Ambient bright light improves behaviour and circadian rhythmicity of institutionalised older adults with dementia

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SUMMARY

Behavioural disturbances, such as nocturnal restlessness and wandering, are seen in 90% of patients with dementia at some point in their course. Non-pharmacologic interventions, such as high intensity lighting, can play an important role in managing these behavioural disturbances by impacting both the visual and the circadian system. In order to assess the behavioural and physiological effects of prolonged exposure to high intensity light on institutionalised older adults with dementia, ceiling-mounted luminaires emitting bluish (6,500 K) and yellowish (2,700 K) light (about 1,800 lx horizontal on table level) were installed in an intervention group (n=15) that was compared to a control group of traditional dim lighting equipment (n=10). The study was performed from May to August 2006. Effects of lighting were assessed by the Dutch Behaviour Observation Scale for Intramural Psychogeriatrics (GIP), and tympanic temperature measurements. In the bluish light scenario, a significant improvement in restless behaviour was observed in the intervention group, as well as a significant increase in the range of tympanic temperature. Further evidence is found that high intensity bluish light may play a role in managing restless behaviour and improving circadian rhythmicity in institutionalised older adults with dementia.

KEYWORDS
Dementia, Older adults, Lighting, Behaviour, Circadian rhythmicity

INTRODUCTION
Worldwide, millions of people suffer from dementia, a syndrome characterised by cognitive impairments, behavioural disturbances, sleep-wake disturbances, and insomnia. Unfortunately, there is currently no cure and only little can be done to manage these disturbances associated with dementia. This makes it very difficult for a partner or relatives to take care of people with dementia in their own sheltered environment, which often leads to institutionalisation. In institutional settings, the problems often continue and become a part of the daily routine for medical and nursing staff.

Light plays an important role in regulating important biochemical processes and neuroendocrine control (for instance, melatonin and cortisol) via the eye (Hughes and Neer, 1981). Light exposure is the most important stimulus for synchronising the biological clock (Czeisler et al., 1986), suppressing pineal melatonin production (Brainard et al., 1997) and elevating core body temperature (Badia et al., 1991). The circadian system is orchestrated by the hypothalamic suprachiasmatic nuclei (SCN). If the clock is not synchronised it will lose its 24-hour cycle, influencing virtually all tissues in the human body, and even more

pronouncedly leads to a loose sleep-wake rhythm. In Alzheimer patients, the SCN are affected by atrophy of the brain, which leads to the behavioural problems.

In the eye, light also activates intrinsically photosensitive retinal ganglion cells (ipRGCs), which discharge nerve impulses that are transmitted to the SCN. These ipRCGs have a different action spectrum from the photoreceptors for scotopic and photopic vision, and show short-wavelength sensitivity (bluish light). Rods, cones and ipRGCs participate in mammalian circadian phototransduction. In older adults, the orchestration by the SCN requires ocular light levels that are significantly higher than those required for proper vision (Aarts and Westerlaken, 2005). Many older adults are not exposed to high enough illuminance levels, due to poorly-lit homes (up to 400 lx), and the short periods of time spent outdoors, where horizontal illuminances can reach between 10,000 and 100,000 lx. Also, a decreased lens transmittance, and eye deficiencies contribute to less light reaching the retina of older adults (Aarts and Westerlaken, 2005).

It is hypothesised that high intensity lighting, with luminance levels of well over 1,000 lx, may play a role in the management of dementia. Van Someren et al. (1997) showed that a prolonged increase in daytime environmental illuminance by ceiling-mounted lighting equipment improved the stability of the rest-activity rhythm in older adults with dementia. Sloane et al. (2007) studied the effects of high-intensity light in public areas of long-term care facilities and found that night-time sleep of older adults with dementia improved. This most adequate form of lighting, that offers light to people in an ethical and unobtrusive way, is yet to be researched and modelled in more detail, since lighting equipment is poorly described in most experiments.

This field study aims to assess the behavioural and physiological effects of prolonged exposure to high intensity light with a high, bluish correlated colour temperature (CCT), and a low, yellowish correlated colour temperature, emitted from ceiling-mounted luminaires on institutionalised older adults with dementia, compared to a control group of traditional dim lighting equipment.

METHODS

A quasi-experiment was carried out among institutionalised older people with dementia, residing in a psychogeriatric ward in Eindhoven, the Netherlands. The ward consisted of three different communal living rooms, which in turn were connected to private bedrooms by a circular corridor. One of the three living rooms (Room 2) was used as the control room, Rooms 1 and 3 were used for the experimental lighting protocol. The study was performed between May and August 2006.

Subjects

Informed consent was signed by 42 residents and/or their responsible relatives out of a total population of 61 residents of the psychogeriatric ward. Of these 42 residents, only 26 people started with the test protocol. The control group consisted of 10 people, and the intervention group of 16 people. In the control group, 1 person passed away during intervention 2, and 1 person did not participate in the tympanic temperature measurements because of hearing aids. Institutionalisation took place on the basis of an indication for psychogeriatric care by a needs assessment centre. All participants were clinically diagnosed by the medical staff, resulting in diagnoses of probable Alzheimer's disease (AD), vascular dementia (VD), or mixed Alzheimer's disease and vascular dementia (MX) (Table 1). There was no clinical basis for assigning the people over the living rooms when entering the nursing home. The residents had

been living in that ward for 22±19 (mean, SD) months with a minimum of 3 months and a maximum of 77 months.

In general, the people were out of bed between 7 am and 9 pm. During the night, people stayed in bed for 11 hours on average. Some residents also went to bed for a nap around 1:30 pm. During day time, most residents were involved in sedentary activities, which included reading and watching television. In the experimental period, 7 people stayed indoors all the time and the rest went outdoors for a limited duration. This behaviour was equally distributed for all groups. Meals (8-10 am, 12 am and 5 pm), as well as tea and coffee (7 am, 10:30 am, 4 pm, 7 pm and 9 pm) were served in the shared living rooms under the test lighting.

The three living rooms were situated on the ground floor. The facades were facing different directions. About two thirds of the façade of intervention room (Room 3) and the control room consisted of windows. This was about 50% in Room 1.

Table 1. Population of the wards.

	Gender		Age [years]		Clinical diagnosis		
	Male	Female	Mean	SD	AD	VD	MX
Control group	3	7	84.4	5.7	6	1	3
Intervention group	4	12	86.3	7.6	10	5	1
Total	7	19	85.6	6.9	16	6	4

Figure 1. View of the psychogeriatric ward, with the lighting equipment installed above the tables.

Lighting
In order to obtain the highest illuminance at eye level without causing visual comfort, the existing luminaires, situated above 2 table clusters, in the intervention rooms (Figure 1), were replaced by 5 new luminaires (type Philips Strato TPH710 SKY). Each contained 8 TL5 fluorescent lamps (TL5-49W/827 or TL5-49W/865). The colour rendering index (R_a) of the lamps were classified as good (85). Based on simulations in the computer program DIALux 4.1 by DIAL GmbH, an arrangement of luminaires was designed in order to obtain the largest illuminance level on vertical eye level as possible. The most efficient layout was a combination of two clusters of luminaires, i.e., one cluster of 2 and a second cluster of 3

luminaires above the dining tables (Figure 2). When measuring the equipment at night, to exclude daylight, horizontal illuminance levels at table height reached 1,750 to 1,810 lx. During daytime, no higher illuminances than 3,000 lx were obtainable in that setting. During the intervention, the lighting was switched on at 7:30 am rising in half an hour from 200 lx to the maximum level. At 6 pm the lighting was gradually lowered to 200 lx again. The lamps had a CCT of 6,500 K (very cool white, bluish), during the first intervention, and during the second intervention the CCT was 2,700 K (extra warm white, yellowish). In the control living room the normal lighting was not replaced, resulting in a horizontal illuminance between 200-300 lx of a warm white colour (CCT 2,700 K).
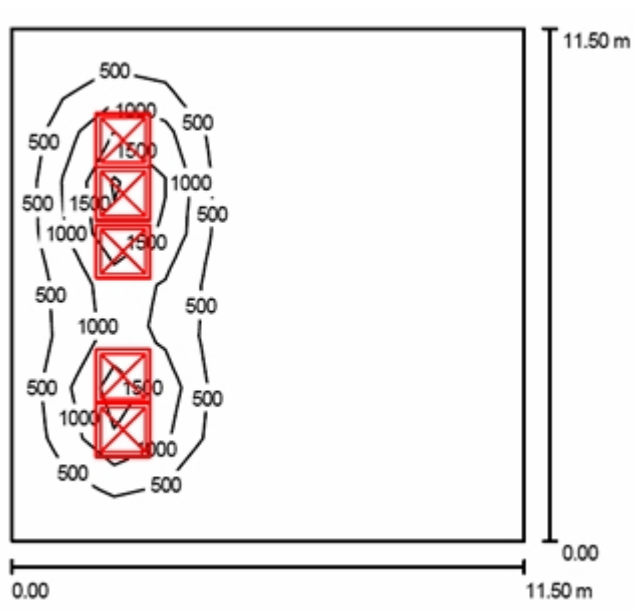

Figure 2. Luminaire lay-out simulated in DIALux, showing isographs for horizontal illumination at a height of 1.2 metres.

Test protocol
To investigate any behavioural or circadian effects, pre-, mid- and post-trial, assessments were taken in week 20 (baseline), week 24 (intervention 1) and week 32 (intervention 2). The study coordinator supplied assessment instructions to the medical/nursing staff and participated in the assessments. During the assessment weeks, both the tympanic temperature and the illuminance at eye level were measured 11 times per day. The sampling hours were (1) at wake up, (2)1 hour after wake up, (3) 2 hours after wake up, (4) approximately 5 hours after wake up, (5) approximately 8 hours after wake up, (6) 3 hours before going to bed, (7) 2 hours before going to bed, (8) 1 hour before going to bed, (9) bed time, (10) early night-time measurement and (11) late night-time measurement.

GIP
The Dutch Behaviour Scale for Intramural Psychogeriatrics (GIP) (Verstraten, 1998), which consists of 14 subscales, was used for determining the behavioural conditions of the participants. In this study, five subscales were used, those for apathic behaviour, disturbances of consciousness, restless behaviour, depressive/sad behaviour, and anxious behaviour. Nurses filling out the scoring lists had to be familiar with the subject (over-time observation). The colour of the lighting was visible to the nurses, although they were not told which lighting intervention (1 or 2) was to have which effect, if any. Nurses were instructed to fill out the lists in compliance with their observations and not with expectations of the study. The scale was filled out by 2 nurses, independently of each other.

Tympanic temperature
Scheer et al. (2005) demonstrated that the endogenous circadian rhythm in core body temperature depends crucially on the presence of functional SCN, and that light has an immediate and circadian-phase dependent core body temperature suppressing effect in rats with intact SCN. This study used tympanic temperature as a marker of circadian rhythmicity. There are 4 types of age-related changes to circadian rhythmicity: (i) reduction in amplitude (ii) earlier circadian rhythm phase, (iii) shortening of natural free-running period, and (iv) worsening of toleration of abrupt phase shifts (Monk, 2005). In healthy humans the body temperature fluctuates over day, with an amplitude of 0.5 K, with a minimum between 4 and 6 am and a maximum between 12 am to 6 pm.

Statistical analyses
Analyses of the effects of both lighting scenarios were carried out using SPSS 14.0 for Windows. The critical p-value was set at 0.05 for between-group comparisons of behaviour and tympanic temperature at baseline. The Bonferroni correction was applied to all other comparisons (critical p-value of 0.025).

Non-parametric statistics for independent and related samples were employed to test whether observed behaviour (GIP) differed between the control and intervention groups, and within groups, for the various lighting scenarios. Mann-Whitney U-tests were used for between group differences, and Wilcoxon signed ranks tests were used for within group differences. For the analyses of tympanic temperature, independent samples t-tests were used for between group differences, and loose paired-samples t-tests for within group differences.
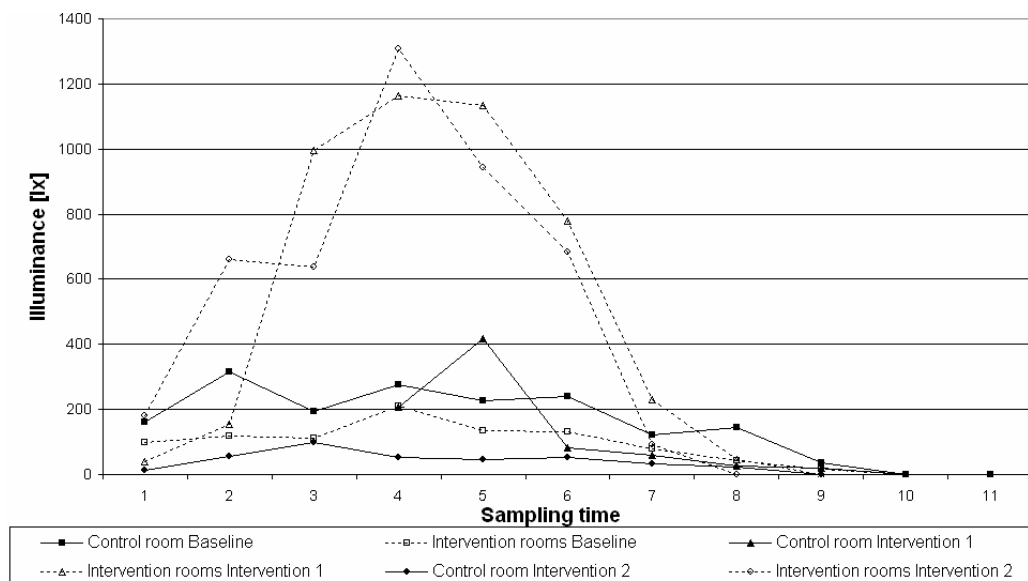

Figure 3. Average illuminance at eye level.

RESULTS
The illuminance at baseline did not differ significantly between the groups. The illuminance during both interventions was significantly higher for the people in the intervention group than in the control group (p = 0.000 and p < 0.05) (Figure 3).

Of the five GIP-scales considered in this study, only the assessments for apathic behaviour, disturbances of consciousness, and restless behaviour were considered for further analyses (Tables 2 and 3). The values found at baseline for these three behaviours showed no

significant between-group differences at baseline. After statistical analyses, a significant decrease was found (p < 0.01) for restless behaviour after the bluish intervention in the intervention group. When the differences from the Wilcoxon signed ranks tests were compared again to the results of the Mann-Whitney U-tests, there was a trend (.05 < p < 0.025) in restless behaviour after intervention 1, indicating that the scores for restless behaviour of the two groups differ from each other, and that the bluish light intervention (6,500 K) reduced restless behaviour (minus one scale unit on a scale ranging from 0 to 15, from 3.5 to 2.5 median values) compared to the control. No significant differences were found after the yellowish light intervention, implying that the spectral built-up of the light may play an important role. This indicates that the intervention with the 6,500 K light reduced restless behaviour. No significant differences were found after intervention 2; the yellowish light intervention.

Table 2. Median scores of GIP subscales and mean tympanic temperatures of control and intervention groups, and results (p-values) of Mann-Whitney U-tests (GIP) and independent-samples t-tests (T_{tymp}) for between-group differences at various research stages.

	Baseline			Assessment period 1			Assessment period 2		
	Control	Int.	p-value	Control	Int.	p-value	Control	Int.	p-value
GIP[*,†]									
	n=11	n=15		n=11	n=15		n=10	n=15	
Apathic behaviour	8.5	7.5		8	10		10	9	
Disturbances of consciousness	8	6.5		6.5	4.5		7	6	
Restless behaviour	5.5	3.5		4	2.5	<u><.025</u>	4.5	2.5	
Depressive/sad behaviour[‡]	4.5	2.5	<.1	2	2		4	2.5	
Anxious behaviour[‡]	5.5	1	<u><.05</u>	3.5	0.5		8	2	
T_{tymp}[§]									
	n=10	n=15		n=10	n=15		n=9	n=15	
Mean temperature [°C]	35.7	35.8		36.0	35.7	<.1	35.9	36.2	
Mean range [K]	1.2	1.3		1.2	1.8	<u><.01</u>	1.2	1.0	
	n=9	n=15		n=9	n=15		n=8	n=15	
Mean late-night temperature [°C]	35.6	35.5		35.6	35.7		36.1	36.2	

*Exact significant differences (two-tailed, α = 0.05 at baseline, α = 0.025 after interventions 1 and 2).
†The .5 median scores in even sample sizes are the mean value of the GIP scores 1 below and 1 above the median value.
‡No analyses for between-group differences after interventions 1 and 2.
§ Significant differences (two-tailed, α = 0.05 at baseline, α = 0.025 after interventions 1 and 2).

The mean tympanic temperature, the mean range and the mean late-night temperature did not show any significant between-group differences at baseline. A significantly higher mean range (and thus amplitude) was found for the intervention group after intervention 1 (p < 0.005).

Table 3. Results (p-values) of nonparametric Wilcoxon signed ranks tests (GIP), and results of parametric paired-samples t-tests (T_{tymp}), comparing assessment periods 1 and 2 to baseline conditions.

	Control		Intervention	
	Assessment period 1	Assessment period 2	Assessment period 1	Assessment period 2
GIP[*]				
Apathic behaviour			<u><.025</u>	
Disturbances of consciousness	<u><.01</u>			
Restless behaviour			<u><.01</u>	
T_{tymp}[†]				
Mean temperature	<u><.01</u>			
Mean range			<u><.01</u>	<u><.01</u>
Mean late-night temperature		<u><.025</u>		<u><.001</u>

[*]Asymptotic significant differences (α = 0.025).
[†]Significant differences (two- tailed, α = 0.025).

DISCUSSION AND CONCLUSION

Although GIP is a validated observation scale, assessments of behaviour unfortunately incorporate a large amount of subjectivity. Moreover, certain semantic problems may arise when using the scale since the between-score intervals are of unequal size (for instance, *never*, *hardly ever*, *sometimes* and *often*), possibly leading to considerable deviations. Even though no information is available on the natural over-time decline in GIP scores for people with dementia, the deterioration is irreversible. We did not only find a stabilising effect of lighting on certain aspects of behaviour, but even improvements.

Body core temperature, and thus tympanic temperature, is one of the most powerful and stable indicators of circadian rhythmicity. The average tympanic temperatures found in the subjects of this study are about 36°C, which is on the lower side of the normal body temperature range for older adults (36.1 to 37.8°C). Sund-Levander and Wahren (2002) have found that dementia was significantly related to lower tympanic temperature. Lower temperatures may also point out to errors in instruments, the way temperature was measured by the staff, and anatomical properties of the ear canal, which are known from studies on infrared tympanic thermometry (McCarthy and Heusch, 2006). Tympanic temperature, however, can be measured objectively in contrast to GIP scores. In a study by Aizawa and Tokura (1997) on the effect of daytime exposure to bright light on tympanic temperature in nine healthy young adults, average tympanic temperatures were significantly lower in the bright than in the dim condition. However, the lower tympanic temperatures found in the study cannot be attributed to the intervention, since they were also found for the control group.

The study was carried out largely in summer and people had the opportunity to go outside in much higher lighting conditions than the test-set up. Even though some residents left the room or fell asleep (eyes closed) during the experiment implying that exposure varied per individual, the exposure to light was always larger in the intervention group than in the control conditions. A similar set-up in winter should determine if comparable results are to be obtained.

Our research has found further evidence that high intensity light with a high correlated colour temperature, emitted by ceiling-mounted luminaires, improves circadian rhythmicity in

institutionalised older adults with dementia, and may positively influence restless behaviour in institutionalised older adults with dementia, without putting extra strain on the nursing staff or being an invasive treatment for residents. However, more research is needed to strengthen the new evidence, for instance, by using a less subjective observation scale to assess behaviour, and conducting experiments in winter. Although lighting undoubtedly has benefits in terms of visual capacities, special lighting can never be a substitute for taking older adults outside or for care capacity problems. Every human being has the right to go outside - not merely for sensory activation - even though there are few (in)formal carers to take residents out for a short walk just to catch some fresh air. This, however, does not imply that residents are not entitled to have the best possible lighting equipment as an additional therapy.

REFERENCES
Aarts M.P.J., and Westerlaken A.C. 2005. Field study of visual and biological light conditions of independently-living elderly people. *Gerontechnology,* 4, 141-152.

Aizawa S., and Tokura H. 1997. Exposure to bright light for several hours during the daytime lowers tympanic temperature. *Int J Biometeorol,* 41, 90-93.

Badia P., Myers B., Boecker M., et al. 1991. Bright light effects on body temperature, alertness, EEG and behaviour. *Physiol Behav*, 50, 583-588.

Brainard G.C., Rollag M.D., and Hanifin J.P. Photic regulation of melatonin in humans: ocular and neural signal transduction. *J Biol Rhythms*, 12, 537-546.

Czeisler C.A., Allan J.S., Strogatz S.H., et al. 1986. Bright light resets the human circadian pacemaker independent of timing of sleep-wake cycle. *Science*, 233, 667-671.

Hughes P.C., and Neer R.M. 1981. Lighting for the elderly: a psychobiological approach to lighting. *Hum Factors,* 23, 65-85.

McCarthy P.W., and Heusch A.I. 2006. The vagaries of ear temperature assessment. *J Med Eng Technol,* 30, 242-251.

Monk T.H. 2005. Aging human circadian rhythms: conventional wisdom may not always be right. *J Biol Rhythms,* 20, 366-374.

Ritchie K., and Lovestone S. 2002. The dementias. *Lancet,* 360, 1759-1766.

Scheer F.A.J.L., Pirovano C., van Someren E.J.W., Buijs R.M. 2005. Environmental light and suprachiasmatic nucleus interact in the regulation of body temperature. *Neuroscience,* 132, 465-477.

Sloane P.D., Williams C.S., Mitchell C.M., et al. 2007. High-intensity environmental light in dementia: effect on sleep and activity. J Am Geriatr Soc, 55, 1524-1533.

van Someren E.J.W., Kessler A., Mirmiran M., and Swaab D.F. 1997. Indirect bright light improves circadian rest-activity rhythm disturbances in demented patients. *Biol Psychiatry,* 41, 955-963.

Sund-Levander M., and Wahren L.K. 2002. The impact of ADL status, dementia and body mass index on normal body temperature in elderly nursing home residents. *Arch Gerontol Geriatr*, 35, 161-169.

Verstraten P.F. 1988. The GIP. 14 Observation scales for psychogeriatric behavior problems. *Tijdschr Gerontol Geriatr,* 19, 147-151 [in Dutch].