

## Exposing People with Dementia to Biodynamic Light

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### Abstract

**Introduction:** The increase of neuropsychiatric symptoms in people with dementia count for 46% of the transit to more controlled environments. Medication to repress these symptoms is widely used, but the side effects are significant, and the effect at start is not predictable. Research that aims at non-pharmacological interventions is important. One of the promising non-pharmacological interventions is lighting. In this study the effectiveness of biodynamic lighting, lighting with variable intensity and color, on neuropsychiatric symptoms in people with dementia is studied. It was hypothesized that the exposure to biodynamic lighting would decrease the amount and/or the severity of the neuropsychiatric symptoms.

**Method:** A biodynamic lighting innovation designed to stimulate a regular and healthy circadian rhythm was installed in the common area of a clinical setting. Two conditions of 21 days with and 21 days without exposure to biodynamic lighting were monitored. After each condition, measures of presence, severity of symptoms and emotional impact were collected using the Neuro Psychiatric Inventory-Questionnaire (NPI-Q).

**Results:** Eighteen participants were included in the research and completed a condition with and without exposure to biodynamic lighting. Per respondent the total index of severity of neuropsychiatric symptoms was lower after exposure. Also on a group level a tendency ( $p=.187$ ) was found for decreasing the total index of severity of the neuropsychiatric symptoms in the condition that received biodynamic lighting. Significance was only found in the severity scores on the symptom disinhibited behavior ( $p=.01$ ).

**Conclusion:** A biodynamic lighting intervention can be used to decrease the severity of neuropsychiatric symptoms, more specific disinhibited behavior. This is important because disinhibited behavior is related to a disturbed circadian rhythm, is distressing for caregivers and can accelerate the process leading to institutionalization. The findings in this study implicate the importance of future research on the possibilities of biodynamic lighting in dementia.

**Keywords:** Biodynamic Lighting; Dementia; Neuropsychiatric Symptoms; Non-Pharmacological

### Introduction

Dementia is a common mental disorder diagnosed in (mostly) elderly individuals. It causes deficits in cognitive, behavioral and social functioning [1]. Dutch Alzheimer society [2] states that the number of people with dementia in The Netherlands will reach one half million people in 2040. The costs of dementia care are high [2] and admittance in a care home has a lot of impact on the patients and their informal caregivers. Several studies find that

neuropsychiatric symptoms are the main determinant of caregiver strain and reported quality of life [3] and hereby an important reason for transition of people with dementia to a more controlled environment. The reasons for institutionalization are the need for more skilled care (65%), informal caregivers strain (49%) and neuropsychiatric symptoms (46%) [4]. Dementia can disturb the circadian rhythm even more than in normal ageing. Due to a disturbed circadian rhythm, some neuropsychiatric symptoms intensify in the evening and night. Just then when the informal caregiver needs rest, leading to high distress on their part [5].

The cardinal symptoms of neuropsychiatric domains are delusions, hallucinations, agitation/aggression, depression/dysphoria, anxiety, elation/euphoria, apathy/indifference, disinhibition, irritability/lability, motor disturbance, nighttime behavior, appetite/eating [6]. In The Netherlands 80% of the people with dementia has one or more neuropsychiatric symptoms [7]. The treatment of these symptoms exists of pharmacological and/or psychosocial interventions [8]. The use of medication increases morbidity and mortality in people with dementia and the treatment effect on the symptoms is not always that clear and predictable [9]. Therefore, researchers became interested in the possibilities of non-pharmacological interventions such as light [1].

In a systematic review by Forbes and colleagues [10] the positive effects of light therapy on cognition, daily functioning, sleep, agitation and neuropsychiatric symptoms in people with dementia is described. Figueiro et al. [11] also found positive effects of light on circadian rhythm, agitation and depression in dementia. Previous research [11-13] showed that the circadian rhythm, the sleeping pattern and nightly activity improved by employment of a light intensity level of 400-1000 lux and short wavelength (bluish) light. These researchers all used a constant light intensity (lux) and color temperature (nanometers). Dynamic lighting offers a variable range of light intensity, light spectrum and color temperature [14]. Dynamic lighting resembles a normal daylight curve and is tailored to stimulate circadian rhythm. Due to age-related changes to the eye and a more disturbed circadian rhythm, dynamic lighting is more suitable for people with dementia. Research has shown that people with dementia in a nursing home only spend 1,6 minutes a day outside [15] and that the indoor light conditions in a nursing home are not sufficient for the visual and the non-visual aspects of light [16-18]. Also, neuropsychiatric symptoms tend to intensify in the evening and night. This nighttime behavior is one of the symptoms which causes a reason for the transition to a more controlled environment because of the impact on the primary caregiver [11]. Thus, people with dementia, especially those living in a nursing home, could benefit highly from dynamic light input [19]. In this study we will focus on the impact of biodynamic lighting on the neuropsychiatric symptoms in people with dementia.

Light therapy has repeatedly shown to reduce agitation behavior in this population [20,21]. It has hardly been investigated whether biodynamic lighting with its characteristic variation in light intensity and color temperature can have a positive effect on neuropsychiatric symptoms in people with dementia. A very recent study [22] that did use biodynamic lighting showed a

significant decrease in agitated behavior in people with dementia in a nursing home. In the present study the impact of biodynamic lighting on neuropsychiatric symptoms in people with dementia is investigated in a clinical setting. It was hypothesized that the exposure to biodynamic light would decrease the amount and/or the severity of the neuropsychiatric symptoms.

## Methods

### Participants and Setting

The participants were recruited from a treatment facility for patients with neurocognitive disorders in psychiatric hospital GGzE in Eindhoven. In the period of January 2016 to January 2017 every new admitted patient was approached to participate. The inclusion criteria for the study were a primary diagnosis of dementia diagnosed by a geriatrician or psychiatrist, based on the Diagnostic and Statistical Manual of Mental Disorders, Fourth Edition (DSM-IV) [23] criteria and the participants had to be identified with neuropsychiatric symptoms. The exclusion criteria were any other neurological disorder, including narcolepsy, sleep apnoea or restless legs syndrome or a serious eye disease incompatible with light therapy, such as retinitis pigmentosa. Patients were also excluded if there is severe comorbidity of psychiatric disorders, like a manic episode, addiction or severe aggression in a psychotic episode, or if they were physically disabled and cannot leave their bed by themselves. No restrictions were made for medication use. All study materials and procedures were approved by the Scientific Board of Mental Health Care Institution, GGzE, Eindhoven, The Netherlands. The METC did not need to be consulted. Informed consent was obtained from participant family members after full explanation of the procedures, in accordance with the Declaration of Helsinki [24].

### Methods and Design

The study was performed using a quantitative prospective quasi experimental cross-over design [25]. The Vitaallichtlamp (VLL, type Bright Brenda) [26] showed in (Figure 1) is used in this study as lighting intervention. The VLL can produce up to 7500 Lux and 2700-6500 Kelvin, direct and indirect exposure of light [26]. During morning and daytime hours, the lamp produces more bright and bluish light and during the evening warm and reddish light. Hereby it resembles a normal “real life” daylight curve to stimulate a normal day-night rhythm. The VLL exposure was dimmed at 75%, approximately 5625 lux, so the amount of lux was endurable by the elderly eye.



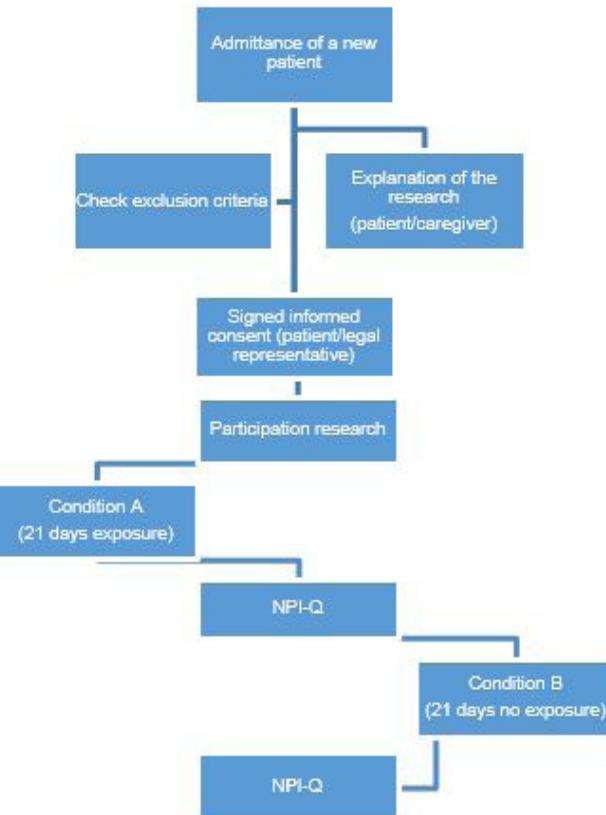
**Figure 1:** Picture of the biodynamic lighting lamp (VLL, type Brenda) used in this study.

In total three VitaalLicht lamps (see section on intervention for details) producing biodynamic lighting were placed at the same time in the common area for 21 days. The whole group is exposed to the biodynamic lighting during that period. The lamps were programmed and started each day at 7.00 a.m. and finished at 23.00 p.m. After 21 days the biodynamic lighting lamps are removed from the common area and the group receives the regular lighting condition during the next 21 days. Participants spend most of their time in this common area. In this room they eat all their meals, play games, read, watch television, listen to music and receive visitors. Dependent on the date of admittance subjects started their condition with or without exposure. The first two weeks of the condition were marked as wash-out period to minimize carry-over effects [27].

When a condition of 21 days with or without exposure to biodynamic lighting was finalized, the neuropsychiatric symptoms of each participant were measured with a standardized questionnaire, the Neuro Psychiatric Inventory Questionnaire (NPI-Q) by the primary formal personal caregiver of each participant [28]. The Neuro Psychiatric Inventory-Questionnaire is a standardized 12-item tool designed to rate the presence of symptoms (present or absent), the severity of the present symptoms (3-point scale) and the caregiver distress of these symptoms (5-point scale) by the primary formal caregiver. A higher score on the NPI-Q is associated with a greater severity of symptoms and greater impact of the symptom manifestation on caregivers [29,30]. The NPI-Q is recently used in a 3-year longitudinal study of 514 patients to confirm the association between dementia severity and neuropsychiatric symptoms [31]. NPI-Q were completed for all participants in both conditions.

Medication dosage and use were monitored during the study

by checking the pharmacotherapy data in the electronic patient files by start and end of the participation in the study. (Figure 2) shows the flow chart of the study protocol.



**Figure 2:** Flow chart study protocol. **Note:** subjects could also receive condition B before A.

### Statistical Analyses

Data were analysed using SPSS, version 19 [32,33]. The sum scores in condition A and B were compared at symptom level, group level and participant level. As the data were not normally equated, non-parametric testing was applied.

### Results

From January 2016 to January 2017 sixty-one patients with dementia were admitted to psychiatric hospital GGzE. Two patients did not sign the informed consent, nineteen patients could not be included because of severe comorbidity of psychiatric disorders (i.e. manic episode, psychotic episode, aggression caused by detox of substance abuse) and/or physical complications (i.e. wheelchair dependence, kidney dialysis) and twenty-two patients did not complete two conditions (i.e. transition, discharge, death). Eighteen participants were included in this study (nine men, nine females; mean age was  $76.4 \pm 11.7$  years) and completed two conditions.

Four participants completed four conditions in an ABAB-design. All participants used medication at start (i.e. antipsychotic medication, antidepressant medication, melatonin, vitamin D, pain medication). In four participant's medication was changed during the study. Two participants received no antipsychotic medication during the condition with exposure and did in the condition without exposure. One participant received no sedating medication in the

condition with exposure and did in the condition without exposure. One participant received no antidepressant medication in the exposure condition and did in the condition without exposure.

For a description of the included study population see (Table 1). Ten participants started with exposure to biodynamic lighting (condition A) and eight participants started with the normal daylight condition (condition B).

Description of study population		n=18	
Age		76,4 (11.7)	
Sex	Male	9 (50%)	
	Female	9 (50%)	
Dementia Type	Alzheimer's Disease	6 (33%)	
	Frontotemporal dementia	1 (5.5%)	
	Dementia due to substance abuse	1 (5.5%)	
	Dementia NOS	10 (55%)	
Medication		Start	End
	Typical antipsychotics	14 (67%)	8 (44%)
	Atypical antipsychotics	3 (16.5%)	6 (33%)
	Sedatives/ Benzodiazepines	9 (50%)	9 (50%)
	Pain medication	7 (38.5%)	6 (33%)
	Antidepressants	4 (22%)	5 (27.5%)
	Other medication (e.g. vitamin D)	13 (71.5%)	13 (71.5%)
SD or Percentages are shown in brackets			

**Table 1:** Description of study population.

## Severity of neuropsychiatric symptoms

As shown in (Table 2), significance was found in only one neuropsychiatric symptom. In the symptom disinhibited behavior a significant decrease was revealed between exposure and no exposure to biodynamic lighting ( $P=0.01$ ). The data were not normally equated. Therefore, the Wilcoxon signed rank test is used to compare the data [25].

Neuropsychiatric symptoms	Condition A n=18 mean (sd)	Condition B n=18 mean (sd)	sign. ( $p$ )	Participants (n)		
				Condition A compared to B		
				Increased	Decreased	Equal
1.Delusions	1,00 (1,00)	1,44 (1,29)	0,11	2	8	8
2.Hallucinations	0,56 (1,04)	0,67 (1,19)	0,49	1	4	13
3.Agitation/aggression	1,11 (1,08)	1,33 (0,98)	0,36	5	6	7

4.Depression/dysphoria	1,17 (0,92)	0,78 (0,81)	0,24	8	3	7
5.Anxiety	1,11 (1,23)	0,72 (1,23)	0,25	7	2	9
6.Euphoria/elation	0,28 (0,75)	0,39 (0,70)	0,48	2	3	13
7.Apathy/indifference	0,50 (0,79)	0,50 (0,92)	1,00	3	2	13
8.Disinhibited behavior	0,33 (0,77)	1,22 (1,26)	<b>0,01*</b>	1	11	6
9.Irritability/lability	0,83 (1,10)	1,22 (1,17)	0,23	2	8	8
10.Abberrant motor	0,39 (0,85)	0,11 (0,32)	0,16	4	1	13
11.Nighttime behavior	0,72 (1,13)	1,17 (0,99)	0,21	4	9	5
12.Appetite/eating	0,17 (0,51)	0,17 (0,71)	1,00	1	1	16

\*Indicates a significant difference at severity of symptoms between condition A (exposure to biodynamic light) and condition B (no exposure)

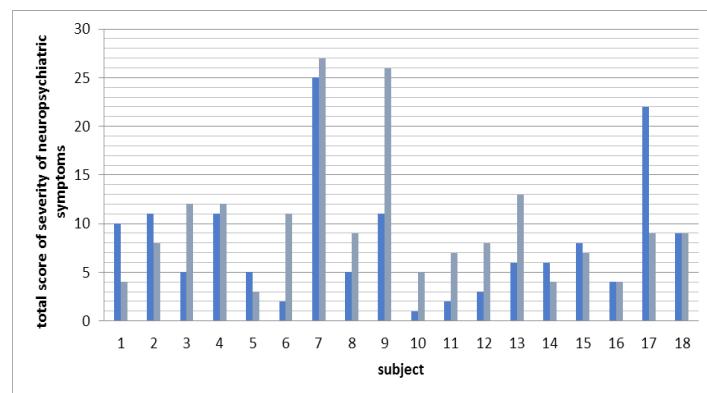
**Table 2:** The scores and comparison on severity of present symptoms in condition A (exposure) and condition B (no exposure).

The mean total score in the exposure condition is 8,1 (SD=6,4) and in no exposure condition 9,6 (SD=6,0) ( $p=.289$ ). Visual inspection of the variables shows that none of the scores were normally equated. The non-parametric Wilcoxon signed rank test was used to analyze the data. At group level a comparison is made in total score with and without exposure to biodynamic lighting. (Table 3) shows the number of participants and the level of severity of symptoms. No significance was found ( $P=0.187$ ).

n	
total severity condition B < total severity condition A	6
total severity condition B > total severity condition A	10
total severity condition B = total severity condition A	2

**Table 3:** Total severity of symptom scores at group level.

The total scores of severity of symptoms at individual level in both conditions is shown in (Figure 3). The first eight participants started in condition B (no exposure). In five participants the total score of severity decreased in condition A (exposure) and in three participants the score increased in condition A. Ten participants started in condition A (exposure) and in five participants the total score of severity of symptoms increased in condition B (no exposure), decreased in three participants and stayed equal in two participants.



**Figure 3:** Total score of severity of symptoms per participant in condition A (blue) and B (grey).

The total score of (formal) caregiver distress was also compared and is shown in (Table 4). There was a decrease in scores on emotional impact on caregivers reported by caregivers in 11 participants in condition A. In one participant the emotional impact scores reported by the caregiver was equal in both conditions. In 6 participants the caregivers reported higher emotional impact scores in condition A compared to condition B.

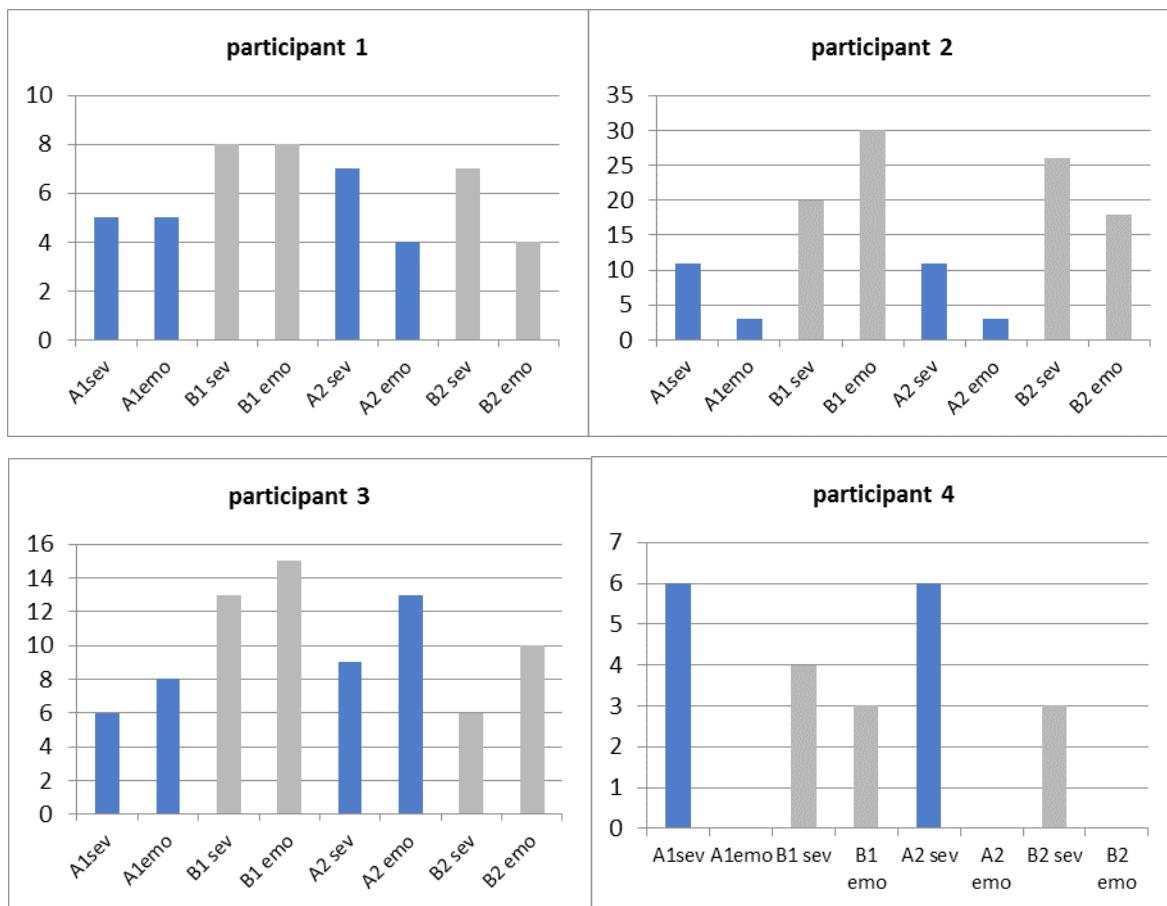
In condition A the mean total score of caregiver distress is 8,89 (SD 7,9) and in condition B 11,00 (SD 6,18). A Wilcoxon

signed rank test is performed and no significance was found ( $p=.087$ ).

	n
total emotional impact condition B > total emotional impact condition A	11
total emotional impact condition B < total emotional impact condition A	6
total emotional impact condition B = total emotional impact condition A	1

**Table 4:** Total emotional impact on caregiver scores at group level.

Four participants completed two A and two B conditions in an ABAB-design. Visual analysis of all participants in figure 4 show that biodynamic lighting has a positive impact.



sev = severity of symptoms, emo = emotional impact on caregiver

**Figure 4:** Results of four participants that completed an ABAB-condition.

In all participants there is a positive effect of scores on severity and emotional impact of the formal caregiver compared to the previous condition. This suggests that biodynamic lighting can have a positive effect on severity of symptoms and emotional impact on caregivers when exposed to this lighting for a prolonged period. The effect is reversible which indicates the positive effect is caused by the exposure to biodynamic lighting. In participant 1 and 4 the effect however is not that strong. Both participants were psychically deteriorating and suffering from alcohol dementia. They were both not able to return to their homes and were admitted in a nursing home.

## Discussion

The present study set out to investigate the effects of a biodynamic lighting intervention on neuropsychiatric symptoms in people with dementia admitted in a psychiatric hospital during January 2016-January 2017. It was hypothesized that exposure to biodynamic lighting during the whole day and evening (7:00-23:00) with an average of 3-6 hours of exposure time would have a more positive impact on the measures of severity of neuropsychiatric symptoms at clients and scores of emotional impact on formal caregivers than the normal lighting conditions in the common room of the hospital. Eighteen participants primarily diagnosed with dementia with a mean age of 76 years were included in this study. The effect of exposure to biodynamic lighting has been measured on different levels (symptom, individual and group). Information and selection bias were minimalized by questioning mostly the same formal caregiver per participant by one and the same investigator. The internal validity was ensured by collecting all data of the NPI-Q and the data of the electronic patient files and registered in SPSS.19. Co-researchers independently controlled all the data and analyses. By placing three VitaalLichtLampen (VLL) in the common area of the ward the internal validity was also ensured.

The present results showed that a 21-day exposure to biodynamic lighting decreased the total score of severity in seven (delusions, hallucinations, agitation/aggression, euphoria/elation, disinhibited behavior, irritability/lability and nighttime behavior) of the 12 symptoms. Only at the symptom disinhibited behavior a significant difference was revealed ( $P=0.01$ ). This finding is consistent with recent research of Wahnschaffe et al. [22] who found that dynamic lighting in a nursing home significantly reduced scores on the Cohen Mansfield Agitation Index (CMAI). The CMAI includes several symptoms of disinhibited behavior. Another study of Brodaty et al. [31] which followed the prevalence and course of neuropsychiatric symptoms on the NPI-Q in dementia over 3 years, found that overall levels of neuropsychiatric symptoms increased over 3 years, in particular delusions, hallucinations, agitation, anxiety, apathy, disinhibition, irritability and aberrant motor behavior significantly increased. It is a very important finding that actually several of these symptoms (delusions, hallucinations, agitation, disinhibited behavior and irritability) even decreased in our study. Medication was monitored and there was no medication prescribed influencing this behavior. Biodynamic lighting also stimulates the circadian rhythm and hereby might have a positive impact on disinhibited behavior because people sleep better, are less tired and can regulate their behavior better.

Ten participants out 18 reported a decreasing of the total score of severity of symptoms based on the exposure to biodynamic lighting. Although, we did not reach significance on a group level, same trend was found on an individual level. Other factors on the

ward also influence neuropsychiatric symptoms in participants and might have contributed in not reaching significance, like a new admittance, the decease of a patient and severe disrupting behavior like suicidal gestures or a patient suffering from a psychosis.

In three participants who started in the exposure condition, the total score of severity of symptoms increased compared with the no exposure condition. This is the opposite result of our hypothesis. Possible reasons for this findings could be that according to Zuidema [7] neuropsychiatric symptoms increase because of the progressive state of dementia. On the other hand, we found also participants who ended in the exposure condition the total score of severity of symptoms decreased. It could be that because of the exposure with VLL people become more active and notice their limitations in daily life more. This assumption could also be seen in our results because of the largest difference was found in symptoms of delusions, disinhibited behavior and nighttime behavior. Another possible explanation for the increase of severity of symptoms during the exposure condition at start of the study could be the emotional impact and consequences of an admittance in a hospital. The Dutch Alzheimer society states on their website [34] several problems with an admittance: denial of their problems, resistance to leaving their home environment, anxiety of losing the control over their life, a negative perception of an admittance.

Four participants completed two full conditions as in an ABAB-phase design. In all conditions there was a positive effect on scores of severity of symptoms and emotional impact on caregivers compared to the previous condition. This effect was reversible in three of the four participants. In the exposure condition the neuropsychiatric symptoms and the emotional impact on the formal caregivers decreased, then it increases during the no exposure condition, it decreases again in the exposure condition. This suggest a positive impact of biodynamic lighting when participants are exposed for a prolonged period. The participant who shows no reversible effect was suffering from increasing somatic complaints and was admitted in a nursing home.

The present study also has some limitations. The exposure to dynamic lighting reduces neuropsychiatric symptoms indicating short-term effects from higher daily light exposure. This study should be replicated using a larger sample size to increase the power of the study and using a longer treatment duration to determine if long-term exposure could significantly reduce neuropsychiatric symptoms in people with dementia, and therefore reduce formal caregiver distress. Further investigation is also needed before results can be extrapolated to at home situations. The results may also be influenced by circumstances within the psychiatric hospital. Therefore, a home situation could be suitable for further research. Furthermore, formal caregivers may have known the purpose of the intervention and answered accordingly, however this is

unlikely because they were unfamiliar with the questionnaire and their responses did not always favor the intervention condition. The choice of using proxy-data instead of self-report data stemmed from the fact that all participants were diagnosed with dementia.

Another limitation is there was no baseline measurement. Several variables could have influenced the symptoms during the treatment duration. To minimize these influences, the conditions should be repeated several times within the subjects to be able to make conclusions about implications [27].

The positive effect of light is also found in previous research. Riemersma- Van Der Lek et al. [12] found an increase of sleep duration with exposure at a maximum of 1100 Lux. In dimmed or red light Nowak and Davis [35] found that people with dementia calmed down. It is not exactly clear what amount of lux the participants received in this study. There were three VLL in the common ward producing a maximum of 5625 lux. The color temperature also varied. In the morning bright-bluish light was produced an in the evening warm red light (2700-6500 Kelvin). Participants were at least 180-360 minutes a day exposed to biodynamic lighting, because of their daily activities. Shirani and Louis [36] concluded positive effects in a study on sleep, depression and dementia with exposure to 5000 lux one hour per day for several weeks.

Medication use and doses intake were monitored during the study. The present study showed that biodynamic lighting exposure for three weeks in a geriatric ward of a psychiatric hospital significantly decreases disinhibited behavior. This finding is consistent with the study of Wahnschaffe et al. [22] and implicates dynamic lighting is a promising intervention in influencing disinhibited behavior in people with dementia. According to the review study of Sink, Holden and Yaffe [37] primary treatment of neuropsychiatric symptoms consists of non-pharmacological interventions, because the effect of medication use is not clear at start and because of the side effects.

## Conclusions

The aim of this study was to investigate a non-pharmacological intervention that can reduce the neuropsychiatric symptoms in people with dementia. The clinical relevance of the exposure to dynamic lighting as non-pharmacological intervention is confirmed in this study and has implications for future research. Future research on the impact of biodynamic lighting is needed in a more longitudinal study with a larger sample size. Dynamic lighting might be suitable for home use and hereby reduce the informal caregiver distress that is one of the main reasons for transition of patients with dementia to more controlled environments.

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### Authorship

“All named authors meet the International Committee of Medical Journal Editors (ICMJE) criteria for authorship for this article, take responsibility for the integrity of the work as a whole, and have given their approval for this version to be published.”

### Disclosures

“Ellen van Lieshout-van Dal, Liselore Snaphaan, Nicole Arkink, and Inge Bongers declare that they have no conflict of interest.”

### Compliance with Ethics Guidelines

“All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.”

### Data Availability

The datasets generated during and/or analyzed during the current study are not publicly available due to confidentiality concerns but are available from the corresponding author on reasonable request.

### Thanking The Participants

We would like to thank all of our participants that have participated in our study.

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