AN INVESTIGATION OF LIGHT SPECTRUM AND INTENSITY ON DEPRESSION IN OLDER ADULTS

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Abstract - Building illumination impacts significantly behavioral and psychological symptoms through because its regulates our circadian system. Considering the age-related changes in eyes and the circadian system, specialized lighting design is essential to promote mood and overall well-being in older people. Depression is a common symptom in older adults with the estimated prevalence of 5-15% among those residing in community dwellings. This study aimed to evaluate the effects of two whole-day ambient lighting interventions on depression in older adults. Both lighting interventions are designed to create an ambient illumination that provides a high illuminance level (500 lux) in the morning (8:00 – 12:00) and then the illumination is dimmed gradually throughout the day and reached 100 lux in the evening (after 20:00). Participants were exposed to two different lighting conditions for 9 days. Using the Geriatric Depression Scale to measure depression levels before, during, and after lighting interventions we found a significant decrease in depression after exposure to both lighting conditions; there was more reduction for the L2 intervention. These findings illustrate the beneficial effects of adding varying illumination and spectrum to the ambient lighting quality in residential buildings. Given that older adults spend the majority of their time indoors, designing whole-day ambient lighting with varying intensity and tuning spectrum could be an effective therapeutic solution to create an antidepressant environment and improve quality of life in older adults.

Keywords - About Four Key Words or Phrases in Alphabetical Order, Separated By Commas.

I. INTRODUCTION

epression is a common symptom among older adults with an estimated prevalence of 5% - 15% among those who are community-dwelling [1]. Depression can bring about psychological distress, functional impairment, and, consequently, poorer overall health outcomes [2]. In older adults, depression is associated with cognitive impairment and could approximately double the risk of dementia [3]. Moreover, these depressive symptoms could place additional stress on caregivers in both institutional and home settings [4]. Lighting is a particularly important element within the living environment that enables more comfortable living. Proper lighting improves older adults' visual performance and prevents falls [5]. Light is also the main stimulus that regulates circadian rhythms, as well as seasonal cycles and neuroendocrine responses, in all creatures on the earth, including humans [6]. A large body of research has proven that dysfunction of the circadian system in humans negatively influences their health and well-being [7] and increases the risk of metabolic syndromes, cardiovascular diseases, and cancer, as well as mental illnesses such as depression [8] and anxiety [9]. Hence, researchers argue that light with the correct characteristics could be as effective as medication in the treatment of depression if it is employed at the right time and with sufficient duration [10]. In older adults, illuminance levels (especially short wavelength light) needed for visual and circadian effects are much higher than those required for other age groups due to age-related changes in the structure and function of eyes such as lens-yellowing, lens thickening, and senile meiosis [11]. These changes lead to a decline in the amount and characteristics of the light that reaches the retina. It has been shown that the retina of a 20-year-old receives 3 times more light than that of a 60-year-old and 6 times more than that of an 80-year-old individual[12]. In practice, most older adults are not exposed to sufficient amount of illuminations [13]. Studies reported poor lighting conditions in senior living communities [14]. Moreover, many older adults do not spend enough time outdoors where high illuminance levels are available from sunlight. Limited exposure to appropriate lighting is one of the main reasons of depression and problematic behaviors in geriatric groups, which creates further stress for caregivers [15]. There is a positive impact of ambient overhead bright blue light on enhancing mood and treating depression among older adults [16]. Researchers demonstrated a significant negative correlation between daytime ambient illuminance levels of over 400 lux and depression scores among older adults [17]. Despite the beneficial impacts of daytime ambient bright light, night- time illuminance exposure is reported to have a positive association with the risk of depression among older adults [18], possibly due to circadian phase delay and impaired sleep quality. In addition to the illuminance levels, the spectrum (or CCT) of the lighting plays a role and certain behavioral and circadian effects that are obtained with bluish cool light (CCT of 6500 K or higher) are not found in yellowish warm light (CCT of 2700 K or lower) [19]. Komastu et al. [20] found that exposure to 200 lux blue light with a CCT of 12000 K in the morning significantly improved

depression symptoms among older adults with Alzheimer's disease. This effect was not found in yellow light with a CCT of 2400 K at 200 lux. Presumably, a whole-day ambient lighting design with varying illuminance levels and spectrum (or CCT) could effectively manage mood and depressive symptoms in older adults. This study evaluates the impact of applying two whole-day ambient lighting interventions in senior living communities on depression in older adults who reside in the community. These lighting interventions are designed specifically to meet visual and circadian needs of older adults and provide a range of illuminance levels, and/or CCTs that change throughout the day.

II. METHODS AND PROCEDURE

A. Participants

Recruitment for the study was conducted through distributing flyers to the residents of two senior living communities in Saint Louis, MO. A total of 23 individuals signed up for the study. However, after screening, 9 individuals were excluded. Exclusion criteria included any evidence of moderate to major dementia based on the Montreal Cognitive Assessment (MoCA) test (score of 25 or lower), blindness, and current use of light therapy. Moreover, potential participants were excluded if they spent most of their daily time (more than 5 hours) outside their private residential units or if they had planned upcoming travel out of the time zone during the study participation period. Informed consent was signed by 14 older adults (11 female). The ages of participants ranged from 65 years to 91 years with a mean age of 73.2 years (SD 7.9).

B. Experimental Intervention

A. Lighting interventions included two whole-day lighting schemes with varying illuminance levels and/or CCTs. Both lighting schemes were designed based on available research to meet circadian lighting needs of older adults. Although no previous study examined the impact of a whole-day lighting intervention on depression in older adults, what we perceived from prior literature indicates that an optimum lighting solution for circadian entrainment should provide:

- High levels of bright blue illuminance (high intensity + high CCT (or blue-enriched spectrum)) early in the morning to phase advance the circadian clock.
- Medium to high levels of illuminance (medium to high intensity + medium CCT (neutral white)) in the afternoon to increase alertness without exerting substantial phase shifting effects on the circadian clock
- Dimmed illumination (low intensity + low CCT (yellowish white light)) in the evening to avoid disruption of circadian rhythms and unwanted phase delay.

Given these primary principals, both lighting interventions designed for this study provided a high illuminance levels (500 lux, corneal) in the morning (8:00 – 12:00) and then the illuminance level was reduced gradually towards the evening and reached 100 lux (corneal) after 20:00. One lighting scheme (L1) delivered a constant CCT of 2700K which is the most common CCT in the residential environment. In the other lighting scheme (L2), the CCT was changing in a range of 6500K – 2700K from morning towards evening. Table 1 shows illuminance levels and CCT of each intervention throughout the day. Studies evaluating the effects of CCT and spectrum on depressive symptoms report inconsistent results; hence, some researchers argue that, perhaps, the color of light is not a significantly effective factor in circadian lighting design.. We designed L2 to examine if adding varying CCT to the ambient illumination with tuning intensity would provide any extra benefits with regards to depression levels in older adults.

	Intervention 1 (L1)		Intervention 2 (L2)	
Time	Illuminance levels (lux)*	CCT (°K)	Illuminance levels (lux)*	CCT (°K)
8:00 – 12:00	500	2700	500	6500
12:00 – 16:00	400	2700	400	4500
16:00 – 18:00	300	2700	300	3500
18:00 – 20:00	200	2700	200	3000
20:00 – 24:00	100	2700	100	2700

Table 1. Whole-day lighting interventions

* Illuminance levels measured at vertical plane, eye level, gazing direction, at the height of 3.5 – 4.5 Ft. (Seating position, depends on the seat height), The numbers do not include daylighting in the living rooms.

Lighting interventions were manipulated by placing 4 to 6 four-foot linear tunable white light fixtures (FloatPlane by Ledalite, Suspended, LED) in the living rooms of the participants and at the height of 7 feet. All light fixtures were set up on Manfrotto stands and provided a direct/indirect lighting distribution (75% up – 25% down). Selected light fixtures offered a wide range of CCTs from 2700K to 6500K. The light fixtures were placed around the main seating spot (usually to create an L-shape or U-shape geometry) to provide the highest amount of corneal light levels in most gazing directions through the indirect light reflection from ceilings and walls. The L-shape and U-shape placement of luminaires helped with the uniformity of lighting distribution as the light is transmitted and reflected from various directions to/around the designated spot.

C. Study Design

A counterbalanced crossover study was designed to evaluate depression levels in participants before, during, and after the lighting interventions using the Geriatric Depression Scale (GDS). In the week prior to the lighting interventions, a pre-test assessment was performed to measure baseline depression levels in participants under their conventional lighting condition. Thereafter, researchers supplied the lighting in the participants' homes (lighting intervention installation) and performed in-home lighting assessments. Participants were exposed to each lighting interventions for 9 days (Intervention session) and depression was evaluated on the last day of each intervention. As it was a counterbalance study design, the 14 participants were randomly divided into two groups of 7 people (group A and group B) that experienced different orders of lighting interventions. Following the intervention sessions, there was a two-week washout period during which the experimental lights were removed from the participants' living room and the original lighting conditions were returned to the participants' living room. A post-intervention depression assessment was performed on the last day of the washout period to evaluate if participants returned to baseline depression levels collected during the pre-test assessment session.

D. Measures

The Geriatric Depression Scale (GSD) was employed to measure depression in participants. The GDS is a 30-item self-report assessment that is widely used to identify depression in older adults. The GDS has high internal consistency (Cronbach's alpha of 0.85), and high test-retest coefficient reliability (0.83) . This questionnaire requires yes/no answers and therefore the scale is particularly easy to administer. The scale focuses mainly on the worries of patients and the way they conceive and interpret their quality of life. In particular, it avoids questions concerning somatic complaints which are common among older adults. Although it does not contain items that assess agitated or psychotic behavior, it is designed to register a cognitive (i.e., thought content) dimension of depression and is highly correlated with the Beck Depression Inventory.

III. RESULTS

The patterns of the depression scores across the study are illustrated in Figure 1. The general pattern is similar for the two groups; namely, depressions scores decrease with the L1 intervention, decrease even more with the L2 intervention, and start returning to baseline levels after the intervention has been discontinued. These general trends were assessed with an independent t-test statistical analysis to determine the effectiveness of the experimental whole-day lighting interventions on depression among older adults. Data were managed and analyzed using IBM SPSS 22.0 statistical software.

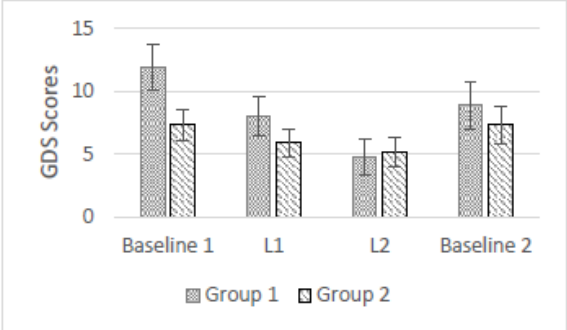

Figure 1. Effectiveness of the L1 and L2 Interventions on Depression

As indicated in Table 2 & 3, exposure to L1 intervention for 9 days decreased the mean GDS score significantly by 3.86 points in group A (t = 3.59, P = 0.04) and 1.43 points in group B (t = 3.59, P = 0.04) compared to baseline measurements. L2 intervention provided even more reduction in the mean GDS score in both groups. Following the L2 intervention, mean GDS score of group A significantly dropped by 7.15 points from the baseline (t = 3.58, P = 0.01) and by 3.29 from the L1 (t = 2.8, P = 0.03). In group B, a significant reduction was observed in the mean GDS score between L2 intervention and the baseline (t = 2.94, P = 0.03); nevertheless, the difference between L1 and L2 was not statistically significant (t = 1.53, P = 0.18). No significant difference was found in the mean GDS score in baseline 1 and baseline 2 in both groups (group A (t = 1.6, P = 0.15), group B (t = -0.44, P = 0.67)), nor between L1 and Baseline 2 (group A (t = -1.03, P = 0.34), group B (t = -1.92, P = 01)). However, the mean GDS score in Baseline 2 was significantly higher than L2 in both group A (t = -5.61, P = 0.001) and group B (t = -3.49, P = 0.01).

Variable	Baseline 1		L1		L2		Baseline 2	
Depression (GDS)	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Group A	11.86	4.85	8.00	4.20	4.71	3.86	8.86	4.88
Group B	7.29	3.25	5.86	2.91	5.14	3.13	7.29	3.82

Table 2. Effectiveness of the L1 and L2 Interventions on Depression (N = 14)

Baseline measurements revealed that the mean GDS score in group A was 4.71 points higher than group B. After 9 days of exposure to the L1 and L2 interventions, we observed more reduction from the baseline 1 in mean depression scores in group A compared to group B (Table 5). However, an independent t-test showed no significant difference in the mean GDS score between groups in baseline 1 (t = 2.12, P = 0.05), L1 (t = 1.11, P = 0.29,) L2 (t = -0.08, P = 0.94), and baseline 2 (t = 0.56, P = 0.58).

Variable	Group A		Group B					
Depression (GDS)	Mean	SD	Mean	SD	Mean Difference	t	P	σ^2
Baseline 1	11.86	4.85	7.14	3.25	4.71	2.12	0.06	17.31
L1	8.00	4.20	5.86	2.91	2.14	1.11	0.29	13.07
L2	4.71	3.86	4.86	3.13	-0.14	-0.08	0.94	12.36
Baseline 2	8.86	4.88	7.57	3.82	1.29	0.56	0.58	18.21

Table 3. Effectiveness of the L1 and L2 Interventions on Depression Between Groups (N = 14, df = 12)

IV. CONCLUSION

The present study investigated the effects of two whole-day ambient lighting schemes (L1 and L2) on depression in older adults residing in senior living communities through a counterbalanced crossover design. As predicted, 9 days of exposure to both lighting interventions significantly decreased mean depression scores obtained from the GDS. Both interventions provided a high illuminance levels of 500 lux in the morning (8:00 – 12:00) and then the illuminance level reduced gradually throughout the day and reached to 100 lux in the evening (after 20:00). L1 intervention delivered a constant CCT of 2700K and yet we observed a significant fall in the depression levels in participants. Exposure to L1 intervention reduced the mean depression scores by 33% and 20% in group A and group B respectively. These findings are consistent with other recent studies that reported the benefits of receiving high intensity morning light for depression and mood regardless of the light color and spectrum . However, all these studies exposed participants to a lighting intervention for 30 – 120 minutes and none examined a whole-day lighting intervention. This demonstrates that illuminance level is a significant light characteristic impacting mood in older adults. Spectrum of the light is an important feature investigated in this study. During the L2 intervention, we added tuning spectrum quality to the ambient illumination with varying illuminance levels to provide a bright cool light in the morning and a dimmed warm light in the evening. L2 intervention reduced mean depression score in participants by 60% in group A and 30% in group B, which were significantly higher than L1 intervention in both groups. This supports the idea that adding tuning spectrum to the environmental lighting quality provides additional benefits to reduce depression in older adults and improve their mood and well-being; hence, the color of light also matters. No previous study applied a similar whole day ambient illumination. Nonetheless, these results are aligned with those from a few other studies that reported the beneficial effects of blue light exposure in the morning on enhancing mood in older adults. Anecdotally, the experimental lightings were received well by our participants and almost all of them preferred the L2 intervention over the L1 as they felt it was more similar to natural lighting, especially in the morning. Although non-significant, we found lower mean depression score in baseline 2 compared to baseline 1 in both groups. This might occur due to the lasting effects of interventions on participants. Further research is needed to determine the longevity of similar lighting interventions on older adults. Moreover, results exhibited no significant effects of order of exposure as the difference between the means of depression scores in L1 and L2 were not significantly different between groups. Applying a whole-day lighting scheme with tuning spectrum and intensity was an effective design approach to reduce depression and improve mood and well-being in older adults.

However, despite the proven effects of light on health in older adults, lighting is not considered a design priority among architects, particularly when it comes to residential units. In most residential units, ceiling mounted luminaires are designed only for kitchen and bathrooms and no permanent lighting system is considered for living rooms and bedrooms. Architects usually rely on daylighting and the floor/table lamps provided by residents to illuminate living rooms. These lighting systems cannot create a uniform lighting distribution and therefore cause poor lighting condition in the living rooms where older adults spend most of their active time when they are home. On the other hand, indoor daylight availability may vary depending upon weather conditions, climate, and daylighting systems types. Consequently, most living units of older adults suffer from very dimmed lighting conditions. Therefore, considering an ambient illumination with tuning intensity and spectrum could be an effective design solution to create a healing living environment and improve mood and overall quality of life in older adults.

This can be achieved through integrating a proper daylighting system with ceiling mounted tunable white luminaires which provide a direct/indirect lighting distribution. Whereas direct lighting distribution provides illumination required for visual tasks, an indirect distribution is needed for the biological effects of light. The tunable white luminaires should incorporate smart lighting and daylighting control systems to adjust light levels and CCT throughout the day based on each individual's need. This is an ethical way of exposing older adults to a therapeutic lighting and form a healing living environment. The ceiling mounted luminaires are especially important for those of older adults living in regions with cold and/or cloudy climates where the benefits of natural light are absent. This field study of course has limitations. Perhaps one main limitation is the small sample size which limits generalization of the results. Additionally, no formal observation was conducted to control the number of hours participants were actually exposed to study interventions.

The lack of a formal control group (such as having the experimental luminaires in the apartment which simulate the conventional lighting condition only) may also limit the findings of this study. Future research efforts should increase the sample size and diversity of participants; expand the exposure period; measure the long-term effects of these whole-day lighting interventions; and compare to a control group.

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