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Research Article

An Experimental Study on the Image Output Emergency Lighting Operating with Smoke Detector

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Abstract: This study is an investigation into the ease and effectiveness of emergency lighting. In the experiment, the evacuation time and elements such as recognition distance, search time, and travel time were compared and analyzed for existing LED emergency lighting and the newly developed image output emergency lighting. This was tested in the process of searching for the emergency lighting at various levels of smoke concentration. In order to examine how information affects evacuation choices of evacuees, image output emergency lighting with smoke detectors were produced and used in the experiments. The results are summarized as follows. First, the recognition distance of the exit in the smoke concentration of 30% was the greatest with the image output emergency lighting. It was determined that the evacuation time was short because the evacuation behavior of the evacuee was detected even from the farthest distance while the evacuee searching for the light of the emergency exit was affected by visual impairment and fear due to the indoor smoke. Second, the recognition distance of the exit in the smoke concentration of 70% was the greatest with the image output emergency lighting. It is judged that this is because evacuees were able to escape the building safely by recognizing the exit in the dense smoke by following along the light of the image output emergency lighting. Third, when the smoke concentration was 100%, the smoke increased, and the existing LED emergency lighting at the top of the exit was not identifiable due to the thick smoke. The image output emergency lighting is displayed on the floor of the passage, so the evacuee was able to accurately recognize the exit by looking at the guidance light of the image output emergency lighting, and evacuate safely.

Kewords: Smoke detector, emergency lighting, image output emergency lighting, evacuee

1. Introduction

The structure of modern buildings is becoming more and more complex, dense, and high-rise, so it is the top priority for residents to identify emergency lighting in an evacuation situation, in order to evacuate quickly and safely. Kim [1] states that occupants in an evacuation situation tend to preferentially select a familiar route to use. According to Kim[2] emergency lighting, passage emergency lighting, and corridor passage emergency lighting should be installed in spaces within the building to help evacuees evacuate the building in evacuation situations. Since it guides occupants to the evacuation floor and out of the building according to the direction of evacuation,

the installation method is specified in the 「Fire Safety Standard for Guidance Lights and Guidance Signs (NFSC 303).[3] Oh[4] states that due to power outages and thick smoke in the event of a fire, evacuees are confused by visual impairment and fear, and their judgment consciousness is clouded, so they cannot find the exit. At the time of the Jecheon Sports Center fire accident on December 21, 2017, the direction of evacuation and the location of the emergency exits were not known due to the lack of installation of firefighting facilities such as emergency lighting, and more than 20 people died because evacuation from the second floor was not possible [5]. Na [6] found that visual impairment was the biggest disruption to evacuees, such as not being able to distinguish the emergency lighting and taking a long time to look for the emergency lighting and the exit, which results in making inaccurate decisions that cause a great loss of life. Son [7] states that emergency lighting should be distinguishable from a distance by having evacuation indicators installed on the floor and in front of emergency doors. Kim [8] states that it is necessary to install evacuation guidance signs on the floor of the corridor in consideration of the rise of smoke so that evacuation guidance signs in the building can be identified from a distance and evacuees can safely evacuate outside.

In this study, the aim is to help evacuees safely evacuate a building even when there is a high smoke concentration causing fear and visual impairment, by having emergency lighting that is visible when there is thick smoke and having evacuation indicators displayed on the floor and in front of doors to guide evacuees to the exit by displaying information of image output emergency lighting linked with a smoke detector with very high identification on the display surface. It is significant in order to reduce the risk to people.

2. Experiment Method

2.1 Configuration of Image Output Emergency Lighting

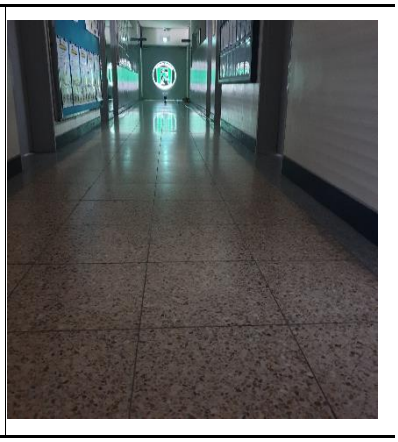
This investigation is an experiment in which a fire situation is created in the corridor of a school building in stages, starting from the central waiting room on the second floor, and participants must evacuate to the entrance staircase on the roof or to the first floor. Each experiment was conducted first with existing LED emergency lighting installed on the floor of the building to guide participants to the exit, then it was repeated with newly developed image output emergency lighting installed, which is displayed on the bottom of the passage and has video information to guide participants towards the exit. The smoke concentration as well as the subject's recognition distance, search time and travel time were measured, in order to analyze the change in recognition distance, search time and travel time. Each experimental step and method are as follows. First, there are 30 participants in the study, made up of men and women aged between 20 and 30 years of age, who all have no experience with the test site. Second, the environment was controlled in the evacuation site, and the smoke concentration was changed to affect the participants' field of vision. When the smoke concentration was 100%, the test took place at night time and artificial light was blocked, in order to make the experiment represent the actual fire environment. Third, before participating in the experiment, the participants were informed about the content of the experiment, and the experiment was conducted twice to ensure reliable results. Fourth, the participants evacuated one at a time in order to avoid following each other, and experiments were conducted in order to test each subject's own cognitive ability, search

time and travel time in the changing smoke concentrations. Fifth, the participants started at appropriate time intervals, and they were accompanied by an investigation recorder to record the experimental data.

2.2 Design of Image Output Emergency Lighting

Image output emergency lighting linked with smoke detectors receives information provided by the projection department and output an image so that the evacuee can check it with the naked eye. The configuration of the image output emergency lighting consists of the main body and an image output unit to guide the evacuee in a safe direction. Since the body is embedded in the bottom surface and coupled with a fixed hinge, it can be rotated forward or toward the passage, and the bottom surface of the main body is fixed with a fixing bolt which is strong enough to resist flames so that it does not shake during image output. The condition of the image output should not be distorted. In addition, the cover is embedded with tempered glass, which is at the same level as the floor surface so that it is not exposed, and when an emergency occurs due to a fire, the image output on the front of the door or the floor surface of the passage is operated to indicate towards the exit. It is desirable that the tempered glass is formed of a heat-resistant material that can withstand high temperatures to protect the projection unit. The 2smoke detector sensor transmits a signal to the projection unit that there is smoke, and the image output unit outputs the image information to guide evacuees to the exit. The image output unit outputs the pre-stored information as an image that displays the direction of the exit door and the floor of the passage, which allows the evacuee to identify it and evacuate safely. Also, when the emergency situation is concluded, the video output of the projection unit is stopped. Figure 1 shows the image output emergency lighting linked with a smoke detector, which was designed for this study.

Figure 1. Image output emergency lighting



(a) Display surface of image output emergency lighting

(b) Main body of image output emergency lighting

(c) Condition of image output emergency lighting

2.3 Subject of Experiment

As shown in Table 1, this study was conducted from January 6 to January 10, 2020 on the second floor of the __ Department, Engineering Building,University. A total of 30 participants were recruited. The participants' visual acuity was normal, which did not affect the ability to discern light in the experiment.

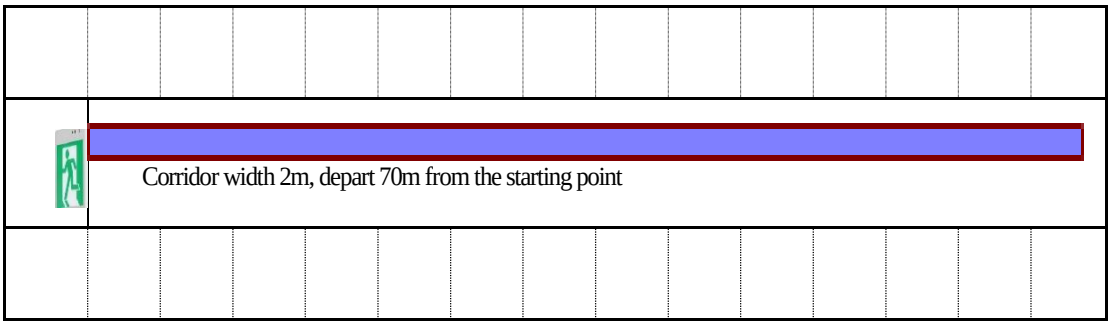
Table 1. Subject of Experiment

Classification	Content
Date	1/6/2020 - 1/10/2020
Location	XX University (xx Campus)
Target Site	xxxx Department, x Engineering Building
Number of people	30 ((20 male, 10 female)
Number of group	3
Age	20-30 years old

2.4 Experiment Scenario

This investigation is an experiment in which a fire situation is created in the corridor of a school building in stages, starting from the central waiting room on the second floor, and participants must evacuate to the entrance staircase on the roof or to the first floor. Each experiment was conducted first with existing LED emergency lighting installed on the floor of the building to guide participants to the exit, then it was repeated with newly developed image output emergency lighting installed, which is displayed on the bottom of the passage and has video information to guide participants towards the exit. The smoke concentration as well as the subject's recognition distance, search time and travel time were measured, in order to analyze the change in recognition distance, search time and travel time. The evacuation test was conducted in a corridor, and the image output emergency lighting was designed according to the placement and scenario. The total corridor length of the test building is 70m, the corridor width is 2m, the ceiling height is 2.5m, and the slope of the floor is 0 degrees. The image output emergency lighting linked with smoke detectors, which was used in this experiment, receives information provided by the projection department and outputs an image at the center of the corridor or floor, so that the evacuee can check it with the naked eye. The configuration of the image output emergency lighting consists of the main body and an image output unit to guide the evacuee in a safe direction. The floor plan of the building to be tested is shown in Figure 2.

Figure 2. Floor plan



3. Result of the Experiment

Figure 3 shows the results of the experiment on the recognizability of existing LED emergency lighting and newly developed image output emergency lighting according to the concentration of smoke. Examining the results of the experiment, the LED emergency lighting and the image output emergency lighting were tested by blocking the artificial light in the dark night time with 30%, 70%, and 100% smoke concentration. The participants were made aware of the contents of the experiment before participating in the A and B experiments, and the test was conducted twice to ensure reliable results. The evacuees were tested individually to prevent them from following one another to evacuate, so that data could be obtained for their own cognitive ability, search time, and travel time, according to the change in smoke concentration. There were 30 participants, consisting of men and women aged between 20-30 years of age, who all had no experience with the test site. The subjects' recognition distance, search time and travel time were measured to compare and analyze their cognitive performance while visually impaired by the smoke concentration and darkness at night.

Figure 3. Recognizability of LED emergency lighting and image output emergency lighting

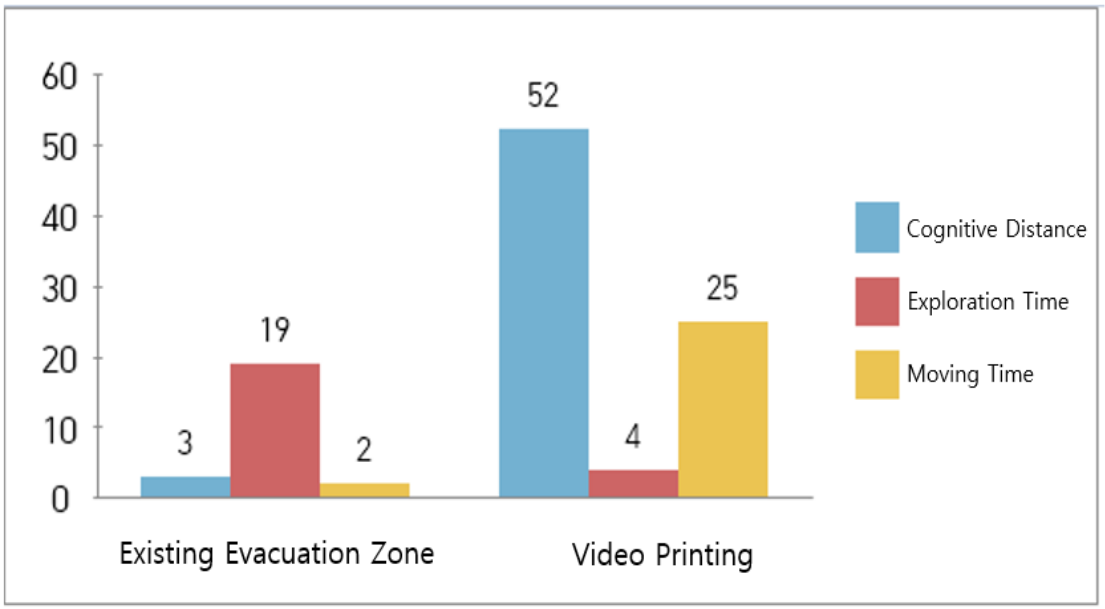
(a) LED emergency lighting **(b) Image output emergency lighting**

3.1 Analysis of the recognizability of emergency lighting at the smoke concentration of 30%

At the smoke concentration of 30%, the recognisability of the LED emergency lighting and the image output emergency lighting was compared. When the smoke concentration is 30%, the interior of the building is generally blurred. At this time, the recognition distance is 3m for the existing LED emergency lighting and 52m for the video output emergency lighting, which is a difference of 49m. The search time was 19 seconds for the existing LED emergency lighting and 4 seconds for the image output emergency lighting, which is a difference of 15 seconds. The travel time was 2 seconds for the existing LED emergency lighting and 25 seconds for the image output

emergency lighting, which is a difference of 23 seconds. In the process of finding the sign on the door while experiencing visual impairment and fear at the smoke concentration of 30%, the image output emergency lighting showed the largest recognition distance of the door from the farthest distance. The search time was also short, 4 seconds, and it was judged that the correct information was selected for the evacuation action and it had an effect on the time required for evacuation. Figure 4 shows the result of the analysis on the recognition of emergency lighting while there is a smoke concentration of 30%.

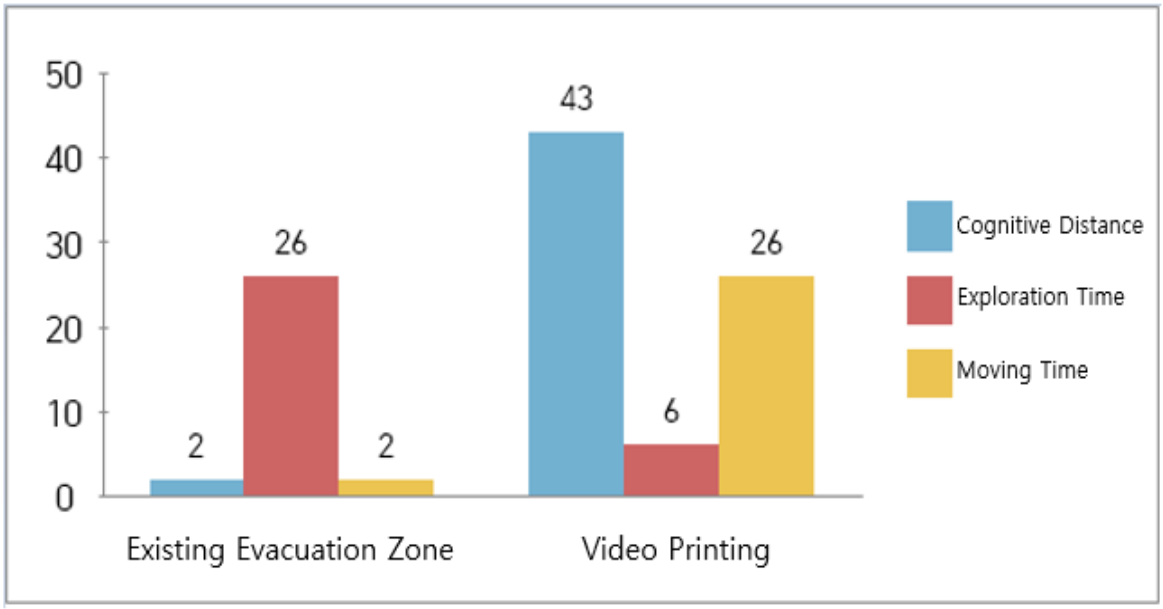
Figure 4. Analysis of the recognizability of emergency lighting at the smoke concentration of 30%



3.2 Analysis of the recognizability of emergency lighting at the smoke concentration of 70%

At the smoke concentration of 70%, the recognisability of the LED emergency lighting and the image output emergency lighting was compared. In the event of a fire, smoke fills the interior of the building over time, but when the smoke concentration is 70%, the interior of the building is difficult to see. At this time, the recognition distance is 2m for the existing LED emergency lighting and 43m for the image output emergency lighting, which is a difference of 41m. The search time was 26 seconds for the LED emergency lighting and 6 seconds for the image output emergency lighting, which is a difference of 20 seconds. The travel time was 2 seconds for the LED emergency lighting and 26 seconds for the image output emergency lighting. It was found that the largest recognition distance of the entrance door was 43m with the image output emergency lighting, which allowed the evacuee to safely exit to the outside while following the emergency lighting. The search time was 6 seconds and the travel time was 26 seconds. The analysis results are shown in Figure 5.

Figure 5. Analysis of the recognizability of emergency lighting at the smoke concentration of 70%



3.3 Analysis of the recognizability of emergency lighting at the smoke concentration of 100%

At the smoke concentration of 100%, the recognizability of the LED emergency lighting and the image output emergency lighting was compared. In the event of a fire, smoke fills the interior of the building over time, but when the smoke concentration is 100%, the interior of the building is impossible to see. At this time, the recognition distance was 38m for the image output emergency lighting, the search time was 6 seconds and the travel time was 27 seconds. However, the existing LED emergency lighting was not identifiable at 100% smoke concentration. When the smoke concentration is 100%, the smoke rises, and the LED emergency lighting at the top of the entrance door was not identified due to the thick smoke. However, the image output emergency lighting outputs an image on the bottom of the passage, so the evacuees could evacuate safely. It was found that the recognition distance of the exit was the largest with the image output emergency lighting, because evacuees could recognize it even from a long distance. The search time with the image output emergency lighting was also short at 6 seconds, and the evacuation time was usually 27 seconds.

The analysis results are shown in Figure 6.

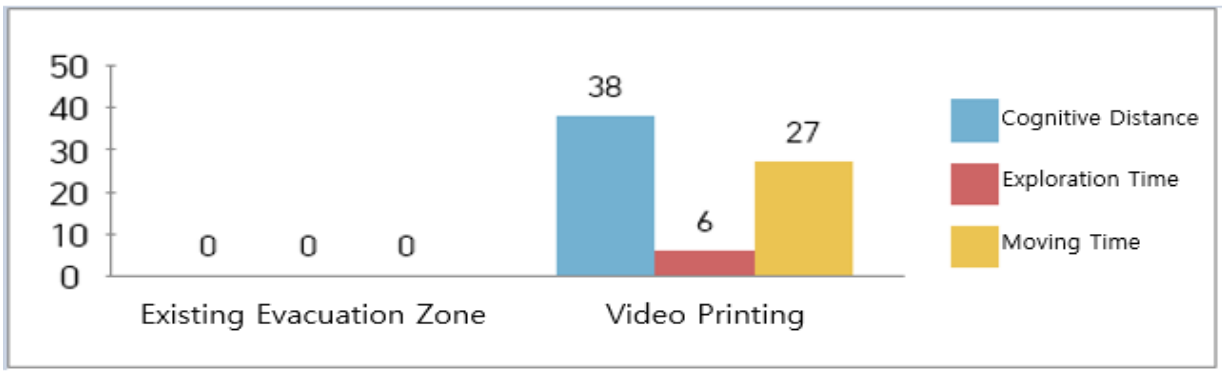


Figure 6. Experiment of the recognition distance of emergency lighting at the smoke concentration of 100%

Table 2 summarizes the results of the experiment with the existing LED emergency lighting and the newly developed image output emergency lighting.

Table 2. Recognizability of LED emergency lighting and image output emergency lighting according to different levels of smoke concentration

Division	LED Emergency Lighting			Image Output Emergency Lighting		
	Smoke Concentration 30%	Smoke Concentration 70%	Smoke Concentration 100%	Smoke Concentration 30%	Smoke Concentration 70%	Smoke Concentration 100%
Recognition Distance (m)	4	2	0	52	43	38
Search Time(s)	19	26	0	4	6	6
Travel Time(s)	2	2	0	25	26	27

4. Conclusions

This study is an experiment that compares and analyzes the variables in evacuation such as recognition distance, search time and travel time in the process of searching for emergency lighting according to smoke concentration changes between existing LED emergency lighting and newly developed image output emergency lighting. In order to examine how information affects the evacuation choices of evacuees, image output emergency lighting linked with smoke detectors were produced and conducted through experiments. The results are summarized as follows.

First, it was found that the performance tests using the image output emergency lighting were favorable. In this case, fake smoke was used for the detector at the upper part of the corridor entrance, and the fire signal and the image output emergency lighting operated together simultaneously. Therefore, it was found that in the event of a fire, the evacuee could safely evacuate to the outside by following the lights which displayed information on the floor of the passage to guide them to the exit.

Second, it was found through the recognizability test that the illuminance of the image output emergency lighting was appropriate. The recognizability test of the image output emergency lighting display was conducted based on technical standards for lighting formal approval and product inspection, with the lighting installed 2m from the floor. It was found that the illuminance at a location 0.5m away from the middle of the lighting and from the front and center part of the lighting was displayed as 1lx or more, which met the standard.

Third, it was found that the identification of the display surface of the image output emergency lighting was clear to guide evacuees to a safe place. In recognizing the lighting, the image output emergency lighting of the image output device was found to be accurately recognized even from a long distance, and the search time was short, so it was found to display accurate information for evacuation behavior and positively affect the time required for evacuation. In the typical environment, the existing LED emergency lighting and image output emergency lighting were tested in a 60m straight distance after turning on the lighting with a commercial power source according to the regulations.

Fourth, in the smoke concentration of 30%, the largest recognition distance of the exit was observed with the image output emergency lighting. In the process of finding the light of the exit while suffering from visual impairment and fear, it is judged that the correct information is displayed for the evacuation action and is recognizable from the farthest distance, which positively influenced the evacuation time.

Fifth, at 70% of smoke concentration, the largest recognition distance of the exit was 43m, which was with the image output emergency lighting. The image output emergency lighting was recognized from the farthest distance and it was observed that the evacuee could safely evacuate while following the image output emergency lighting.

Sixth, when the smoke concentration is 100%, the LED emergency lighting at the top of the exit door was not identifiable due to the thick smoke, which had risen. The indicator of the image output emergency lighting was shown on the floor of the corridor so that the evacuee can evacuate safely while following the image output emergency lighting. The largest recognition distance was shown with the image output emergency lighting.

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