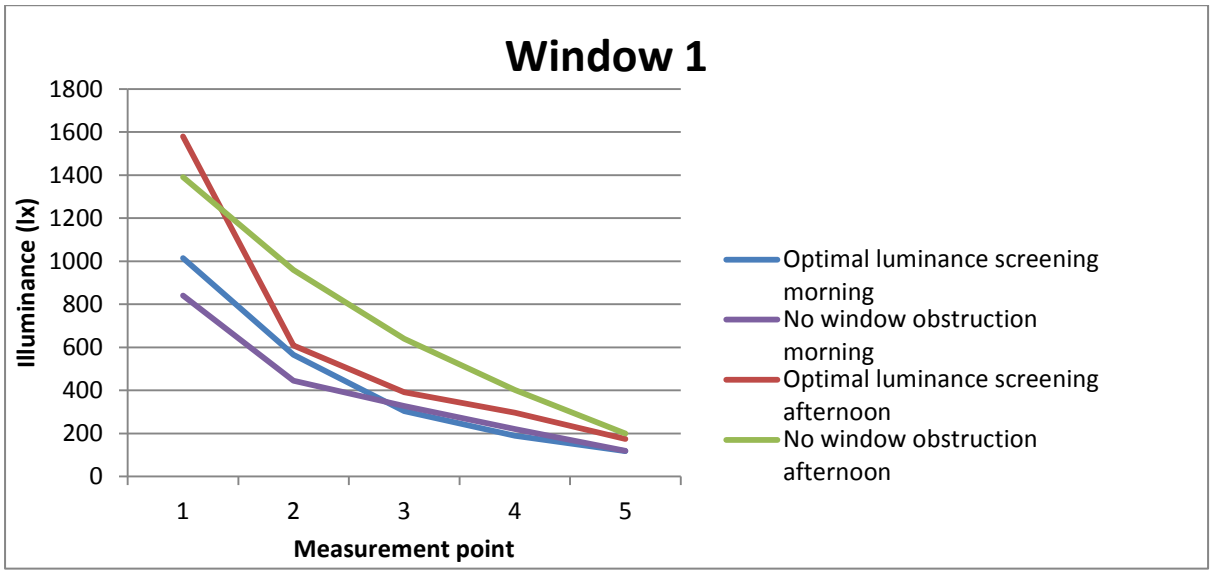

Figure 2: Daylight contribution in lux for living room 1, window 2.

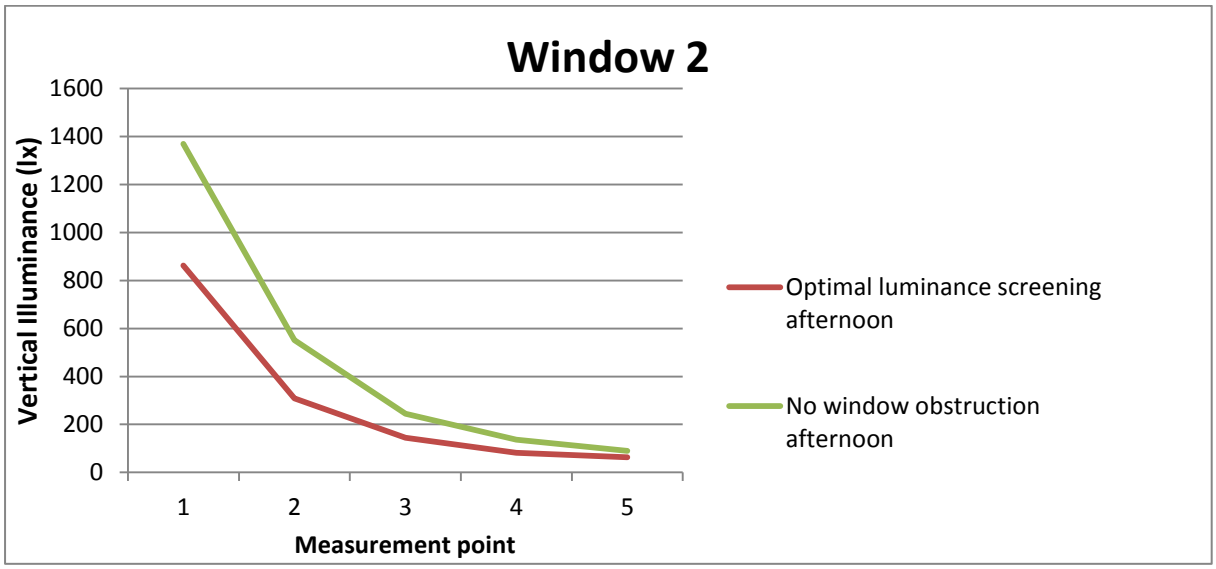

Figure 3: Daylight contribution in lux for living room 1, window 2.

Living room 2.

In the second living room we also performed two measurements. The first measurement (window 1) was, similar to the first living room, done at the windows located at the upper part of the room, close to which two chairs were positioned. The common table for this living room is also positioned next to this window. The second measurement was performed at the window near the bottom of the room, again near the television corner. While for this living room the daylight contribution is direct, a lot of it is blocked by large trees in front of the windows. The results of the first measurement are shown in Figure 4. We see that most measurements for the first window were

close together with the exception of the first measurement point without luminance screening in the afternoon. The light intensity, albeit lower than for the first living room, also does not decline as fast. However, for most of the room the illuminance values are below 200 lux, which is again quite low.

For the second window, depicted in Figure 5, we see quite big differences in intensity for the first measurement point nearest to the window. For example a difference of almost 600 lux between optimal luminance screening and no window obstruction in the afternoon. We also see that the light intensity of just daylight in the afternoon goes to around 200 lux, which is already quite low. In the morning, we see even lower lux values, dropping below 100 lux for measurement point 3 and higher. This shows that it can become quite dark in that part of the living room if no electrical light is used.

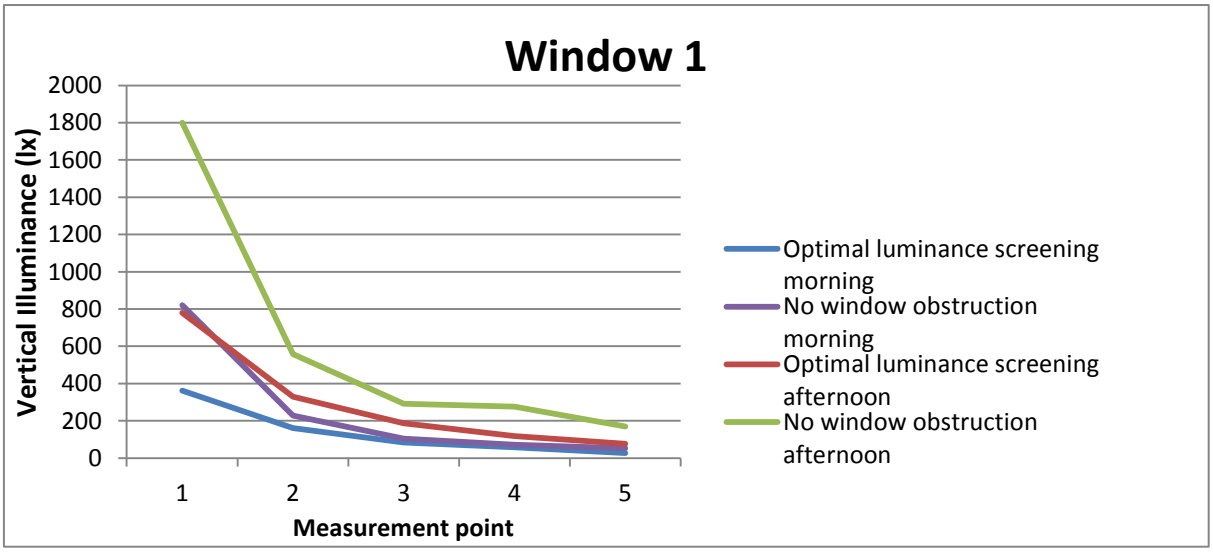

Figure 4: Daylight contribution in lux for living room 2, window 1.

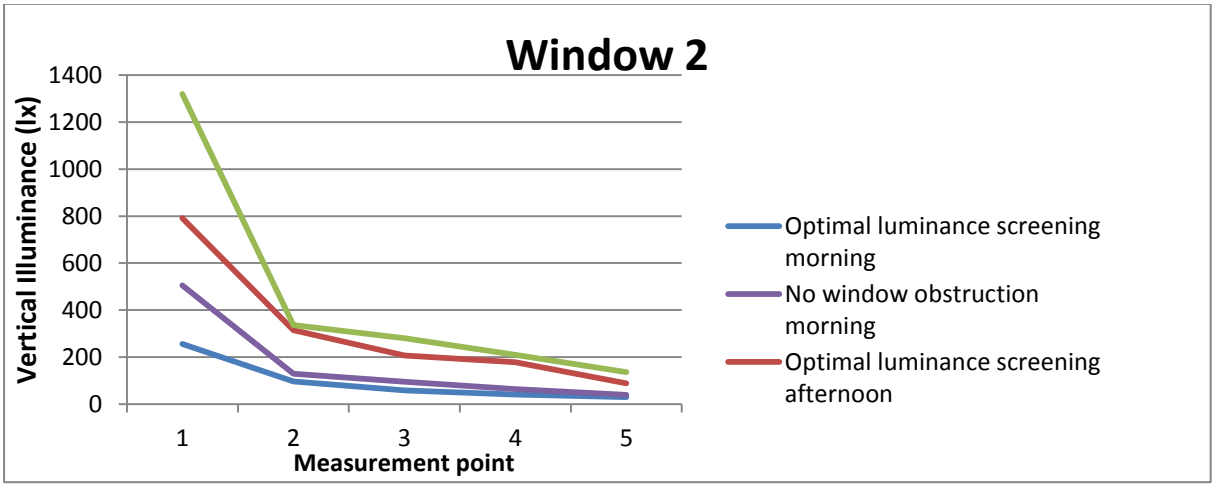

Figure 5: Daylight contribution in lux for living room 2, window 2.

Electrical light.

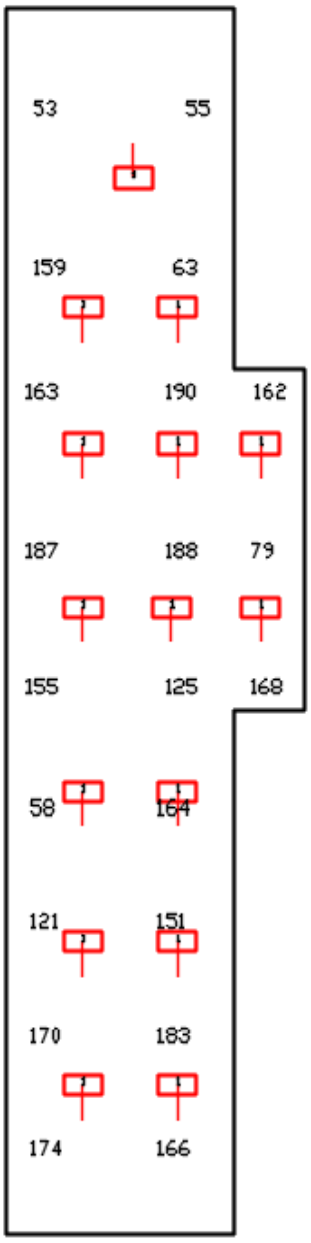

Figure 6: Lux values of the electrical light measurements for common living room 1.

Figure 6, 7 and 8 depict the two common living rooms in the nursing home and the apartment of one of the clients, respectively. In these figures the lux values across the room are depicted as the black numbers, while the luminaires present in the rooms are shown in red. The lamps used in the living rooms are two Philips PL-L 18W 830 per luminaire. For the clients' apartments, the luminaires above the bed and at the door use Halogen Eco Osram 30 watt lamps. The luminaire in the kitchen of the apartment uses the same lamps as in the living rooms, namely the Philips PL-L 18W 830 lamp. More detailed figures of both the living rooms and the apartment including furniture can be found in appendix B.

In Figure 6 we see the first common living room in the nursing home. The figure shows that the maximum illuminance in the room is 188 lux in the middle of the room and that the minimum illuminance is 53 lux on the upper side of the room. This is mostly because on the upper side of the room there is just one luminaire installed, which creates quite a dark area in the room. On the other hand, in the middle of the room there are six luminaires installed, where the light intensity is much higher. The average light intensity in the first living room was 139 lux.

Figure 7 shows the second common living room. We again see a dark area in the room, namely in the middle where the light intensity is just 41 lux. Notably, this part is also where the highest light intensity was measured, which is 338 lux. Reason for this is that during the vertical measurements we pointed the lux meter towards the nearest light source in order to measure the maximum light intensity at that measurement point. The average light intensity in the room is just 102 lux, which is quite low. There are also quite large differences in light intensity between different areas in the living room.

The apartment of one of the clients is shown in Figure 8. We see a maximum light intensity of 1730 lux, which is really close to the luminaire in the kitchen which has quite a high light output. This can also be seen in the other lux values in that area, which are much higher than in other parts of the apartment. In the apartment, we see some areas that have a very low light intensity, especially on the right side of the apartment beneath the cabinet next to the kitchen. Reason for this

is that there are no luminaires for that area and that most of the light coming from the lights at the door and kitchen are blocked by the cabinet. This also causes quite a high contrast in the room. The average light intensity is the room is 123 lux, which is quite skewed because of the higher values in the kitchen. In comparison, if we exclude the kitchen area, the average light intensity is only 67 lux.

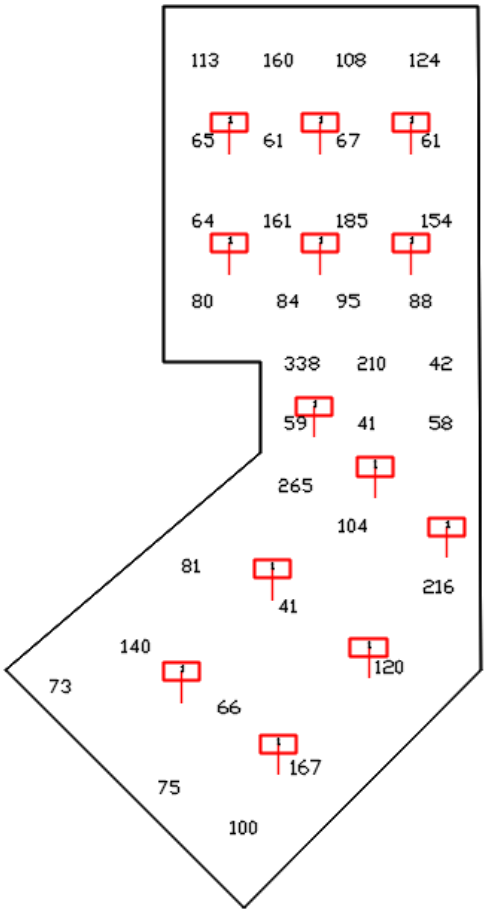

Figure 7: Lux values of the electrical light measurements for living room 2.

Figure 8: Lux values of the electrical light measurements for the apartment of one of the clients

Actigraphy

First, the data that resulted from the actigraphy were inspected to explore differences between the sleep variables in the baseline condition and the experimental condition. This was done both on a personal and on a general level. This is depicted in Table 1, in which the means for sleep onset, sleep offset, sleep duration, sleep latency, sleep efficiency and wake after sleep onset are shown. In addition, we included the sleep onset and offset range, number of naps and mean duration of these naps. For all of the data used, the naps done during the daytime were excluded. This was done because we want to focus on the differences in night time sleep of the participants.

Table 1: Means of the actiwatch data for each participant and overall. Times are specified in hh:mm, except for Sleep Efficiency, which is depicted in percentages. Standard deviations for each measure are placed within the brackets.

		Sleep onset	Sleep onset range	Sleep offset	Sleep offset range	Sleep duration	Sleep latency	Sleep efficiency (%)	Wake After Sleep Onset	Number of naps	Duration of naps
Participant 1	**Baseline**	22:10 (00:44)	21:47 – 23:02	9:49 (00:27)	09:18 – 10:11	10:54 (01:26)	00:14 (00:14)	93 (5)	00:21 (00:54)	-	-
	Experimental	23:26 (01:46)	21:06 – 01:25	9:56 (02:54)	05:59 – 12:57	9:47 (02:28)	00:06 (00:07)	94 (6)	00:20 (00:32)	1	05:54 (00:00)
Participant 2	**Baseline**	20:42 (00:54)	19:41 – 21:54	10:27 (00:54)	09:26 – 11:35	10:16 (01:17)	00:29 (00:35)	75 (6)	01:11 (00:27)	-	-
	Experimental	20:56 (00:18)	20:34 – 21:24	10:14 (00:33)	09:32 – 10:51	11:08 (00:28)	00:31 (00:36)	84 (5)	01:02 (00:31)	-	-
Participant 3	**Baseline**	19:01 (02:14)	17:26 – 20:36	17:40 (06:13)	22:04 – 13:16	7:00 (06:49)	00:35 (00:40)	59 (17)	02:35 (00:44)	3	04:05 (02:37)
	Experimental	22:22 (02:08)	20:22 – 00:37	6:48 (03:43)	02:54 – 10:20	6:02 (06:02)	00:06 (00:04)	73 (7)	01:46 (01:12)	3	05:24 (04:37)
Participant 5	**Baseline**	21:58 (01:12)	20:37 – 23:09	6:47 (01:30)	04:59 – 09:09	7:43 (02:10)	00:01 (00:01)	88 (7)	00:49 (00:36)	-	-
	Experimental	21:24 (00:40)	20:42 – 22:14	8:01 (03:15)	03:50 – 10:50	7:44 (02:00)	00:37 (00:32)	74 (10)	00:54 (00:08)	-	-
Participant 6	**Baseline**	23:06 (03:15)	20:48 – 01:24	12:33 (03:24)	10:09 – 14:58	8:39 (02:21)	00:33 (00:23)	68 (16)	01:29 (00:22)	5	01:29 (01:55)
	Experimental	20:06 (01:39)	18:13 – 21:20	6:51 (01:12)	06:02 – 08:14	7:29 (01:42)	01:37 (01:55)	71 (20)	01:19 (00:30)	3	03:05 (02:03)
Overall	**Baseline**	21:58 (02:51)	-	11:27 (02:30)	-	8:54 (02:49)	00:22 (00:23)	77 (10)	01:17 (00:37)	8	02:47 (01:50
	Experimental	20:35 (02:39)	-	8:22 (02:19)	-	8:26 (01:44)	00:35 (00:38)	79 (10)	01:04 (00:35)	7	04:47 (01:30)

Sleep onset.

When comparing the sleep times of the participants for the baseline and for the experimental condition, we see overall that the sleep times are earlier in the experimental than in the baseline condition. However, this is not shown for each participant. We see for example that for participant 1 the sleep onset time increased by more than an hour. For the other participants we either see no change or a decrease. Most notably participant 3, for which the sleep onset decreased by almost 5 hours. If we look at the standard deviations of sleep onset, we see that this has decreased in the experimental condition overall. The standard deviation has also decreased for most participants, especially participant 6 in which the standard deviation decreased with almost 2 hours.

Sleep offset.

When looking at sleep offset of the participants, we again overall see that the wake up times were earlier in the baseline condition than in the experimental condition. The only exclusion in this is participant 5, which woke up more than one hour later on average. Again, most notably, participant 3 shows the largest difference, for which the sleep offset advanced by 9 hours. However, it must be noted that this participant has a very fragmented sleeping pattern. This is shown in Figure 9 which shows the sleep onset, sleep offset and sleep duration of participant 3 for the experimental condition. The same fragmentation was seen in the baseline condition. The standard deviation of sleep offset has decreased by 11 minutes overall. However, if we look at a personal level, we see that it varies a lot per participant. For example we see that for participant 3 the standard deviation has decreased by almost 3 hours, while for participant 1 and 5 it has increased for about 2 hours. The most notable difference between standard deviations can be seen for participant 2, which showed a very low standard deviation in the experimental condition. This is also depicted in Figure 10, which shows the sleep onset, sleep offset and sleep duration for participant 2 for both the baseline and experimental condition. The first week in this figure shows the experimental condition, while the second week shows the baseline condition.

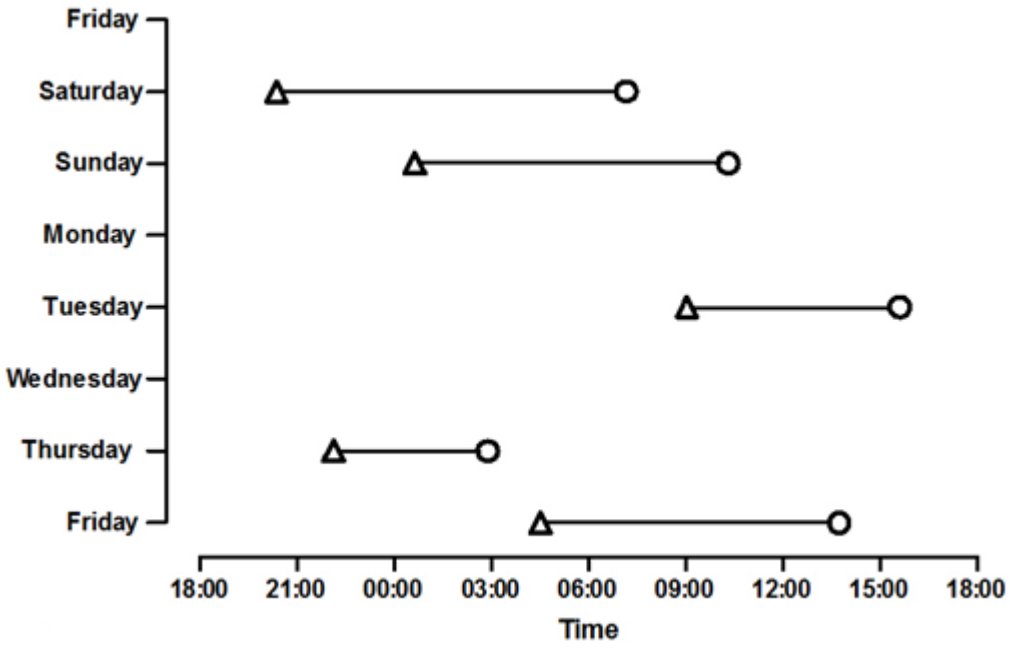

Figure 9: Sleep onset, sleep offset and sleep duration in the experimental week for participant 3. Triangles depict the sleep onset, the line depicts the sleep duration and the circle the sleep offset.

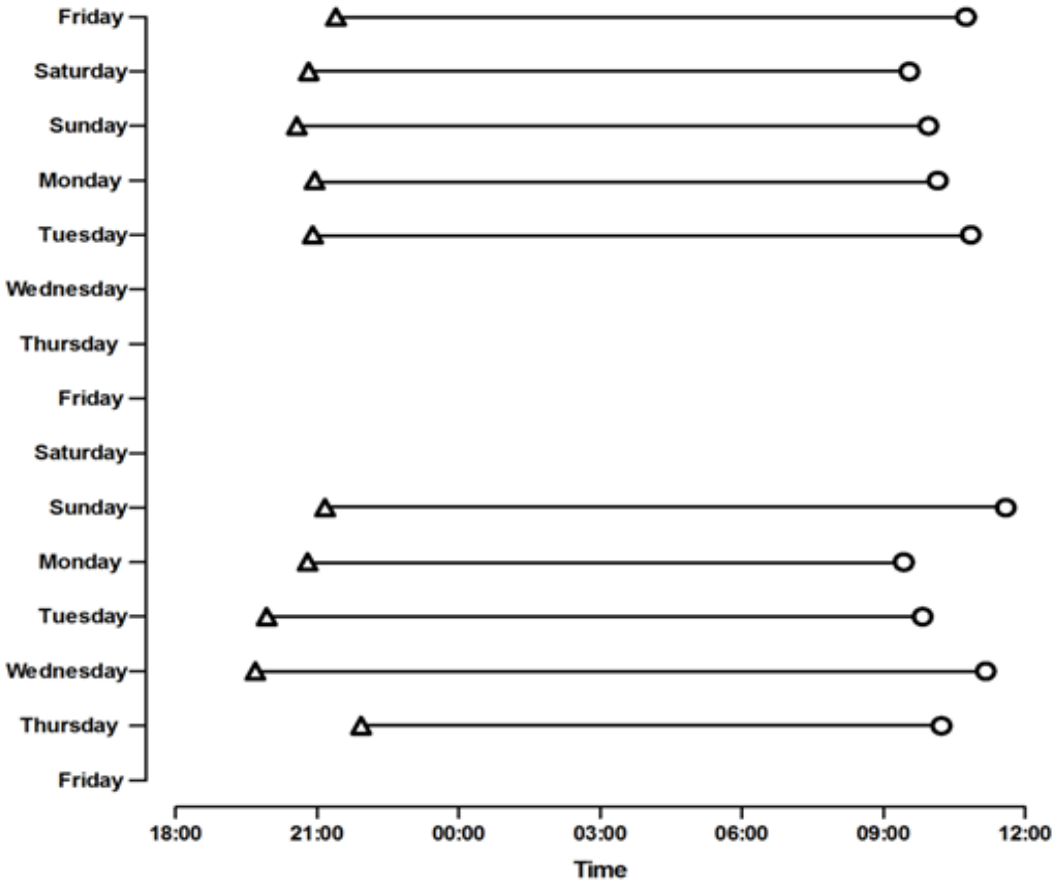

Figure 10: Sleep onset, sleep offset and sleep duration in both conditions for participant 2. Triangles depict the sleep onset, the line depicts the sleep duration and the circle the sleep offset.

Sleep duration.

The mean sleep duration of the participants overall has decreased in the experimental condition compared to the baseline condition. When comparing the sleep durations in both conditions on a participant level, we do not see very large differences. The biggest observed difference is a decrease of about 1 hour for participant 1, 3 and 6. We should note, however, that when we include the naps for participant 6, we see that the sleep duration and the total amount of sleep throughout the week increased quite a lot in the experimental condition compared to the baseline condition. This is depicted in Table 2. Looking at the standard deviations of sleep duration, we see overall that this has decreased in the experimental condition with about an hour. This is also reflected on a personal level, where for all but one participant (participant 1), the standard deviation of sleep duration has decreased in the experimental condition.

Table 2: Mean sleep duration and total sleep duration for participant 6, times are specified in hh:mm format.

	Participant 6	
	Baseline	**Experimental**
Average sleep duration	03:32	05:17
Total sleep duration	24:45 (over 7 days)	31:44 (over 6 days)

Sleep latency.

Regarding the sleep latency of the participants we see that overall it has increased by 13 minutes in the experimental condition, compared to the baseline condition. Looking at the sleep latency on a personal level, we see that for 2 out of 5 participants the sleep latency actually decreased, it stayed the same for 1 participant and that the other 2 participants showed an increase. Participant 6 showed the largest increase in sleep latency, namely an increase of 64 minutes.

Sleep efficiency.

Sleep efficiency overall shows a small increase of 2 percent in the experimental condition. This increase is also seen in all but one of the participants, with varying degrees of differences. For example participant 3 shows an increase of 14% in the experimental condition, while participant 1 only shows an increase of 1%. For participant 5 we see a decrease of 12%, which causes the overall increase to be much lower.

Wake after sleep onset.

Lastly, looking at the wake after sleep onset, we see a decrease in awakenings of 13 minutes in the experimental condition compared to the baseline condition. The only participant that shows an increase is participant 5 with an increase of 5 minutes. Again we see that participant 3 has the biggest difference between the experimental and baseline condition, namely a decrease of 49 minutes.

Number of naps and nap duration.

For the amount of naps during the study, we see overall that there were slightly more naps in the baseline week, compared to the experimental week. The most notable difference here is for participant 6, with 5 naps in the baseline week and only 3 naps in the experimental week. However, when looking at the average duration of naps, we see that this has increased in the experimental week by 2 hours overall.

Daily questionnaires

In this section we will discuss the results of the daily questionnaires. This will be done by calculating the means of each score for each measured variable per participant per condition, which is depicted in Table 3. These variables are the extent to which the participants were cooperative, talkative, friendly, cheerful, awake and calm. In addition, for the lunch and dinner questionnaire, there was a variable measuring the appetite of the participants. We will also discuss the noteworthy special occurrences throughout the study. In addition, we will provide an example of a statistical test which shows how the data could be analyzed quantitatively in future studies if there would be a large enough sample size.

Overall we do not see big differences in mean scores between the baseline and the experimental condition. The largest difference we have observed is a difference of 0.08 for the cheerful variable. The cause of the small differences between means is that the participants scored a 4 ('Same as normal') for most of the time on all of the variables. An example of this is given in Figure 11 for the cooperative variable. In this figure it can be seen that the majority of scores given is the score 4, with a frequency of 71 in the baseline condition and a frequency of 72 in the experimental condition. The other scores are just sparsely given, for example a score of 5 is only given 9 times in the baseline condition and only 4 times in the experimental condition. This is found for all the other variables as well. Below we discuss the effects per variable in more detail.

Cooperative.

When looking at the cooperative variable at a personal level, we see the influence of the light in the experimental condition is higher for some participants than for others. We also see that the direction of the effect varies between participants. For example for participant 1 we see a negative effect of the light with a difference of 0.25 in means when comparing the baseline and experimental condition. On the other hand, for participant 3 we see that the mean has increased in the experimental condition to 4.13 (0.09), compared to 4 (0) in the baseline condition.

Table 3: Mean scores for the measured variables in the daily questionnaires, the standard error is depicted between brackets.

		Cooperative	Talkative	Friendly	Cheerful	Awake	Calm	Appetite
Participant 1	**Baseline**	4 (0)	4.11 (0.20)	4 (0)	4.22 (0.15)	4.33 (0.33)	3.67 (0.33)	4 (0)
	Experimental	3.75 (0.13)	4.25 (0.18)	4.08 (0.08)	4.08 (0.08)	4.33 (0.26)	3.75 (0.30)	4 (0)
Participant 2	**Baseline**	4 (0)	4 (0)	4.14 (0.14)	4.29 (0.18)	4.29 (0.18)	4 (0)	4 (0)
	Experimental	3.9 (0.23)	4 (0)	4 (0)	3.9 (0.1)	4.1 (0.1)	3.7 (0.21)	3.9 (0.1)
Participant 3	**Baseline**	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)
	Experimental	4.13 (0.09)	4.2 (0.11)	4.13 (0.13)	4.13 (0.09)	4.07 (0.18)	4.07 (0.15)	4.27 (0.12)
Participant 5	**Baseline**	4 (0)	4.08 (0.08)	4.08 (0.08)	4.08 (0.08)	4 (0.12)	4.08 (0.08)	4.08 (0.08)
	Experimental	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)	4 (0)
Participant 6	**Baseline**	4.15 (0.15)	4.15 (0.15)	4.15 (0.15)	4.08 (0.14)	4.15 (0.15)	4.08 (0.08)	4 (0.23)
	Experimental	4 (0)	3.89 (0.11)	4.11 (0.11)	4 (0.17)	3.89 (0.11)	4.11 (0.11)	4 (0)
Overall	**Baseline**	4.04 (0.04)	4.08 (0.05)	4.08 (0.05)	4.12 (0.05)	4.13 (0.08)	3.98 (0.06)	4.02 (0.06)
	Experimental	3.96 (0.06)	4.09 (0.05)	4.07 (0.04)	4.04 (0.05)	4.09 (0.08)	3.93 (0.09)	4.06 (0.04)

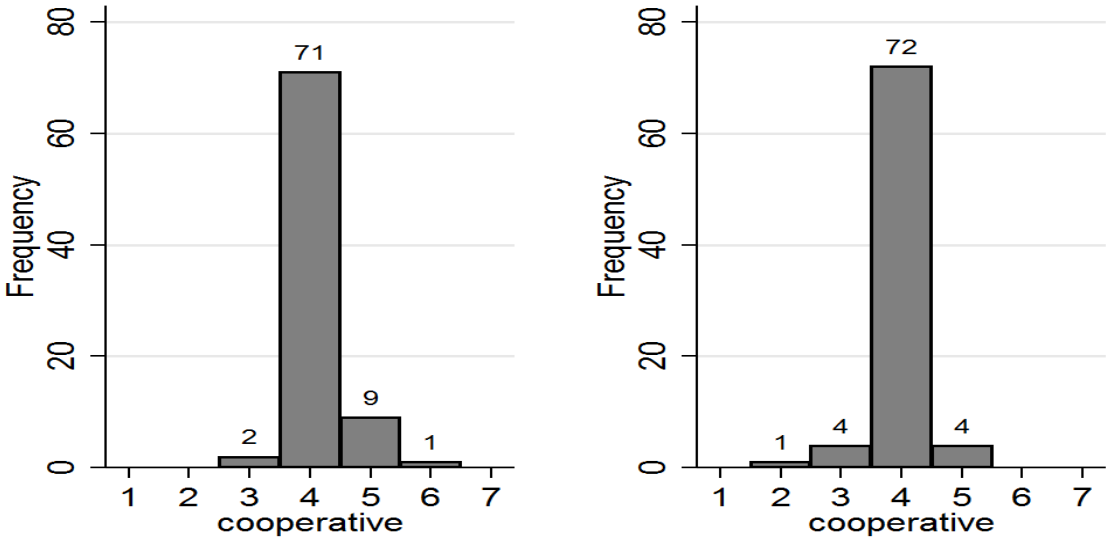

Figure 11: Frequencies of the scores of the cooperative variable. The left graph depicts the frequencies in the baseline condition while the right depicts the frequencies in the experimental condition.

Talkative.

For the question on how talkative the participants were, we see similar results as for the cooperative variable. Again we find that the differences vary in direction and size for the participants. For example, both participant 1 and 3 show a reasonable increase in means in the experimental condition, while participant 6 shows an even larger decrease in the week that the participant was exposed to the light.

Friendly.

In the friendly variable we again see similar results as in the other variables. However, this time the differences are smaller than in the other variables, with the biggest difference being a decrease of 0.14 in the experimental condition for participant 2. We again see that the direction of the effect varies between participants.

Cheerful.

The cheerful variable shows one of the biggest differences overall, in participant 2 we see a decrease of 0.39 in the experimental condition, compared to the baseline. For this variable we also see mostly negative effects of the light on the participants, with the exception of participant 3 who shows a positive effect of light manipulation.

Awake.

We see that for most of the participants the lighting manipulation caused them to be less awake in the experimental condition than in the baseline condition. This time with the exception of participant 1, which did not show any difference, and participant 3, which again shows a small increase.

Calm .

This variable again shows how varied the effects of the light are. We see that some participants were calmer in the experimental condition compared to the baseline, but others were not. Participant 1, 3 and 6 were calmer in the experimental condition. On the other hand, participant 2 and 5 were less calm in the experimental condition.

Appetite.

Appetite was only measured in 2 of the three questionnaires, namely just after lunch and just after dinner. We do not see many big differences in appetite for most participants, only participant three shows a relatively large increase in appetite in the experimental condition.

Other observations.

If we look at the differences across all variables per participant, we see some noteworthy observations. For all the participants except participant 1 and the calm variable for participant 6, we

see that the direction of the effect of the light is the same for each variable. For participant 2, 5 and 6, the score on each variable decreased or stayed the same (with the exception of the calm variable for participant 6, which increased). On the other hand, for participant 3 we only see increases of the mean for each variable in the experimental condition. The directions of the effects for each variable per participant can be seen in Table 4.

Table 4: Direction of the effects of the lighting manipulation. I.e. a "-" means that the average score was lower in the experimental condition compared to the baseline condition. A "=" means there was no difference and a "+ " means that the average score was increased.

	Cooperative	Talkative	Friendly	Cheerful	Wake	Calm	Appetite
Participant 1	-	+	+	-	=	+	=
Participant 2	-	=	-	-	-	-	-
Participant 3	+	+	+	+	+	+	+
Participant 5	=	-	-	-	-	-	-
Participant 6	-	-	-	-	-	+	=

The most noteworthy participant is participant 3. This participant shows a mean score of 4 with a standard error of 0 for each variable in the baseline condition, while showing an increase of the mean for every variable in the experimental condition. These differences range from an increase of 0.07 to an increase of 0.27 in mean. In contrast, participant 5 shows the same but then vice versa. Although the difference between the baseline and experiment condition is smaller, participant 5 shows a mean score of 4 with a standard error of 0 for each variable in the experimental condition, while scoring higher on all the variables in the baseline condition.

Example statistical analysis.

Even though for our data it does not make sense to run a statistical model since we only have 5 participants and a very low power, we will provide an example of a statistical analysis that could be run if a future study were to run a similar experiment but with a larger sample size. The data that we received from the experiment has a nested structure; Therefore we will have to conduct a Linear Mixed Model (LMM) analysis in order to investigate the effect of the lighting manipulation on the variables of interest. In this example analysis we used participant number, measurement week and day of the week as random intercepts. The predictor variables that are used are condition, day and block. These are used in order to investigate the effects of condition, day of the week and time of day on the variable of interest.

In this example LMM analysis we will run the model on the variable "cheerful " of our data. This analysis, surprisingly given our low sample size, yielded a significant effect of lighting condition ($b = 0.09$, $Z = 3.26$, $p = 0.001$), of the 8^{th} day ($b = 0.20$, $Z = 2.85$, $p < 0.05$) while others were not

significant, and the third block (b = -0.08, Z = - 2.26, p < 0.05). The participants were more cheerful in the experimental condition (EMM = 4.15, SE = 0.03) compared to the control condition (EMM = 4.06, SE = 0.04), this is also shown graphically in Figure 12. The significant effect of the third block compared to the other blocks also shows that participants were less cheerful later in the day (EMM = 4.07, SE = 0.04) compared to at the start of the day (EMM = 4.16, SE = 0.06).

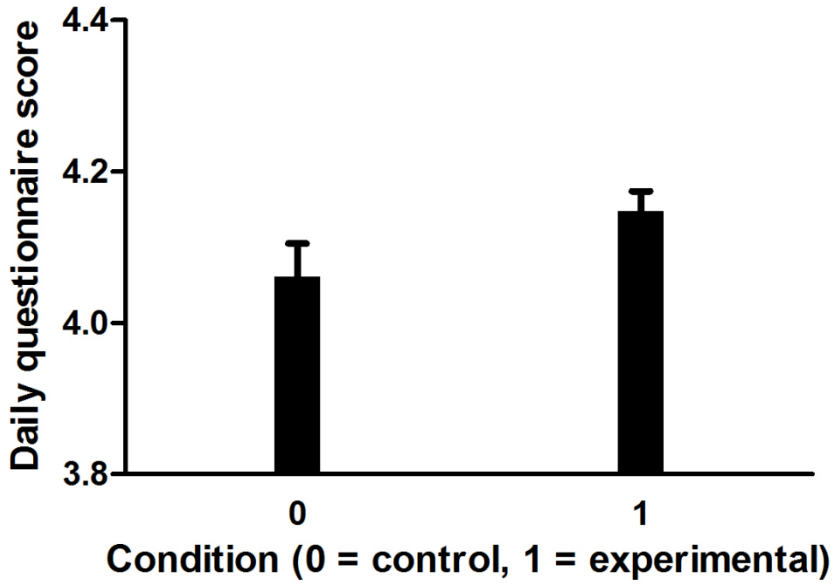

Figure 12: Estimated Marginal Means (EMM's) of the daily questionnaire scores between conditions.

Interviews

In this section we will discuss the insights we gained from conducting the interviews with three nurses of the nursing staff at the nursing home. In addition, we asked others of the nursing staff to fill in a questionnaire, using roughly the same questions as in the interview to gain any extra insights. In total there were 7 respondents of which 3 were interviewed and of which 4 filled in the questionnaire. The respondent of which the used quote belongs to is depicted after the quote, for example (N1) for the first interviewee. The interview and questionnaire were divided into four topics, namely the lighting manipulation including questions about the lamp itself and its output, actigraphy including questions about the actiwatches, the daily questionnaires including questions about the applicability of the questionnaire and questions about the study in general. Each topic will be discussed below using thematic analysis.

Lighting manipulation.

Changes in participants.

The responses of the nursing staff on this theme varied a lot. Some of the nursing staff did notice positive changes of the sleep/wake rhythm, cooperation and mood for the participants.

"You could see a difference in the day and night cycle." (N4)

However, these differences were not found for every participant.

"We did not see changes for 4 of the 6 participants. For 1 client we saw that their mood was better throughout the day and for another client it was mostly improved during the nursing hours in the morning." (N1)

On the other hand, most of the nursing staff reported that they did not notice any differences in the participants.

"I have not noticed any differences." (N5)

"No, I did not see any changes, maybe for participant 5, but that could also be because of their change in medication" (N2)

Response of participants to the lamp in the bedroom

This theme is about how the participants reacted to having the new lamp in their bedrooms. For this theme it was found that most participants did not really respond to the lamp, only that it started out too bright.

"Some clients found that the light was too bright" (*N5)*

"Sometimes when the clients went to bed the lights were still quite bright. However, other than that, nobody was really bothered by it. The ones that I expected to do something against it also did not do anything." (N2)

Other complaints were that sometimes the light was on while the participants wanted to go to sleep.

"One of the clients was bothered by the fact that the light was turned on when he wanted to go to sleep. This was at 19:00." (N1)

Actigraphy.

Wearing of actiwatches.

In general, the actiwatches were worn most of the time, by most participants. There were however some participants who fidgeted with the watch a lot and therefore did not wear it all the time. In addition, the participants did not want to wear the watch above their clothes which was needed in order to measure light exposure.

"They were worn by the clients, but some did not wear them above their sleeves." (N5)

"They were worn pretty well, it differs between participants. The watch is something that the clients often fidget with a lot to have something to do with their hands. It was also lost sometimes by the nursing staff because they put it somewhere when they had to shower the participant and then forgot to put it back on." (N1)

Agitation as a result of actiwatches.

This again is dependent on the participant itself, there were participants that did not really like wearing the actiwatch and therefore took it off sometimes. On the other hand some participants liked the watch so much that they did not want to take it off when they had to.

"There were some participants that took it off themselves, but there was also a client that ran off as soon as I came near because they liked their watch so much and they did not want to take it off." (N2)

"In general they were not really bothered by it, however most of the clients were not used to wearing a watch so sometimes they were a bit annoyed by it." (N1)

Daily questionnaires.

Workload of the daily questionnaires for nursing staff.

In general, most of the nursing staff did not find that the extra workload of filling in the questionnaire three times a day was too much for them. The only problem was that in the morning it was very busy, so oftentimes they filled in the morning questionnaire a bit later during their coffee break or at the same time as the lunch questionnaire.

"In principal it was not that hard to do. I also tried to make sure that the questionnaires were filled in every time, and with that I noticed that it occasionally was forgotten. I myself always filled it in during the coffee break, while others filled it in at the same time as the lunch questionnaire." (N1)

"In the morning until 11:30 you're just very busy. Between the nursing sessions it was not filled in that much, so then it was postponed until lunch. But lengthwise, I think that the questionnaire is fine this way. It doesn't take too long which is very important, because you're so busy. In short, the questionnaire is fine and clear" (N2)

However, the questionnaires could be made even easier by filling in the participant data beforehand. This would decrease the time the nursing staff needs to fill in the questionnaire.

"The questionnaires wouldn't be too much work if the participant data would be filled in beforehand." (N6)

However, the biggest problem that caused a lot of missing questionnaires was not the length of the questionnaire. The cause of most missings was that the nursing staff accidentally forgot to fill in the questionnaires because they were too busy with other things.

"No it was not too much to fill in, but you work in a regular system in which you do one thing after another so it's easy to forget. Even if you placed the papers on a clear spot and you communicate that they have to be filled in you still have to pursue others about it, but that is not because of the questionnaire in itself." (N3)

A suggestion to remedy the forgetting of the questionnaires in the morning would be to put the questionnaires in the closet in the apartments of the participants themselves instead of in the nursing staff office.

"Maybe you should put the questionnaires in the participants' rooms, in the closet. Otherwise as soon as you're in the hallway the next client comes to you for caretaking." (N2)

It was also mentioned by one of the nurses that she had the feeling that a lot of times a score of 4 was filled in because that was easier and faster.

"*I had the feeling that a lot of the time they would just fill in a score of 4, just to be done with it faster.[1]" (N6)*

Quality of the questionnaire.

Overall, the nursing staff was very satisfied with the quality of the questionnaire.

"It's just clear. It is very clearly stated what the questions are and what the response options are. There is also a separate field for any special occurrences. It's just a very clear questionnaire." (N2)

"The questions asked in the questionnaire are the right ones in my opinion, these are the things that we pay attention to during our normal work." (N1)

When asked what the nursing staff would remove or add to the questionnaire, we received several suggestions. It would be good to add a question to specify in which way the participant was cheerful.

"Maybe you could add a questions to the "how cheerful is the participant" question to specify in what way the participant was cheerful. These expressions of cheerfulness can be interpreted in more than one way."

Another suggestion was to add a question about expressions of what the participant thinks about the lamp and the light.

"It might be interesting to see if the clients themselves say something about the lamp and the light, because you have some clients that often express things so you could add that" (N3)

[1] Mentioned during the filling in of the questionnaire, not in the questionnaire itself.

General about the study.

In general the nursing staff was pretty satisfied about how the study went.

"Apart from some small problems with the actiwatches and the filling in of the questionnaire, I think the study went pretty well." (N1)

"I thought everything was clear, well taken care of and well communicated. We had a starting date and discussed the study during a staff meeting where everyone could ask their questions. It was clear what was expected of us." (N3)

Things that could be improved next time a study like this is organized would be a better communication about which lights should be turned on and which lights should be turned off. In this study not all participants had the lights on during the same week, which caused some confusion for the nursing staff.

"What could be done better next time is the communication about when which lamp should be on and which lamp should be off. Now it was sometimes unclear whether or not the plug should be in or out. For example sometimes a plug was in but we were not sure who had done that and if it should be." (N1)

Discussion

The current study explored how elderly patients suffering from dementia experienced dawn/dusk simulation, which was tuned to support their sleep-wake patterns as well as their daytime functioning. The main goal of this research was to gain more insight in how dawn/dusk simulation affects sleep patterns and behavior of this specific research population and how applicable the employed measures are. Before the experiment of the study started, we first investigated the current lighting situation in the nursing home both for daylight contribution and electrical light contribution. This was done to get an insight into how much lighting the clients of the nursing home were already exposed to without the lighting manipulation of our study. During the experiment, a group of seven clients of nursing home "De Riethorst Stromenland", participated in the study for three weeks. However, two of these clients dropped out, leaving us with five participants in total. During these weeks the remaining participants were exposed to the dawn/dusk simulation for one week. The other weeks consisted of one week of recording the normal sleep/wake patterns of the participants and one week of baseline measurements. During these three weeks, the participants also had to wear actiwatches in order to objectively measure the sleep and wake patterns as well as sleep efficiency. In addition, daytime functioning of the clients was subjectively measured through three daily questionnaires which were be filled in by the nursing staff. One questionnaire in the morning, one just after lunch and one just after dinner. The questions in this questionnaire probed how cooperative, friendly, cheerful, awake and calm the client was. In the lunch and dinner questionnaires there was an extra question about the appetite of the client. At the end of the experiment, closing interviews were held with several nurses. The data gathered from the interviews was used to support the conclusions on the applicability of the used methods. In the study, we found that the effects of the lighting manipulation differed a lot between participants. For some it was found to have a positive effect, while for others it was found to have no effect or even a negative effect. These mixed results were found for both sleep and for the daily functioning of the participants. In the case of the applicability of the methods used in this study, we found that all of the used methods had some problems which should be overcome in future studies. It should be noted that the study we conducted was a first explorative study. This means that the sample size was very low, thus the results we found should be considered with caution. In order to confirm these results, the study should be run with a larger sample size.

Current Lighting Situation

The current lighting situation was investigated in both of the common living rooms of the nursing home and for one of the clients' apartments. The daylight contribution was measured in both of the common living rooms of the nursing home, while the electrical light contribution was

measured in both living rooms and the clients' apartments. No daylight contribution measurements were done in the apartment of the client, since the clients were in the common living rooms most of the day. It was found that, for the daylight contribution, the light intensity was quite high close to the window area with lux values of above 1000 lux without luminance screening (in this case a thin curtain in front of the windows) and around 800 lux with luminance screening, vertically at eye level in a seating position. However, this light intensity quickly declined further away from the window, where most clients would be sitting. Around the area where the clients would sit the most, the light intensity often only reached values between 200-400 lux for both with and without luminance screening. Furthest away from the window, in the back of the room, the lighting intensity often did not reach more than 100 lux. Next to this, the clients of the nursing home cannot go outside by themselves when they want to. Because of this, there is not much daylight exposure since they are almost never outside, where the light intensity is much higher than inside. As discussed in the review by Khademagha, Aries, Rosemann & van Loenen (2016), this higher intensity, with a by reviewed studies agreed to threshold of 1000 lux, vertically at eye level, is what humans need for normal functioning. Additionally, this is also dependent on the duration and timing of the exposure to the light. Therefore, it is important that in the nursing home there is maximum usage of the daylight contribution in the rooms to attain an as high as possible light exposure during the day to improve the functioning of the clients living in the nursing home.

The electrical light measures were done in the evening in order to solely measure the light output of the electrical light and to eliminate the daylight contribution. We found that in both living rooms and in the clients' apartments the light intensity was quite low, with the intensity ranging from about 65 to 140 lux. In addition, especially in the clients' apartment, there were quite some dark areas. For example in the clients' apartment there was an area in the corner in which the light intensity only reaches about 25 lux at eye level, in a seating position, on average.

The basic illuminance level for the living rooms in nursing homes is recommended to be between 500 and 1000 lux, horizontally at table level (Stoer, 2006), while in our study we measured vertical illuminance levels. These two types of illuminance levels are not equal and cannot be derived from each other. However, since there is no recommendation available for vertical levels, we have assumed a ratio of 1:2. This means that when using the middle point of the threshold range horizontally at table level of 750 lux, this would correspond to a level of 375 lux vertically at eye level. If we take this value as our threshold, this light intensity is often only reached within 1.8 m of the windows in the direction of the windows itself during the day and almost nowhere when the sun is down. This shows that the lighting in these rooms have a need for improvement in order to reach the desired light intensity levels. However, based on an assessment by Sinoo et al. (2011), the low

values found for this particular nursing home seem to be more common than expected in nursing homes in the Netherlands. Sinoo et al. (2011) assessed 7 different nursing homes with 59 common or living rooms and corridors. In these assessments they found that 55% or more measured vertical and horizontal illuminances in the common rooms fell below their set threshold of 750 lux, with one of the nursing homes even scoring lower than this threshold for almost all of the measurements (13 out of 14). In short, all nursing homes showed a significantly high number of measurements below the 750 lux threshold, which they also based on recommendations by Stoer (2006). This indicates that there is still a lot that can be improved in nursing homes.

Actigraphy

Using visual inspection of the sleep/wake patterns of the participants in the baseline condition we see that the rhythms of the clients are very different from each other. While one of the participants shows quite a stable rhythm for sleep and wake, others show a very fragmented sleep/wake pattern. Visual inspection of the sleep/wake patterns of the participants in the experimental condition shows that the effects of dawn/dusk simulation (DDS) can actually be quite different between participants. While one participant showed positive effects of the DDS, meaning a decrease in variation of sleep onset, offset and duration, we see opposite effects for another participant and a null effect for other participants. When investigating the sleep quality variables, we again do not see a consistent direction of sleep latency. While overall the sleep latency seemed to increase based on visual inspection, on a more personal level we see that for two out of five participants it has increased, while also for two out of five participants the sleep latency has decreased. On the other hand, looking at sleep efficiency, we see a more consistent direction of the effect. For four out of five participants we see a small increase of sleep efficiency in the DDS condition. Same goes for the wake after sleep onset, in which we again observed a decrease in duration of nocturnal awakenings for four out of five participants. This indicates that sleep quality might be improved by the use of DDS. However, it should again be noted that in our study we had a small sample and a large diversity in participants in addition to a short measurement period. In order to prove these effects, it should thus be investigated with a larger sample size, a longer measurement period and preferably also a matched control group.

If we compare these results to the study by Gasio et al. (2006), in which they had thirteen participants in total with nine participants assigned to a DDS condition and four participants assigned to the placebo condition, we see some similar and some different results. They also did not find a significant difference of DDS on sleep and wake timing of the participants. In addition, both we and Gasio et al. found a positive effect on sleep efficiency. However, they also found that the DDS treatment tended to increase sleep duration, amount of immobile phases (which is comparable to

our WASO variable) and to shorten sleep latency. For each of these variables we found opposite effects. There could be several reasons for these differences between results. First and foremost, since both the study by Gasio et al. (2006) and our study had a very low sample size, interpersonal differences could explain a lot of these variations. Similarly, the progression in dementia of the participants could have been different between both studies. Next to this, the studies used different approaches in setting the lights' on and off times of the DDS. While we based the times on the normal sleep/wake patterns of the individual participants, Gasio et al. (2006) defined only two time settings based on time in bed during baseline. This was done by choosing two dates and latitudes to provide the DDS parameters. Additionally, while the DDS in both studies were almost the same, the participants in the study by Gasio et al. (2006) were exposed to the DDS or placebo condition for three weeks in a row, while in our study only one week of DDS was used.

In a study by Leppämäki et al. (2003), they investigated the effect of dawn simulation on subjective sleep quality for a random sample consisting of inhabitants of southern Finland. The dawn simulation in this study started with a light intensity of the lamp of <1 lux, increasing to a value of 100, 200 or 300 lux, depending on the participants' preference. The main outcome measure of the study was sleep quality, using the Groningen Sleep Quality Scale (GSQS; Mulder-Hajonides van der Meulen, Wijnberg, Hollander, De Diana & van der Hoofdakker, 1980). This questionnaire asks questions about the sleep latency, sleep efficiency, sleep duration and nocturnal awakenings. They found that the sleep quality improved constantly and significantly each day. Comparing this to our study we find some similarities. We also found (small) improvements in sleep efficiency and wake after sleep onset. However, we did not find these effects on sleep duration and sleep latency.

While the study performed by Riemersma et al. (2008) had a very different design, there are parts that we can to make our study more effective in the future. In the study, they used a combination of melatonin administration and bright light (around 1000 lux at eye level) throughout the day, while we used DDS as our lighting intervention. This is one of the studies that combined a large sample size with a long sampling period, namely a sample size of 189 participants with a sampling period of up to 3.5 years. During the study, they found much clearer results regarding sleep variables. For example, they found that the combined treatment decreased nocturnal restlessness, increased sleep efficiency and reduced sleep fragmentation. These results indicate that, while in our study we only found small and mixed effects, light has the possibility to improve sleep variables when measured in a larger sample size with a longer sampling period. From this, we can take away that it would be good to improve on these factors in follow-up studies.

Daily Questionnaires

Investigating the effects of the DDS on the variables in the daily questionnaire, we see very small differences between scores in the baseline condition compared to the experimental condition. Often the difference in score for a participant is, on average, around 0.10 on a 7-point scale. Because we only have five participants we cannot say if this difference is because of normal daily variations for the participants or an actual significant difference. There are, however, some notable observations in the daily questionnaire data. We again see that the direction of the differences in daily functioning is often different between participants. For some participants we see positive changes of the DDS in the experimental condition, while for other participants we see negative changes. However, both the negative and positive changes were still small and showed low variability between days. On the other hand, when we look at the direction of the differences in daily functioning within participants, we often see the same direction for all variables for that particular participant. These findings suggest that, while being small differences when averaged across participants and different direction between participants, DDS often has a clear direction of changes per participant. Unfortunately, we cannot compare these finding to other studies, since to the best of our knowledge no other studies has used these variables in a questionnaire format for this particular research population.

Applicability of Methods

In this section we will discuss the applicability of the used methods in the study for this particular research population. These methods are the DDS, the use of the actiwatches and the employment of daily questionnaires.

Dawn dusk simulation.

As has been stated in previous sections, the results that we found regarding the effect of DDS on sleep and daily functioning are mixed and differ between participants. One of the biggest problems that might have caused these mixed effects of DDS is the timing of the lights in the morning and evening. The lights that were used to administer the DDS could only be turned on and off at preprogrammed times. As a result of this, we were not sure whether or not all of the participants actually experienced the lighting manipulation in the experimental condition, since some of the participants showed very fragmented sleep/wake patterns. This made it close to impossible to determine correct times for the lights to turn on and off in the morning and evening.

These incongruent timings of the light also caused participants to being bothered by the light, since sometimes they actually wanted to go to sleep but the light was still on for, for example, another hour, keeping the participant awake. Another annoyance of the light was that it was too bright at the beginning of the cycle in the evening. Besides these problems, there were no other

annoyances caused by the light.

These problems with the timing of the lights could be solved in several ways. One of these ways is to improve the lighting by connecting the lamp to the actiwatches, so that the actiwatches can send information about the sleep and wake pattern of the participants to the lamp. This could enable the lamp to receive information about when the participant is in bed and when they wake up. This could then be used to change the timing of the light when needed. This is necessary, because in this research population the sleep wake pattern is often very fragmented. However, these improvements might prove difficult to implement. Another way is for the nursing staff to bring the participants to bed and waking them up at set times of the day, so that the DDS can be programmed accordingly. This solution is also not ideal since this will put even more strain on the nurses' workload.

Use of actiwatches.

How well the watch was worn was also different between participants. The biggest problem when it comes to consistently wearing the actiwatches is that some participants like to fidget a lot, and the watch is just another thing to fidget with. This caused the participants to take the watch off a lot of times, while not actually being annoyed by it. On the other hand, one of the participants liked the watch so much that he/she did not want to take it off anymore and walked away when he/she was approached by one of the nurses. Another reason for when the watch was not worn by the participant is when one of the nurses took it off in order to let the client take a shower, and then forgetting to put it back on. In addition, the participants did not like to wear the watch above their sleeves, thus it will be hard to investigate the light exposure during the day for this research population using actiwatches.

Next to the wearing of the actiwatches, there were some other problems with using this type of measurements. At times, the watch recorded that the participant was sleeping, while this actually was not the case based on data gathered from the interviews. Reason for this could be is that the participant was sitting very still, causing the watch to measure a sleeping period. This happened quite some times (more for some participants than others), especially during the day. This often made it hard for us to distinguish naps from incorrect data.

These findings show that the employment of actiwatches in order to accurately measure sleep/wake patterns can be problematic if used in this particular research population. In order to improve the accuracy of the measurements the aforementioned problems should be overcome. Improving the percentage of time the actiwatch is worn can be done for example by using watertight actiwatches so that the participants can keep it on during their shower. Improving the accuracy of the measurements of the actiwatches could be done by using observation of the participants by a

dedicated nurse to determine whether or not the participants are actually taking a nap or just sitting very still. Another option might be to implement bed sensors that will measure when the participant is in bed. Commonly used alternatives to measure sleep/wake patterns such as self-reporting are difficult to use for this research population, since the clients are often not capable of answering questions related to this.

Daily questionnaires.

The opinions on the workload of daily questionnaires used in the study were generally positive, most nurses found that the questionnaire was not too much work to do along with their normal work activities. However, we still noticed some problems regarding the workload of the daily questionnaires. The biggest problem was that in the morning, the nurses were much busier than in the afternoon, so the morning questionnaire was often postponed to the afternoon (or to the coffee break). Because of this, the morning questionnaire was often not filled in right after the caretaking of the participant, which might have led to the nurses scoring the questionnaire differently because of recall bias. In addition, it was often forgotten to fill in the questionnaire during the caretaking in the morning, because the questionnaire was located in the office of the nurses instead of in sight in the clients' apartment. There was another signal that the questionnaire was actually a bit too much to fill in next to their normal activities. One of the nurses had the feeling that a lot of the time the nurses would just fill in a score of 4 ("same as normal"), because this was easier and faster. This shows that there was also a possible central tendency bias when the nurses were completing the questionnaire.

Regarding the quality of the questionnaire, it was found that the nurses were very positive. It was said that both the questions asked in the questionnaire and the response options were very clear. In addition, the questions asked in the daily questionnaire were about the things that the nurses also paid attention to throughout the day. This signals that we captured the most important aspects of the daily lives of the participants. There were, however, some things that might improve the daily questionnaire. It was mentioned that it might be a good idea to add another question that specifies the way in which the client expresses him/herself when he/she is cheerful. This was said because there are a lot of different ways in which cheerfulness can be expressed. Next to this, it was mentioned that it might be interesting to add another question that asks about the expressions of the clients themselves about the lamp and the light.

To summarize, the applicability of the daily questionnaires is decent, if some improvements are made to decrease the workload. This needs to be done especially in the morning because that is the most workload heavy part of the day.

Limitations

During the study, there were some limitations that we came across. The first and foremost limitation of our study is the low amount of participants. We started out with seven participants, of which only five remained. This means that the sample size was very low, thus the results we found should be considered with caution. In order to be able to perform statistical tests on the effect of the DDS you need a much larger sample size.

Another limitation of the study is the luminaire that was used. The used luminaire was a prototype and thus did not have the full capabilities needed to provide a perfect DDS. For example, the luminaire could only be programmed in blocks of 15 minutes. This means that no continuous increase or decrease of the light intensity was possible, but instead the light changed in intensity every 15 minutes. Because of this we were not able to perfectly mimic dawn and dusk. Next to this, the lowest light intensity the lamp could provide was already 40 lux at eye level. This is quite a high start of the light, which might have caused participants to wake up right away or to keep them awake during the dusk simulation. In addition, as has been said before, the lamps could only be programmed before the study started. This caused participants to often miss their light exposure in the morning and evening.

Last, the results of the daily questionnaires could be influenced by the particular nurse that completed it on that day. Every nurse has their own view in wat constitutes “better than normal” or "worse than normal” when filing in the questionnaire. In addition to this, some nurses filled the morning questionnaire in during lunch (which is about 4 hours later) and some during their coffee break (about 2 hours later). This could also influence the results due to the nurses incorrectly recalling the participants’ behavior and affective state in the morning. Another influence on the results might be that be that some nurses were more busy than others, causing them to forget to fill in the questionnaire more often or filling in a score of 4 everywhere to be faster. To this end, it is preferable to have this questionnaire filled in by the same nurse about a specific client for each questionnaire. However, with often changing work shifts, this may be challenging.

Future Research

The amount of participants in our study that remained in the end was just 5 participants. This is a very small sample size. Moreover, due to time constraints, the sampling period of the study was 3 weeks with only one week of lighting manipulation and one week of pre-recording. To get better insights in the effects of DDS on this research population, a longer sampling period and a longer lighting manipulation is recommended. If this is done, it should be made sure that the workload of the nursing staff is not increased too much. A possibility to solve the workload problem would be to hire an independent nurse that could fill in the questionnaires for every participant. This

way the normal daily workload of the nurses does not increase and there will be no influence of different people filling in the questionnaire.

Additionally, in future research, it should be considered to employ more objective and subjective measures next to the used measures in this study. Examples of subjective measures are previously tested questionnaires such as the mini-mental state examination (MMSE; Folstein, Folstein & McHugh) to measure cognitive performance, the cornell scale for depression in dementia (CSDD; Alexopoulos, Abrams, Young & Shamolan, 1988; Hardoow, Ownby & Duara, 1998) to measure depression or the neuropsychiatric inventory in the nursing home version (NPI-NH; Cummings et al., 1994) to measure behavioral patterns. These measures are especially relevant for studies of a longer duration, otherwise an effect might not be found. It could also be considered to employ objective measures such as the collection of saliva samples to measure cortisol levels and melatonin levels. These measures were also used in another study by Lieverse et al. (2011) to measure the melatonin and stress response to bright light therapy. This could provide more objective information on the influence of the light treatment on sleepiness and stress.

Another improvement that should be done in future research is overcoming the problems using DDS. The timing of the lights needs to be able to be adapted throughout the study in order to make sure that the participants are actually exposed to the light every day. In addition, lights with more capabilities such as a lower starting light intensity and the ability to gradually and continuously increase and decrease the light intensity should be used. These improvements are needed in order to provide a more accurate DDS.

Last, the current study was conducted during the winter time (namely in February). During this time it becomes light later and dark earlier than during the spring or summer time. This causes the participants to be exposed to lower levels of illuminance during the day than they would have in the spring or summer. This might have had an influence on the effects of the dawn dusk simulation, since there have been studies that found seasonal variations of the effects of light on non-image forming effects (Huiberts, Smolders & de Kort, 2017; Smolders, de Kort & van den Berg, 2013). Therefore, it would be good to conduct more research on the influence of light on dementia in other seasons as well to avoid biased results.

Conclusion

Although previous studies have been conducted investigating the influences of light on elderly suffering from dementia, only few studies investigated the applicability of a different lighting system than one employing bright light. The new insights gathered in this study by using mostly qualitative measures (although with a small sample size) provides a good starting point for future research using DDS for this research population. In the study, it was found that the DDS had small,

mixed effects on the sleep and wake patterns of elderly suffering from dementia. Same goes for the effects on daily functioning of the participants. When looking at the applicability of the measures, we have found varying results. The use of DDS and actigraphy showed some difficulties that need to be overcome in order to properly employ these methods for this research population. Additionally, the daily questionnaires were found to be hard to complete next to the nurses' normal workload. Although during the interviews it was mentioned that the questionnaires were not too long, it was noticed that, especially in the morning, the questionnaires were often forgotten.

Future studies should try to solve the problems associated with these methods when conducting similar research in this particular population. Additionally, we provided several recommendations of improvements that could be used in future studies. In short, this study is one of the first steps forward towards developing a lighting system to support the sleep and wake patterns as well as the daytime functioning of elderly suffering from dementia.

References

Aitken, R. C. (1969). Measurement of feelings using visual analogue scales. *Proceedings of the royal society of medicine*, *62*(10), 989.

Akerstedt , T . (1995) . Work hours, sleepiness and the underlying mechanisms . Journal of Sleep Research , 4 (S2) , 15 – 22 .

Alexopoulos, G. S., Abrams, R. C., Young, R. C., & Shamoian, C. A. (1988). Cornell scale for depression in dementia. *Biological psychiatry*, *23*(3), 271-284.

Ancoli-Israel, S., Klauber, M. R., Jones, D. W., Kripke, D. F., Martin, J., Mason, W., ... & Fell, R. (1997). Variations in circadian rhythms of activity, sleep, and light exposure related to dementia in nursing-home patients. *Sleep*, *20*(1), 18-23.

Avery, D. H., Bolte, M. A., Dager, S. R., Wilson, L. G., Weyer, M., Cox, G. B., & Dunner, D. L. (1993). Dawn simulation treatment of winter depression: a controlled study. *American Journal of Psychiatry*, *150*, 113-113.

Avery, D. H., Bolte, M. A. P., Wolfson, J. K., & Kazaras, A. L. (1994). Dawn simulation compared with a dim red signal in the treatment of winter depression. *Biological psychiatry*, *36*(3), 181-188.

Avery, D. H., Eder, D. N., Bolte, M. A., Hellekson, C. J., Dunner, D. L., Vitiello, M. V., & Prinz, P. N. (2001). Dawn simulation and bright light in the treatment of SAD: a controlled study. *Biological psychiatry*, *50*(3), 205-216.

Badia, P., Myerse, B., Boecker, M., & Culpepper, J. (1991). Bright light effects on body temperature, alertness, EEG and behavior. Physiology & Behavior, 50, 582-588.

Baehr , E.K. , Eastman , C.I. , Revelle , W. , Olson , S.H. , Wolfe , L.F. , & Zee , P.C . (2003) . Circadian phase-shifting effects of nocturnal exercise in older compared with young adults . American

Journal of Physiology – Regulatory and Integrative Comparative Physiology , 284 (6) , R1542 – 1550 .

Barger , L.K. , Wright , K.P. , Jr ., Hughes , R.J. , & Czeisler , C.A . (2004) . Daily exercise facilitates phase delays of circadian melatonin rhythm in very dim light . American Journal of Physiology – Regulatory and Integrative Comparative Physiology , 286 (6) , R1077 – 1084 .

Basics of Alzheimer's disease: what it is and what you can do (2017, June). Retrieved from http://www.alz.org/national/documents/brochure_basicsofalz_low.pdf

Benedetti, F., Colombo, C., Pontiggia, A., Bernasconi, A., Florita, M., & Smeraldi, E. (2003). Morning light treatment hastens the antidepressant effect of citalopram: a placebo-controlled trial. Journal of Clinical Psychiatry, 64(6), 648-653.

Berson, D. M. (2003). Strange vision: ganglion cells as circadian photoreceptors. Trends in Neuroscience, 26, 314-320.

Berson, D. M., Dunn, F. A., & Takao, M. (2002). Phototransduction by retinal ganglion cells that set the circadian clock. Science, 295, 1070-1073.

Boivin, D. B., Duffy, J. F., Kronauer, R. E., & Czeisler, C. A. (1996). Dose-response relationships for resetting of human circadian clock by light. Nature, 379, 540-542.

Bonnet MH and Arand DL (1995) We are chronically sleep deprived. Sleep 18:908-911.

Boulos , Z. , Campbell , S.S. , Lewy , A.J. , Terman , M. , Dijk , D.J. , & Eastman , C.I . (1995) . Light treatment for sleep disorders: consensus report. VII. Jet lag . Journal of Biological Rhythms , 10 (2), 167 – 76 .

Boyce, P. R. (2003). Human Factors in Lighting. Lighting Research Center.

Boyce, P. r., & Cuttle, C. (1990). Effect of correlated color temperature on the perception of interiors and color discrimination performance. Lighting Research and Technology, 22, 16-36

Boyce, P. R., Beckstead, J. W., Eklund, N. H., Strobel, R. W., & Rea, M. S. (1997). Lighting the graveyard shift: The influence of a daylight-simulating skylight on the task performance and mood of night-shift workers. Lighting Research and Technology, 29, 104-134.

Brainard, G. C., Hanifin, J. P., Greeson, J. M., Byrne, B., Glickman, G., Gerner, E., & Rollag, M. D. (2001). Action spectrum for melatonin regulation in humans: evidence for a novel circadian photoreceptor. The Journal of Neuroscience, 21(16), 6405-6412.

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative research in psychology*, 3(2), 77-101.

Cajochen, C., Munch, M., Kobialka, S., Kräuchi, K., Steiner, R., Oelhafen, P., ... & Wirz-Justice, A. (2005). High sensitivity of human melatonin, alertness, thermoregulation, and heart rate to short wavelength light. The Journal of Clinical Endocrinology & Metabolism, 90(3), 1311-1316.

Cajochen, C., Zeitzer, J. M., Czeisler, C. A., & Dijk D-J. (2000). Separation of circadian and wake duration-dependent modulation of EEG activation during wakefulness. Neuroscience, 114, 1047-1060.

Carskadon MA, Acebo C, and Seifer R (2001) Extended nights, sleep loss, and recovery sleep in adolescents. Arch Ital Biol 139:301-312.

Cohen-Mansfield, J., Marx, M. S., & Rosenthal, A. S. (1989). A description of agitation in a nursing home. *Journal of gerontology*, *44*(3), M77-M84.

Cummings, J.L., Mega, M., Gray, K., Rosenberg-Thompson, S., Carusi, D.A., Gornbein, J., 1994. The neuropsychiatric inventory: comprehensive assessment of psychopathology in dementia. Neurology 44, 2308–2314.

Czeisler, C. A., Allan, J. S., Strogatz, S. H., Ronda, J. M., Sanchez, R., Rios, C. D., ... & Kronauer, R. E. (1986). Bright light resets the human circadian pacemaker independent of the timing of the sleep-wake cycle. Science,233(4764), 667-671.

Czeisler , C.A. , Duffy , J.F. , Shanahan , T.L. , Brown , E.N. , Mitchell , J.F. , Rimmer , D.W. , … Kronauer , R.E . (1999) . Stability, precision, and near-24-hour period of the human circadian pacemaker . Science , 284 (5423) , 2177 – 2181 .

Czeisler, C. A., & Wright, K. P. (1999). Influence of light on circadian rhythmicity in humans. In Turek & Zee (EDS.), Regulation of sleep and circadian rhythms (pp 149-180). New York: Marcel Dekker.

Dacey, D. M., Liao, H-W., Peterson, B. B., Robinson, F. R., Smith, V. C., Pokorny, J., Yau, K-W., & Gamlin, P. D. (2005). Melanopsin-expressing ganglion cells in primate retina signal colour and irradiance and project to the LGN. Nature, 433, 749-754.

David-Gray, Z. K., Janssen, J. W., DeGrip, W. J., Nevo, E., & Foster, R. G. (1998). Light detection in a'blind'mammal. Nature neuroscience, 1(8), 655-656.

Dementia: fact sheet (2017, September). Retrieved from http://www.who.int/mediacentre/factsheets/fs362/en/

Deschenes, C. L., & McCurry, S. M. (2009). Current treatments for sleep disturbances in individuals with dementia. *Current psychiatry reports*, *11*(1), 20-26.

Dinges DF, Pack F, Williams K, Gillen KA, Powell JW, Ott GE, Aptowicz C, and Powell JW (1997) Cumulative sleepiness, mood disturbance, and psychomotor vigilance performance decrements during a week of sleep restricted to 4-5 hours per night. Sleep 20:267-277.

Drake , C.L. , Roehrs , T. , Richardson , G. , Walsh , J.K. , & Roth , T . (2004) . Shift work sleep disorder: Prevalence and consequences beyond

Duffy, J. F., & Czeisler, C. A. (2009). Effect of light on human circadian physiology. Sleep Medicine Clinics, 4, 165-177.

Dawson, D., & Campbell, S. S. (1991). Timed exposure to bright light improves sleep and alertness during simulated night shifts. Sleep, 14, 511-516.

Foerch , C. , Korf , H.W. , Steinmetz , H. , & Sitzer , M . (2008) . Abrupt shift of the pattern of diurnal variation in stroke onset with daylight saving time transitions . Circulation , 118 (3) , 284 – 290 .

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). “Mini-mental state”: a practical method for grading the cognitive state of patients for the clinician. Journal of psychiatric research, 12(3), 189-198.

Foster, R. G., Provencio, I., Hudson, D., Fiske, S., De Grip, W., & Menaker, M. (1991). Circadian photoreception in the retinally degenerate mouse (rd/rd).Journal of Comparative Physiology A, 169(1), 39-50.

Fratiglioni L, Rocca WA. Epidemiology of dementia. In: Boller F, Cappa SF, eds. Handbook of Neuropsychology, 2nd ed. Amsterdam: Elsevier, 2001:193–215.

Freedman, M. S., Lucas, R. J., Soni, B., von Schantz, M., Muñoz, M., David-Gray, Z., & Foster, R. (1999). Regulation of mammalian circadian behavior by non-rod, non-cone, ocular photoreceptors. Science, 284(5413), 502-504.

Gasio, P. F., Kräuchi, K., Cajochen, C., van Someren, E., Amrhein, I., Pache, M., ... & Wirz-Justice, A. (2003). Dawn–dusk simulation light therapy of disturbed circadian rest–activity cycles in demented elderly. Experimental gerontology, 38(1), 207-216.

Goel , N . (2005) . Late-night presentation of an auditory stimulus phase delays human circadian rhythms . American Journal of Physiology – Regulatory and Integrative Comparative Physiology , 289 (1) , R209 – 216 .

González-Salvador, T., Lyketsos, C. G., Baker, A., Hovanec, L., Roques, C., Brandt, J., & Steele, C. (2000). Quality of life in dementia patients in long-term care. International journal of geriatric psychiatry, 15(2), 181-189.

Gooley, J. J., Lu, J., Fischer, D., & Saper, C. B. (2003). A broad role for melanopsin I nonvisual photoreception. Journal of Neuroscience, 23, 7093-7106

Gumenyuk , V. , Howard , R. , Roth , T. , Korzyukov , O. , & Drake , C.L . (2014) . Sleep loss, circadian mismatch, and abnormalities in reorienting of attention in night workers with shift work disorder . Sleep , 37 (3) , 545 – 556.

Gumenyuk , V. , Roth , T. , Korzyukov , O. , Jefferson , C. , Kick , A. , Spear , L. , … Drake , C.L . (2010) . Shift work sleep disorder is associated with an attenuated brain response of sensory memory and an increased brain response to novelty: An ERP study . Sleep , 33 (5) , 703 – 713 .

Hamilton, M. (1960). A rating scale for depression. *Journal of neurology, neurosurgery, and psychiatry*, *23*(1), 56.

Hankins, M. W., Peirson, S. N., & Foster, R. G. (2008). Melanopsin: an exciting photopigment. Trends in Neuroscience, 31, 27-36.

Harwood, D. G., Ownby, R. L., Barker, W. W., & Duara, R. (1998). The factor structure of the Cornell Scale for Depression in Dementia among probable Alzheimer's disease patients. *The American Journal of Geriatric Psychiatry*, *6*(3), 212-220.

Hattar, S., Kumar, M., Park, A., Tong, P., Tung, J., Yau, K-W., & Berson, D. M. (2006). Central projections of melanopsin-expressing retinal ganglion cells in the mouse. The Journal of Comparative Neurology, 497, 326-349.

Hattar, S., Liao, H-W., Takoa, M., Berson, D. M., & Yau, K-W. (2002). Melanopsin-containing retinal ganglion cells: Architecture, projections, and intrinsic photosensitivity. Science, 295, 1065-1070.

Helmes, E., Csapo, K. G., & Short, J. A. (1987). Standardization and validation of the multidimensional observation scale for elderly subjects (MOSES). *Journal of Gerontology*, *42*(4), 395-405.

Holmes, D., Teresi, J., Weiner, A., Monaco, C., Ronch, J., & Vickers, R. (1990). Impacts associated with special care units in long-term care facilities. *The Gerontologist*, *30*(2), 178-183.

Horne, J. A., & Ostberg, O. (1976). A self-assessment questionnaire to determine morningness-eveningness in human circadian rhythms. International journal of chronobiology, 4(2), 97-110.

Huiberts, L. M., Smolders, K. C. H. J., & De Kort, Y. A. W. (2017). Seasonal and time-of-day variations in acute non-image forming effects of illuminance level on performance, physiology, and subjective well-being. *Chronobiology international*, *34*(7), 827-844.

Janszky , I. , Ahnve , S. , Ljung , R. , Mukamal , K. J. , Gautam , S. , Wallentin , L. , & Stenestrand , U . (2012) . Daylight saving time shifts and incidence of acute myocardial infarction – Swedish Register of Information and Knowledge About Swedish Heart Intensive Care Admissions (RIKS-HIA) . Sleep medicine , 13 (3) , 237 – 242 .

Janszky , I. , & Ljung , R . (2008) . Shifts to and from daylight saving time and incidence of myocardial infarction . New England Journal of Medicine , 359 (18) , 1966 – 1968 .

Jonghe, J. F., & Kat, M. G. (1996). Factor structure and validity of the Dutch version of the Cohen-Mansfield Agitation Inventory (CMAI-D). *Journal of the American Geriatrics Society*, *44*(7), 888-889.

De Jonghe, J. F., Kat, M. G., Kalisvaart, C. J., & Boelaarts, L. (2003). Neuropsychiatric inventory questionnaire (NPI-Q): A validity study of the Dutch form. *Tijdschr Gerontol Geriatr*, *34*(2), 74-77.

Kantermann , T. , Juda , M. , Merrow , M. , & Roenneberg , T . (2007) . The human circadian clock ’ s seasonal adjustment is disrupted by daylight saving time . Current Biology , 17 (22) , 1996 – 2000 .

Karni A and Sagi D (1993) The time course of learning a visual skill. Nature 365:250-252.

Katz, S. F. A. M. (1963). The index of ADL: a standardized measure of biological and psychosocial function. *J Am Med Assoc*, *185*, 914-919.

Kaufer, D. I., Cummings, J. L., Ketchel, P., Smith, V., MacMillan, A., Shelley, T., ... & DeKosky, S. T. (2000). Validation of the NPI-Q, a brief clinical form of the Neuropsychiatric Inventory. *The Journal of neuropsychiatry and clinical neurosciences*, *12*(2), 233-239.

Khademagha, P., Aries, M. B. C., Rosemann, A. L. P., & van Loenen, E. J. (2016). Implementing non-image-forming effects of light in the built environment: A review on what we need. *Building and Environment*, *108*, 263-272.

Knauth , P. , Landau , K. , Droge , C. , Schwitteck , M. , Widynski , M. , & Rutenfranz , J . (1980) . Duration of sleep depending on the type of shift work . International Archives of Occupational and Environmental Health , 46 (2) , 167 – 177 .

Lahti , T.A. , Haukka , J. , Lonnqvist , J. , & Partonen , T . (2008) . Daylight saving time transitions and hospital treatments due to accidents or manic episodes . BMC Public Health , 8 , 74 .

Lawton, M. P. (1975). The Philadelphia geriatric center morale scale: A revision. *Journal of Gerontology*, *30*(1), 85-89.

Lawton, M. P., Van Haitsma, K., & Klapper, J. (1996). Observed affect in nursing home residents with Alzheimer's disease. *The Journals of Gerontology Series B: Psychological Sciences and Social Sciences*, *51*(1), P3-P14.

Lee, H. B., & Lyketsos, C. G. (2003). Depression in Alzheimer’s disease: heterogeneity and related issues. Biological psychiatry, 54(3), 353-362.

Leontjevas, R., Gerritsen, D. L., Vernooij-Dassen, M. J., Teerenstra, S., Smalbrugge, M., & Koopmans, R. T. (2011). Nijmegen Observer-Rated Depression scale for detection of depression in nursing home residents. Int J Geriatr Psychiatry. doi: 10.1002/gps.2819

Lewy, A. J., Wehr, T. A., Goodwin, F. K., Newsome, D. A., & Markey, S. P. (1980). Light suppresses melatonin secretion in humans. Science, 210, 1267-1269.

Lockley, S. W., Evans, E. E., Scheer, F. A. J. L., Brainard, G. C., Czeisler, C. A., & Aeschbach, D. (2006). Short-wavelength sensitivity for the direct effects of light on alertness, vigilance, and the waking electroencephalogram in humans. SLEEP-NEW YORK THEN WESTCHESTER-, 29(2), 161.

Lucas, R. J. (2013). Mammalian inner retinal photoreception. Current Biology, 23, 125-133.

Lucas, R. J., Douglas, R. H., & Foster, R. G. (2001). Characterization of an ocular photopigment capable of driving pupillary constriction in mice. Nature neuroscience, 4(6), 621-626.

Lucas, R. J., Freedman, M. S., Muñoz, M., Garcia-Fernández, J. M., & Foster, R. G. (1999). Regulation of the mammalian pineal by non-rod, non-cone, ocular photoreceptors. Science, 284(5413), 505-507.

Martiny, K. (2004). Adjunctive bright light in non-seasonal major depression. *Acta Psychiatrica Scandinavica*, *110*(s425), 7-28.

McIntyre, I. M., Norman, T. R., Burrows, G. D., & Armstrong, S. M. (1989). Human melatonin suppression by light is intensity dependent. Journal of Pineal Research, 6, 149-156.

van der Meulen, M. H. (1980). WREH Mulder-Hajonides van der Meulen, JR Wijnberg, JJ Hollander, IPF De Diana, RH van den Hoofdakker. *Measurement of subjective sleep quality, Eur. Sleep Res. Soc. Abstr*, *5*, 98.

Morris, J.C., Heyman, A., Mohs, R.C., Hughes, J.P., van Belle, G., Fillenbaum, G., Mellits, E.D., Clark, C., 1989. The consortium to establish a registry for Alzheimer's Disease (CERAD). Part I. Clinical and neuropsychological assessment of Alzheimer's disease. Neurology 39, 1159–1165.

Myers, B. L., & Badia, P. (1993). Immediate effects of different light intensities on body temperature and alertness. Physiology & Behavior, 54, 199-202.

Natale, V., Adan, A., Chotai, J. (2002). Further results on the association between morningnesseveningness preference and the season of birth in human adults. Neuropsychobiology 46:209–14.

Partonen T, Pandi-Perumal SR (Eds.), (2010). Seasonal Affective Disorder: Practice and Research. 2nd edn. Oxford University Press, Oxford.

Phipps-Nelson, J., Redman, J. R., Dijk, D-J., & Rajaratman, S. M. W. (2003). Daytime exposure to bright light, as compared to dim light, decreases sleepiness and improves psychomotor vigilance performance. Sleep, 26, 695-700.

Provencio, I., Rodriquez, I. R., Jiang, G., Hayes, W. P., Moreira, E. F. & Rollag, M. D. (2000). A novel human opsin in the inner retina. Journal of Neuroscience, 20, 600-605.

Purandare, N., Burns, A., Craig, S., Faragher, B., & Scott, K. (2001). Depressive symptoms in patients with Alzheimer's disease. International journal of geriatric psychiatry, 16(10), 960-964.

Rea, M. S. (2000). The IESNA lighting handbook: Reference and application. New York, NY: Illuminating Engineering Society of North America.

Revell, V. L., Arendt, J., Fogg, L. F., & Skene, D. J. (2006). Alerting effects of light are sensitive to very short wavelengths. Neuroscience letters, 399(1), 96-100.

Riemersma-Van Der Lek, R. F., Swaab, D. F., Twisk, J., Hol, E. M., Hoogendijk, W. J., & Van Someren, E. J. (2008). Effect of bright light and melatonin on cognitive and noncognitive function in elderly residents of group care facilities: a randomized controlled trial. Jama, 299(22), 2642-2655.

Roenneberg, T., Wirz-Justice, A., & Merrow, M. (2003). Life between clocks: daily temporal patterns of human chronotypes. Journal of biological rhythms, 18(1), 80-90.

Rüger, M., Gordijn, M. C. M., Beersma, D. G. M., de Vries, B., & Daan, S. (2006). Time-of-day-dependent effects of bright light exposure on human psychophysiology: comparison of daytime and nighttime exposure. American Journal of Physiology-Regulatory, Integrative and Comparative Physiology, 290, 1413-1420.

Ryden, M. B., & Knopman, D. (1989). Assess not assume: measuring the morale of cognitively impaired elderly. *Journal of gerontological nursing*, *15*(11), 27-32.

Schibler , U. , & Sassone-Corsi , P . (2002) . A web of circadian pacemakers. Cell , 111 (7) , 919 – 922

Schmidt, T., Chen, S.K., & Hattar, S. 2011. Intrinsically photosensitive retinal ganglion cells: many subtypes, diverse function. Trends in Neurosciences, 34, 572-580

Sekuler, R., & Blake, R. (2002). Perception (4th edition). New York, NY: McGraw-Hill.

Shapiro , C.M. , Blake , F. , Fossey , E. , & Adams , B . (1990) . Daylight saving time in psychiatric illness . Journal of Affective Disorders , 19 (3) , 177 – 181 .

Sheikh, J.A., Yesvage, J.A., 1986. Geriatric depression scale (GDS): recent findings and development of a shorter version. In: Brink, T.L., (Ed.), Clinical Gerontology: A Guide to Assessment and intervention, Harworth, New York, pp. 165–173.

Smolders, K. C. H. J., De Kort, Y. A. W., & van den Berg, S. M. (2013). Daytime light exposure and feelings of vitality: Results of a field study during regular weekdays. *Journal of Environmental Psychology*, *36*, 270-279.

Van Someren, E.J.W., Swaab, D.F., Colenda, C.C., Cohen, W., Mc Call, W.V., Rosenquist, P.B., 1999. Bright light therapy: improved sensitivity to its effects on rest–activity rhythms in Alzheimer patients by application of nonparametric methods. Chronobiol. Int. 16, 505–518.

Soni, B. G., Philp, A. R., Foster, R. G., & Knox, B. E. (1998). Novel retinal photoreceptors. Nature, 394, 27-28.

Souman, J. L., Tinga, A. M., te Pas, S. F., van Ee, R., & Vlaskamp, B. N. (2017). Acute alerting effects of light: a systematic literature review. *Behavioural Brain Research*.

Stoer GW, editor. Licht, welzijn en de ouder wordende mens. 1st ed. The Netherlands: Nederlandse Stichting Voor Verlichtingskunde, Ede; 2006 [in Dutch].

Terman, M., Schlager, D., Fairhurst, S., Perlman, B., (1989). Dawn and dusk simulation as a therapeutic intervention. Biol. Psychiatry 25, 966–970.

Terman, M., & Terman, J. S. (2006). Controlled trial of naturalistic dawn simulation and negative air ionization for seasonal affective disorder. *American Journal of Psychiatry*, *163*(12), 2126-2133.

Terman, J.S., Terman, M., Lo, E.S., Cooper, T.B., (2001). Circadian time of morning light administration and therapeutic response in winter depression. Arch. Gen. Psychiatry 58, 69–75.

Thapan, K., Arendt, J., & Skene, D. J. (2001). An action spectrum for melatonin suppression: evidence for a novel non-rod, non-cone photoreceptor system in humans. The Journal of Physiology, 535, 261-267.

Vandewalle, G., Balteau, E., Philips, C., Degueldre, C., Moreau, V., Sterpenich, V., Albouy, G., Darsaud, A., Desseilles, M., Dang-Vu, T. T., Peigneux, P., Luxen, A., Dijk, D-J., & Maquet, P. (2006). Daytime light exposure dynamically enhances brain responses. Current Biology, 16, 1616-1621.

Vandewalle, G., Maquet, P., & Dijk, D-J. (2009). Light as a modulator of cognitive brain function. Trends in Cognitive Sciences, 13, 429-438.

Velds, M., & Christoffersen, J. (2001). Monitoring procedures for the assessment of daylighting performance of buildings. *Daylighting in buildings: a source book on daylighting systems and components*.

Vogels, I. M. L. C., & Bronckers, X. (2009). The effect of context and lighting characteristics on the perceived atmosphere of a space. Proceedings Experiencing Light 2009, the Netherlands, Eindhoven.

Wirz-Justice A (2006). Biological rhythm disturbances in mood disorders. Int Clin Psychopharmacol 21: 511-515.

Wood, B., Rea, M. S., Plitnick, B., & Figueiro, M. G. (2013). Light level and duration of exposure determine the impact of self-luminous tablets on melatonin suppression. Applied Ergonomics, 44, 237-240.

Wright, H. R., Lack, L. C., & Kennaway, D. J. (2004). Differential effects of light wavelength in phase advancing the melatonin rhythm. Journal of pineal research, 36(2), 140-144.

Yokoi, M., Aoki, K., Shiomura, Y., Iwanaga, K., & Katsuura, T. (2003). Effect of bright light on EEG activities and subjective sleepiness to mental task during nocturnal sleep deprivation. Journal of physiological anthropology and applied human science, 22(6), 257-263.

Zee, P. C., & Turek, F. W. (1999). Introduction to sleep and circadian rhythms. In Turek & Zee (Eds.), Regulation of sleep and circadian rhythms (pp 1-17). New York: Marcel Dekker.

Zeitzer, J. M., Dijk, D-J., Kronauer, R. E., Brown, E. N., & Czeisler, C. A. (2000). Sensitivity of the human circadian pacemaker to nocturnal light: melatonin phase resetting and suppression. Journal of Physiology, 526, 695-702.

Zung, W. W. (1965). A self-rating depression scale. *Archives of general psychiatry*, *12*(1), 63-70.

Appendix A

Table 5: Outcome measured used in the studies by Riemersma et al. and Gasio et al.. Filled in black means the corresponding measure is used in the study.

Outcomes	Outcome measures	Definition of outcome measure	Riemersma et al.	Gasio et al.
Cognitive performance	MMSE		■	■
	CERAD			■
Mood	CSDD		■	
	GDS			■
Self-Esteem	PGCMS		■	
Behavior	PGCARS		■	
	MOSES		■	
	NPI-Q		■	
	NPI-NH			■
	CMAI		■	
Limitations of activities	NI-ADL			■
Actigraphy	Quantity of sleep and wakefullness	Duration of sleep	■	
		Onset latency	■	
		Nocturnal Restlessness	■	
	within sleep structure	Average durations of nocturnal awakenings	■	■
		Average durations of uninterrupted sleep	■	
	Motor activity			■
	Light exposure			■
	Circadian rhythm organization	Intradaily Stability (IS)		■
		Interdaily Variability (IV)		■
	Circadian phase			■
	Relative Amplitude (RA)	Most active 10 hour period (M10)		■
		Least active 5 hour period (L5)		■

Note: outcome measures shown in the table are the Mini-Mental State Examination (MMSE; Folstein, Folstein & McHugh, 1975), neuropsychological tests developed for the Consortium to Establish a Registry for Alzheimer's disease (CERAD; Morris et al., 1989), Cornell Scale for Depression in Dementia (CSDD; Alexopoulos, Abrams, Young & Shamolan, 1988; Hardoow, Ownby & Duara, 1998), Geriatric depression scale (GDS; Sheikh and Yesvage, 1986), Philadelphia Geriatric Centre Moral Scale (PGCMS; Lawton, 1975; Ryden & Knopman, 1989), Philadelphia Geriatric Centre Affect Rating Scale (PGCARS; Lawton, Haitsma & Klapper, 1996), Multi Observational Scale for Elderly Subjects (MOSES; Helmes, Csapo & Short, 1987), Neuropsychiatric Inventory (NPI-Q; de Jonghe, Kat, Kalisvaart & Boelaarts, 2003; Kaufer, Cummings & Ketchel, 2000), Neuropsychiatric Inventory in the nursing home version (NPI-NH; Cummings et al., 1994), Cohen-Mansfield Agitation Index (CMAI; Cohen-Mansfield & Rosenthal, 1989; de Jonghe & Kat, 1996) and the Nurse-Informant Adaptation (NI-ADL; Holmes et al., 1990; Katz, 1963). Interdaily Stability gives an indication of how strong the coupling between zeitgebers and the rest-activity rhythm is, while the Interdaily variability is a measure of the fragmentation of the rhythm (Van Someren et al., 1999).

Appendix B

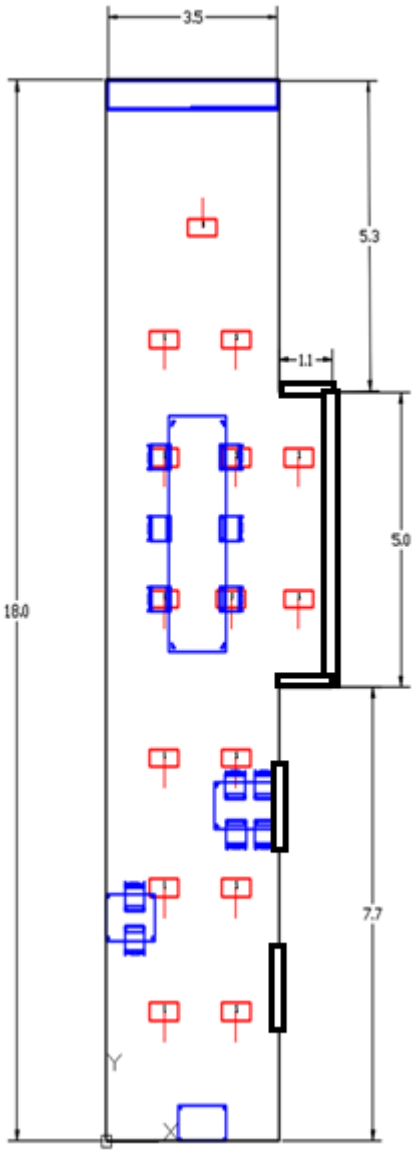

Figure 13: Schematic of living room 1. Red items depict the luminaires in the room, blue items depict furniture in the room.

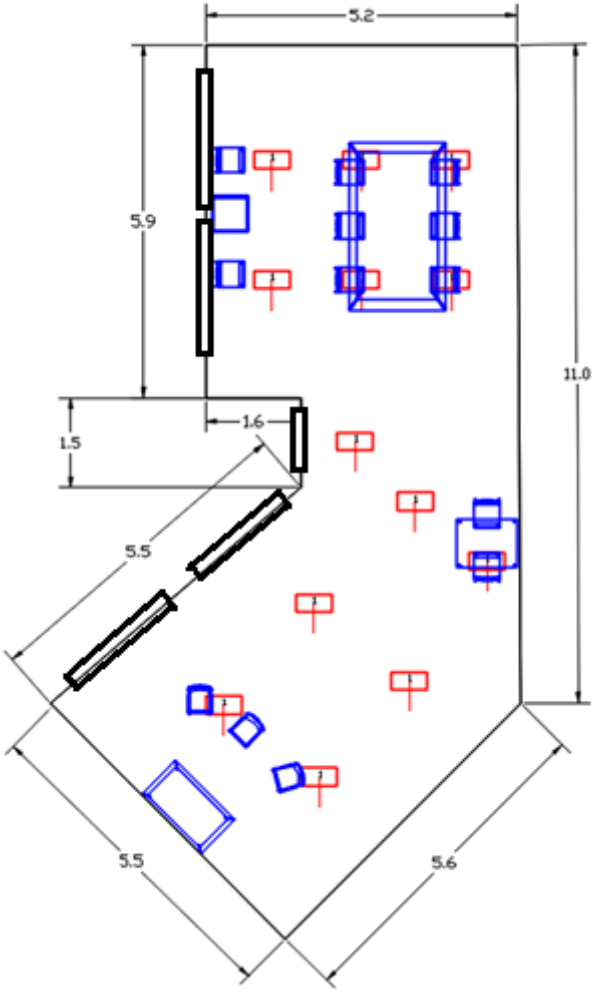

Figure 14: Schematic of living room 2. Red items depict the luminaires in the room, blue items depict furniture in the room.

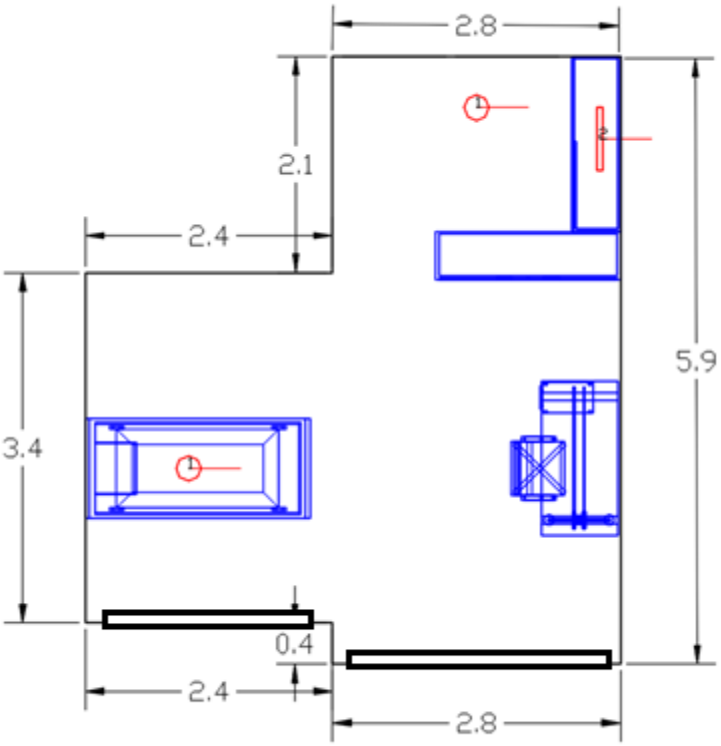

Figure 15: Schematic of the apartment of the client. Red items depict the luminaires in the room, blue items depict furniture in the room.

Appendix C

Daily questionnaires

Morning questionnaire.

Klantnaam:_____ _____ **Geboortedatum klant_____**(dd/mm/yyyy)

Participant nummer: ___ **Invuldatum:** _____ (dd/mm/yy) **Ingevuld door:_____**

Tijd: _____ (hh:mm**)** **Opstatijd klant: _____** (hh:mm)

Gelieve deze lijst in te vullen tijdens de verzorgperiode net na het opstaan van de betreffende klant door een kruisje te zetten bij de score die de situatie het beste weergeeft. De schaal in deze vragenlijst loopt van 1 (Veel minder dan normaal) tot 7 (Veel meer dan normaal). De overige betekenissen van de nummers kunnen gevonden worden in de vragenlijst. Graag de score bepalen door de huidige situatie te vergelijken met de normale situatie, zoals beschreven in de instructies.

	1. Veel minder dan normaal	**2. Minder dan normaal**	**3. Enigszins minder dan normaal**	**4. Hetzelfde als normaal**	**5. Enigszins meer dan normaal**	**6. Meer dan normaal**	**7. Veel meer dan normaal**
Hoe goed werkte de klant mee?							
Hoe spraakzaam is de klant?							
Hoe vriendelijk is de klant?							
Hoe opgewekt is de klant?							
Hoe wakker is de klant?							
Hoe rustig is de klant?							
Bijzonderheden vanuit nachtdienst	Beschrijf hier eventuele bijzonderheden die zijn opgetreden tijdens de nacht.						
Bijzonderheden	Beschrijf hier eventuele bijzonderheden die zijn opgetreden. Eventuele problemen met de actiwatches (de horloges) kunnen hier ook genoteerd worden.						

Lunch and Dinner Questionnaire.

Klantnaam:_____ _____ **Geboortedatum klant_____**(dd/mm/yyyy)

---✂

Participant nummer: ___ **Invuldatum:** _____ (dd/mm/yy) **Ingevuld door:_____**

Tijd: _____ (hh:mm**)**

Gelieve deze lijst in te vullen net na de lunch van de betreffende klant door een kruisje te zetten bij de score die de situatie het beste weergeeft. De schaal in deze vragenlijst loopt van 1 (Veel minder dan normaal) tot 7 (Veel meer dan normaal). De overige betekenissen van de nummers kunnen gevonden worden in de vragenlijst. Graag de score bepalen door de huidige situatie te vergelijken met de normale situatie, zoals beschreven in de instructies.

	1. Veel minder dan normaal	**2. Minder dan normaal**	**3. Enigszins minder dan normaal**	**4. Hetzelfde als normaal**	**5. Enigszins meer dan normaal**	**6. Meer dan normaal**	**7. Veel meer dan normaal**
Hoe goed werkte de klant mee?							
Hoe spraakzaam is de klant?							
Hoe vriendelijk is de klant?							
Hoe opgewekt is de klant?							
Hoe wakker is de klant?							
Hoe rustig is de klant?							
Hoe goed is de eetlust van de klant?							
Bijzonderheden	Beschrijf hier eventuele bijzonderheden die zijn opgetreden. Eventuele problemen met de actiwatches (de horloges) kunnen hier ook genoteerd worden.						

Nijmegen Observer-Rated Depression (NORD) scale

Deze vragenlijst is anders dan de dagelijkse vragenlijsten. Hij wordt in totaal twee keer afgenomen, een keer voordat de studie begint en een keer als de studie is afgelopen. Dit om te kijken of in de weken dat de studie loopt er verandering is opgetreden als gevolg van het veranderde licht. Het is belangrijk dat deze vragenlijst beide keren door dezelfde persoon ingevuld wordt. Bij het invullen van de vragenlijst wordt er gevraagd om 'ja' te beantwoorden wanneer het gedrag wel voorkomt, en 'nee' wanneer het gedrag niet gezien is. Antwoord ook 'nee' als het gedrag niet van toepassing is op de cliënt. De term 'vaak' in deze vragenlijst betekent dat het gedrag "op meer dagen wel dan niet in tenminste de laatste twee weken, meerdere uren" aanwezig is geweest. Na het invullen van vragen 1 tot en met 5, wordt er gevraagd om een totaalscore in te vullen. Deze totaalscore is de punten van de vragen 1 tot en met 5 bij elkaar opgeteld.

Cliëntnaam:_____ _____ **Geboortedatum cliënt_____**(dd/mm/yyyy)

---✂

Participant nummer: ___ **Invuldatum:** _____ (dd/mm/yy) **Ingevuld door:_____**

Tijd: _____ (hh:mm**)**

Instructie

- De Eerst Verantwoordelijke Verzorgende vult de NORD schaal in
- Antwoord 'ja' wanneer het gedrag voorkomt. Antwoord 'nee' wanneer u het gedrag niet hebt gezien de afgelopen week. Antwoord ook 'nee' als het gedrag op de cliënt niet van toepassing is. "Vaak" betekent hier dat het gedrag "op meer dagen wel dan niet in tenminste de week, meerdere uren" aanwezig is geweest.

	Ja	**Nee**
1. Maakt de cliënt vaak een verdrietige, sombere of moedeloze indruk?		
2. Huilt de cliënt vaak of is hij/zij vaak geëmotioneerd?		
3. Ontbreekt bij de cliënt vaak een positieve reactie op sociale contacten of op plezierige gebeurtenissen?		
4. Moet de cliënt vaak worden aangemoedigd om iets te ondernemen of deel te nemen aan gezamenlijke activiteiten?		
5. Zijn er vaak problemen met slapen (inslapen, doorslapen, wakker worden) of met eten (geen eetlust, ongewoon veel trek)?		
TOTAALSCORE Scoor '1' voor iedere 'JA' en tel op	☐	