

RESEARCH ON THE POSSIBILITY OF APPLYING LED LIGHTING TO DEMENTIA TREATMENT

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Abstract

In countries where the elderly population is rapidly increasing, including Korea, dementia is emerging as a social problem. Dementia increases the socio-economic costs of the community, as well as the direct suffering of patients and their families. However, there are no ways to effectively treat dementia. For this reason, studies related to dementia in various fields are increasing rapidly in recent years. Dementia-related studies mainly focus on prevention of dementia and delayed onset of dementia, and are seeking solutions focusing on environmental design, exercise, augmented reality, and play programs. However, the most important topic in dementia is memory. Most of the symptoms of dementia such as memory loss, problem solving ability reduction, and emotional change are closely related to memory. Recent studies have reported that light affects memories and even human emotions. Therefore, finding out the relationship between light and memory can be seen as having sufficient potential for dementia prevention, onset delay, and dementia treatment. To this end, this study aims to analyze the effects of LED lighting on long-term memory, focusing on illumination, and to find ways to apply the results.

Keywords: LED lighting, memory, dementia, long-term memory

1. INTRODUCTION

Various lighting studies report that light affects human emotions, attention, sleep, fatigue, cognitive performance, and memory. In particular, among these, memory is a very important subject to be dealt with in modern society. This is because memory is closely related to cognitive disorders such as dementia. Recently, due to the rapid increase in the elderly population, cognitive disorders such as dementia are rapidly emerging as a social problem in Republic of Korea. According to the Central Dementia Center, the number of dementia patients over 65 in Korea is expected to be 1 million in 2024 and 2 million in 2039. And the annual management cost per dementia patient is estimated at about \$ 18,000 in 2017, accounting for 38.9% of the monthly average income per household. The bigger problem is that there is still no effective treatment, so individual and social costs must continue to be spent on dementia patient care until death. Therefore, dementia is one of the challenges that our society must solve. For this reason, dementia-related studies have been rapidly increasing in various areas in recent years. Research related to dementia mainly focuses on the prevention or delay of onset of dementia, and various approaches such as environmental design, exercise, augmented reality, and play programs are being conducted. However, the most important thing in dementia is memory. Representative symptoms of dementia are memory impairment, lack of problem-solving ability, disorientation, and emotional changes. These are all closely related to memory. In addition, it is reported that light affects human emotions as well as memories. Therefore, understanding the relationship between light and memory is also important in the prevention and delayed onset of dementia.

Light and memory studies report that the characteristics of light affect human attention, working memory, and long-term memory. Among them, studies related to the effect of light on attention and working memory report that the performance is excellent in the condition of high illumination of light, that is, bright light condition. For example, Smolders et al. (2012) measured attention through the reaction time under the conditions of 200 lx and 1,000 lx, and as a result, the reaction time was statistically significantly faster under the conditions of 1,000 lx than under the conditions of 200 lx. However, some studies have reported that they did not find the excellence of working memory in bright

light conditions or, rather, performed poorly. Representatively, Huiberts et al. (2015) measured working memory through a numeric span task at 200 lx and 1,000 lx illuminance in the morning and afternoon hours. As a result, bright light conditions induce improved working memory in easy tasks measured in the afternoon. However, in a difficult task experiment conducted in the afternoon, it was reported that the bright light rather reduced performance. These inconsistent results mean that there is still much to be explored about the effect of light on attention and working memory. In addition, studies related to color temperature have shown more inconsistent results.

Although there are some inconsistent studies on the relationship between light and memory, efforts to apply light to the treatment of dementia are still very attractive. Because light is always an environmental condition with our lives, and it is very easy to access, cost and applicability. Therefore, this study aims to analyze the effect of light characteristics on memory, focusing on LED lighting, and propose the possibility of applying dementia through this. For this purpose, this study examines the characteristics of light and the rate of forgetting of long-term memory over time through a experiment, and analyzes whether there is a difference in the rate of forgetting depending on the light conditions. In addition, through these differences, it is intended to explore the possibility that the characteristics of light can have an effect on the forgetting speed of memory, and the possibility of using light to maintain the memory.

2. METHODS

2.1. Lighting environment

The lighting used in this experiment used an automatic LED lighting device based on a light sensor developed for the experiment. The LED lighting device has an advantage of being able to maintain a set lighting environment regardless of the surrounding environment because an illuminance sensor and a color temperature sensor are inserted. The lighting conditions in this study were treated under two conditions, 400 lx and 1,000 lx, and the color temperatures were all set to 5,000 K.

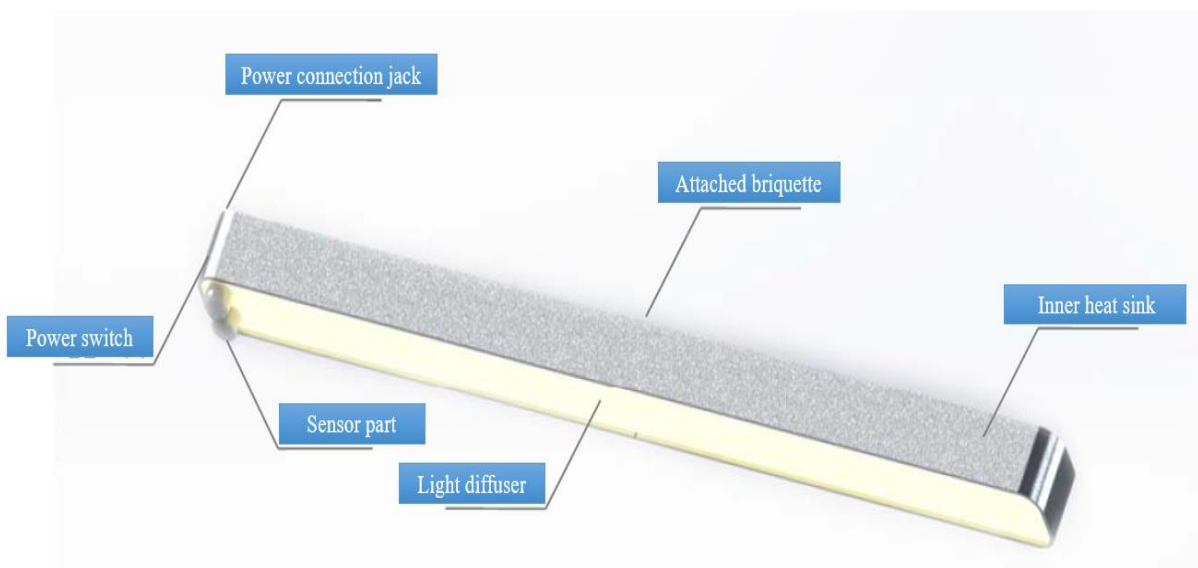


Fig. 1. Automatic LED lighting device based on a light sensor

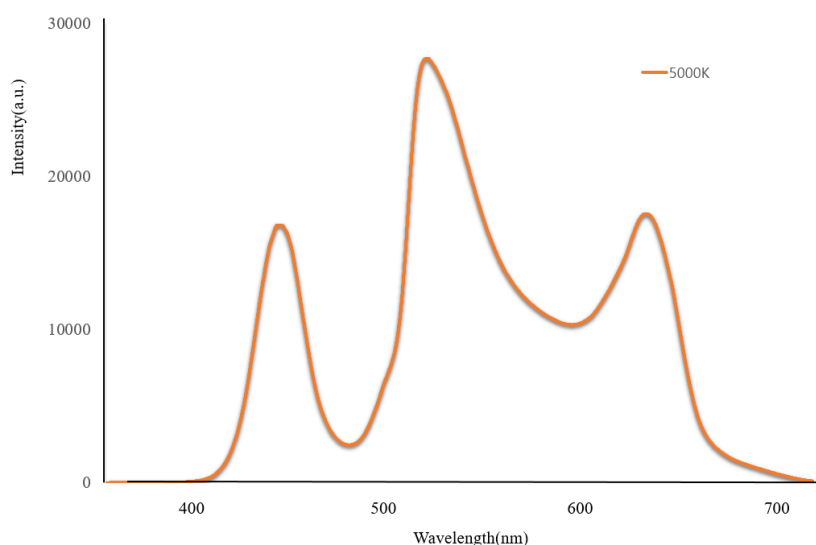


Fig. 2. Automatic LED lighting device's wavelength

2.2. Participants

There were 18 participants in this experiment, 6 males and 12 females, and the average age was 22.8(SD=2.4) years old. Orientation was conducted before the experiment. In the orientation, the experiment was explained and tasks were preliminarily carried out. Through this, the test participants' cognitive impairment and the suitability of participation in the experiment were verified. In addition, in order to block the factors that may affect the experiment as much as possible, they took enough sleep and prohibited alcohol or caffeine. The average sleep time of the experimental participants was 7.36 hours.

2.3. Measurement

Long-term memory was measured through the Word Fragment Completion (WFC) task. WFC task is one of the tools that can indirectly measure long-term memory by completing words by filling in missing letters based on learned information. In this experiment, after consciously learning meaningless words composed of only English consonants, after a certain period of time, the procedure of retrieving information from memory through the WFC task was conducted. The number of spellings of meaningless words used in this experiment consisted of 7 words, and the number of spellings to be filled in the retrieval stage was 2 words. The learning task and the WFC task consisted of a total of 7 items, and the number of items that completed words correctly among the total tasks was used as a measure of long-term memory.

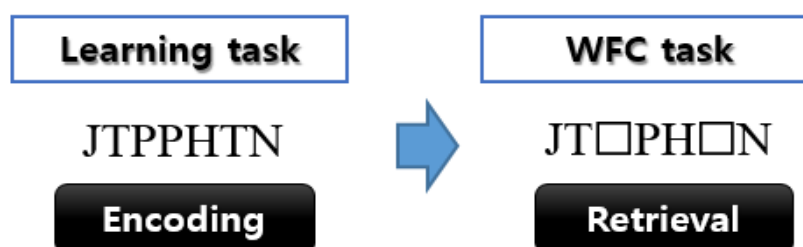


Fig. 3. An example of the WFC task used in the experiment

2.4. Experiment Procedure

This study was conducted through repeated measurement experimental design. Experimental participants were placed in both lighting conditions, and the order was assigned randomly. First of all, participants adjusted to the lighting environment through 2 minutes of dark adaptation and 2 minutes of light adaptation. After that, participants studied 14 learning tasks for 14 minutes, and then conducted an interference task to prevent rehearsal for 5 minutes. Immediately after the interference task was completed, the amount of memory retrieval after 5 minutes was measured. Out of a total of 14 learning tasks, 7 WFC tasks were presented randomly. The total time to complete the WFC task was 5 minutes. After that, an interval was set for 20 minutes, and the amount of memory retrieval at the time 30 minutes had passed was measured again.



Fig. 4. Experiment procedure

3. RESULTS

As a result of the descriptive statistical analysis of the long-term memory retrieval amount according to the illumination and time of the LED lighting, the long-term memory retrieval amount after 5 minutes was Mean=4.83 in the 1000 lx condition, which is higher than Mean=4.61 in the 400 lx condition.

	400 lx(Mean(SD))	1,000lx(Mean)(SD))	N
5minutes	4.61(2.20)	4.83(1.89)	18
30minutes	3.94(2.01)	2.83(1.95)	18

Table 1. Result of Descriptive statistical analysis

Then, repeated measures ANOVA (Analysis of Variance) was conducted to verify whether there was a significant difference in long-term memory between the four experimental conditions of LED lighting. As a result of the analysis, it was found that there was a statistically significant difference in the amount of retrieval of long-term memory between the four experimental conditions with $F=9.50$ ($p=.00$). In order to explore more specific differences between conditions, a post-hoc test was performed through the LSD method.

	Sum of Square	df	Mean of Square	F	P
Long-term memory	43.56	3	14.52	9.50	.00**

* $p < .05$ ** $P < .01$

Table 2. Result of repeated measures ANOVA

Illumination/Time	Mean Difference(I-J)	P
400 lx/5m(I) vs. 400 lx/30m(J)	.67	.097
400 lx/5m(I) vs. 1,000 lx/5m(J)	-.22	.508
400 lx/5m(I) vs. 1,000 lx/30m(J)	1.78**	.002
400 lx/30m(I) vs. 1,000 lx/5m(J)	-.89*	.038
400 lx/30m(I) vs. 1,000 lx/30m(J)	1.11**	.008
1,000 lx/5m(I) vs. 1,000 lx/30m(J)	2.00**	.001

* $p < .05$ ** $P < .01$

Table 3. Result of Post-hoc test

In the post-hoc test results, statistically significant differences were found between several conditions. First, there was a significant difference with a mean difference of 1.78 between the 400 lx/5m condition and the 1000 lx/30m condition. It can be considered a natural result that the amount of memory retrieval decreases as time passes. However, in this study, there was no difference in memory retrieval over time under the lighting condition of 400 lx. These results can be said to show that the forgetting of memory appears relatively slowly at 400 lx illuminance.

Second, a significant difference was found with a mean difference of 1.11 between the 400 lx/30m condition and the 1000 lx/30m condition. These results indicate that memory retrieval was good in a relatively dim 400 lx condition when about 30 minutes elapsed after learning. This supports the results of previous light and long-term memory studies. However, no statistically significant difference was found, but the memory retrieval was excellent at 1,000 lx, which is a relatively bright light condition under the 5-minute condition. This is a very interesting result. Carefully inferred, these results can be said to show that learning can be superior in bright light conditions, while memory retention can be seen in relatively dim light conditions.

Finally, a significant difference was found with a mean difference of 2.0 between the 1000 lx/30m condition and the 1000 lx/30m condition. This is a result showing that memory oblivion over time can appear relatively rapidly under relatively bright light conditions.

In summary, although learning is performed better in relatively bright light conditions, forgetting occurs more quickly over time, and in dim conditions, it can be seen that there is an advantage in delaying forgetting rather than learning. These contradictory results can lead to agonize about whether bright light or dim light is better in terms of learning effect. However, with regard to dementia, the delay in forgetting may be more important than learning. Therefore, inferring based on this experiment, I think that the possibility of maintaining memory for a longer time cannot be ruled out if a relatively dim 400 lx light is used in terms of treatment or delay of onset of dementia patients.

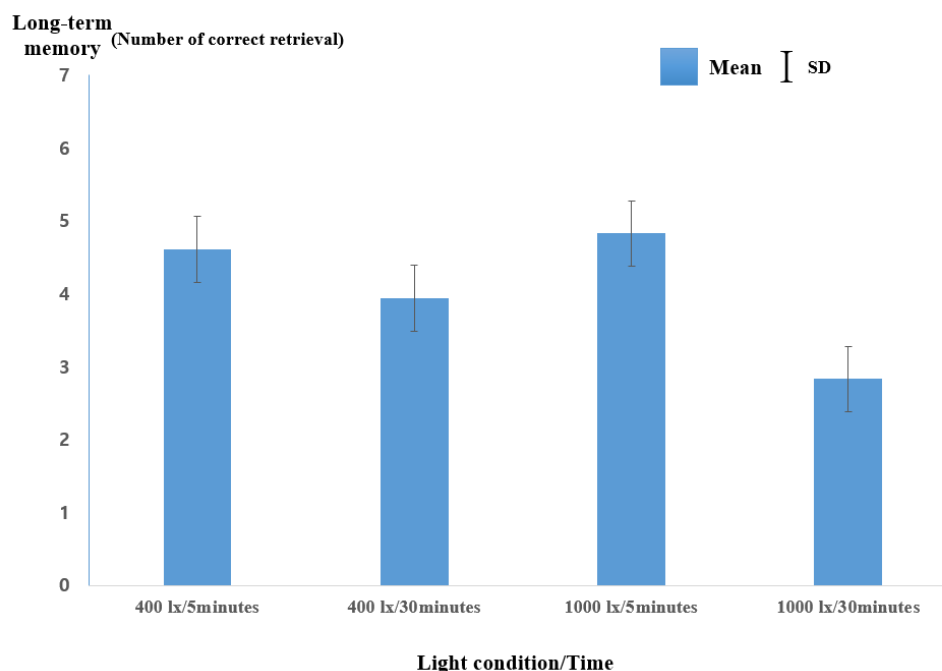


Fig. 5. Long-term memory according to illumination and time

4. DISCUSSION

The purpose of this study was to compare the light illuminance and the amount of memory retrieval over time, focusing on LED lighting, and to explore the possibility of applying it to dementia through this. For this, the retrieval amount was measured at 5 and 30 minutes under a relatively dim illumination condition of 400 lx and a bright illumination condition of 1,000 lx. As a result of the study, memory retrieval was excellent in the condition of 1,000 lx at the time of 5 minutes after learning, whereas memory retrieval was excellent in the condition of 400 lx in 30 minutes. From the results of this study, it was found that high illumination conditions are advantageous in terms of learning, and relatively dim 400 lx conditions are advantageous in terms of memory retention. In addition, through this study, it was confirmed that the illuminance of LED lighting can affect forgetting. These findings imply that the possibility of applying LED lighting to dementia may be sufficiently possible, and it may be said that a rather dark light illuminance may be effective in maintaining memory. These research results can be said to show the possibility of using light for the treatment or prevention of dementia in the future.

Nevertheless, this study has limitations in several aspects. First, this study measured the retrieval of memory only for 5 and 30 minutes. According to Ebbinghaus's forgetting study, about 58% of memories are reported to be forgotten after about 20 minutes. Therefore, in order to properly understand the illuminance of light and oblivion over time, it is judged that an additional study of about 20 minutes should be conducted. It seems that there is a need to explore this through further research. Second, in this study, memory retrieval was measured using meaningless spelling. However, according to existing studies, it is reported that the forgetting pattern of meaningful words is slower than that of meaningless spelling. Considering that the forgetting of meaningful words rather than meaningless words is a problem in real dementia patients, it is judged that it is necessary to conduct a study of forgetting according to illumination and time through meaningful words or tasks in future studies. Finally, the participants in this study were mainly young people. Although this study explores the possibility of applying dementia, it is still a big limitation that it was not conducted in the elderly, closely related to dementia. Therefore, it is judged that there is a need to secure diversity of participants including the elderly in future studies.

5. CONCLUSIONS

Dementia is a disease that is considered very serious in Korea and other countries where an aging society is rapidly progressing. However, there are still almost no treatment methods to dramatically improve dementia. Therefore, many studies are making great efforts to prevent or improve dementia. Based on the research findings that light affects human memory and emotions, I think that there is enough possibility that light can be applied to dementia. Light is one of the environmental stimuli that modern people are most exposed to, and it is closely related to our lives. Therefore, there are many ways to use light, and its accessibility is easy. However, studies related to light and memory are still lacking in their number and repetition verification. This study investigated the effect on memory retention in order to explore the possibility of utilizing the field of dementia of light through the illuminance of LED lighting and memory retrieval according to time. Through this study, it was found that bright light conditions are easy to learn, but forgetfulness occurs quickly over time. On the other hand, the dim light condition showed that the learning effect was inferior to the bright light condition, but the retention of memory was excellent. These results mean that light can be fully utilized for the promotion and maintenance of memory. Starting with this study, it is expected that various studies that can help improve memory of dementia patients, delay onset of dementia patients or improve memory are expected to be triggered.

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