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Comparison of Viewing Contents Using Large LED Display and Projector by Psychological Evaluation

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Abstract. Displaying content on a large screen using an LED display or projector has many possible applications including entertainment. Therefore, which one is appropriate depending on the various situation is an important theme. In this research, a psychological experiment was conducted to compare the cases where video contents were displayed on a 200-inch LED display and a 200-inch screen with a projector under three different brightness conditions. As the content, we used 6 kinds of lecture videos with a wide variety including science, technology, psychology, art, etc. by Kyoto University professors. We asked 34 subjects to watch each lecture video for 20 minutes and then fill out a questionnaire. As a result, the brighter the LED display, the better the evaluation result, while the brighter the projector, the lower the evaluation result. Also, a further detailed analysis was performed by analysis of variance (ANOVA).

Keywords: Projector, LED display, Large display, Lighting, Psychological experiment, two-way ANOVA

1 Introduction

Displaying images and videos on a large screen is suitable as a means of appealing image information to many people. Such display method is suitable for events, conference presentations, street advertisements, entertainment, art exhibitions, etc. As a method of displaying a large screen image or video, there are a method of displaying on a large LED display and a method of projecting with a projector. Although large LED displays are expensive, they have excellent visibility even in bright conditions, so they are often used in places with high daytime traffic such as train stations and street corners. On the other hand, the method of displaying using a projector has the drawback that it is difficult to see in a bright situation but has the advantage that it can be displayed without changing an existing wall or building. In particular, projection mapping [1], which projects a three-dimensional image using the shape of a building as it is, is attracting attention as a new display method and is often used in entertainment and other situations [2]. On the other hand, as the price of large LED displays has fallen and the

brightness of projectors has improved, the scenes in which both are used are beginning to overlap.

In this study, we conducted a comparative experiment between LED displays and projectors showing contents on a large screen. For the experiment, several conditions were set for the brightness, and various video contents to be displayed were prepared. And the experiment was conducted using the framework of the psychological experiment in which the subjects filled out questionnaires. In this paper, we will describe the experimental contents, analysis results, and consideration based on them. This paper is useful in that it presents reference data on which condition is to be used when images/videos are displayed on a large screen using LED displays and projectors.

2 Related Work and Background

Psychological studies on the visibility of displayed images have been conducted for long time. Gilinsky showed that the distance to the image and the size of the image have a great effect on visibility [3]. Since then, as display methods, projectors, LED displays, and LCD televisions have become widespread, research on the visibility of displayed images/videos has been actively conducted.

For example, regarding display by a projector, research on the effect of screen size and distance to the screen on visibility [4] and research on screen size suitable for building a VR environment were conducted [5]. Regarding LED displays, visibility when used for signs was studied [6]. In addition, researches on the visibility of high-resolution image/video display using HDTV were conducted [7] [8].

However, it seems that no experiment has been reported so far that directly compares the display by the LED display and the projector under various conditions. As we think it is necessary to systematically carry out such a comparative experiment, in our previous research we carried out the psychological experiment in which we asked the subjects to watch contents on the LED display and the projector and to comparatively evaluate the two methods [9]. In the experiment, a comparative experiment was conducted using two types of contrasting content, art content [10][11], and text-based content. In addition, as for the lighting conditions, there were two conditions; with lighting and without lighting. As a result, when the art content was viewed using the LED display under the condition without lighting, it was highly evaluated, followed by the condition of art content x LED display x lighting and art content x projector x no lighting. The results showed that the art content was highly evaluated compared to the case of text-based content.

On the other hand, however, the fact that the art content is used has a great influence on the evaluation result. Also, the presentation time of the content was as short as 1 minute. Since most of the viewing using a large display/screen is a scene such as a lecture or a conference presentation, we received requests to carry out a comparative experiment under such realistic conditions. To meet such demands, we assumed more realistic scenes such as lectures and conference presentations and conducted a comparative experiment using an LED display and a projector when viewing such scenes for a certain period.

3 Method

3.1 Experimental condition

Two types of display methods and three types of lighting conditions were arranged, and as a result, six types of experimental conditions combining these were arranged.

(1) Display method

To simulate the content displayed on a large screen and to make an accurate comparison between the LED display and the projector, a method of displaying contents on a 200-inch LED display and a 200-inch screen using a 10,000-lumen projector are used. The size of both the display and the projector is 4.43m in width and 2.5m in height (ratio 16: 9). The LED display is made by arranging SMD elements at a pitch of 2.5 mm, and the total resolution is 1760 pixels x 960 pixels, which is almost full HD resolution. The brightness is 1200 cd/m². The 10,000-lumen projector is also full HD resolution. All projected images were in HD.

Figure 1 shows the 200-inch LED display and Figure 2 shows the screen and projector. The LED display, projector, and screen necessary to realize these environments were installed in a laboratory with an area of about 300 square meters.



Fig. 1. 200-inch LED display used for the experiment.



Fig. 2. 200-inch screen and projector used for the experiment.

(2) Lighting condition

To compare the difference between a bright environment and a dark environment, in a laboratory equipped with an LED display and a projector + screen, three types of bright environments were prepared: full lighting, half lighting, and no lighting. A comparative experiment was conducted under the above conditions. To realize complete darkness, the experiment was conducted at night after sunset, and the lighting of the entire laboratory was controlled in a way of fully turned on, half turned on, or turned off. As a result, complete darkness could be realized when the lights were turned off. Under this condition, the illuminance at the subject's position is about 400 lux when all the lights are turned on, 200 lux when half the lights are turned on, and 0 lux when all the lights are turned off.

The subject sat in a chair 5 m away from the display and screen in front of their center and watched the content displayed on them. This is within the range of 5m to 6m calculated from the screen size (inch) \times 0.3 to 0.25, which is the optimum viewing distance generally referred to. When the subject looks at the projection plane, the elevation angle is 27° and the viewing angle is 42° (Fig. 3).

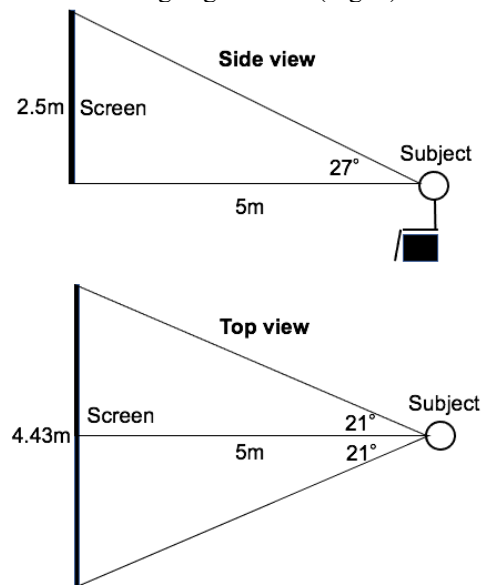


Fig. 3. Position of a subject and a screen

(3) Content

In the previous experiment, we compared art content and text-based content. On the other hand, since displays and screens of about 100 inches to 200 inches are often used in the case of lectures and presentations, in this research the content was selected assuming such a situation. Six lecture videos are used: science, engineering, medicine, philosophy, psychology, and art from Kyoto University OCW (<https://ocw.kyoto-u.ac.jp>), which are the lecture videos released by Kyoto University faculty members.

3.2 Experimental procedure

(1) Subject

The subjects were 34 students from Kyoto University (23 males and 11 females). All of them are in their late teens and twenties (avg.=20.6, sd=1.68).

(2) Image/video presentation procedure

There are 6 conditions that combined the experimental conditions described in 3.1 (1) and (2). For each of the subject all of these conditions were presented randomly as 6 trials. For each trial the above contents were assigned in well-balanced way using the design of experiment [12]. Each trial consists of; break (30 seconds)-> content viewing (10 minutes) -> intermediate evaluation (5 minutes) -> content viewing (10 minutes) -> final evaluation (5 minutes) (Fig. 4).

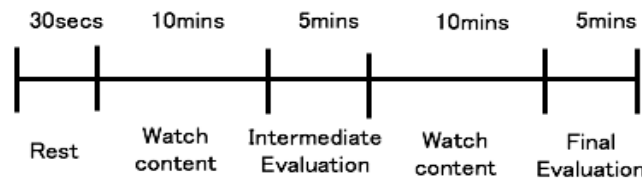


Fig. 4. Procedure of content viewing and evaluation

(3) Measurement method

The semantic differential (SD) method was adopted as the subjective evaluation method. The SD method uses an evaluation scale in which adjectives with opposite meanings are placed at both ends and the space between them is divided into 7 or 5 stages. In this experiment, a 7-stage evaluation scale was used.

(4) Evaluation items

While referring to subjective evaluation items of the previous studies [4] [5] [7][8], we adopted the 6 subjective evaluation measurement items shown in Table 1 and asked each subject to fill out a questionnaire.

When displaying on a large screen, whether or not a sense of presence is realized is often used as an evaluation item [13]. However, assuming that the large screen display is becoming normal and that it will be used in lectures and classes, we did not include items related to the sense of presence. In addition, considering the wide range of subjects' fields of study, the content was selected equally from the science and humanities, rather than the content biased to some fields. In addition, since the degree of understanding of the lecture content will affect the evaluation results, the content was selected from a slightly higher level of lecture content for students in specialized fields rather than for the general public. Instead of having subjects evaluate their comprehension, we used general evaluation items such as "Is it easy to see" or "Is it possible to concentrate?"

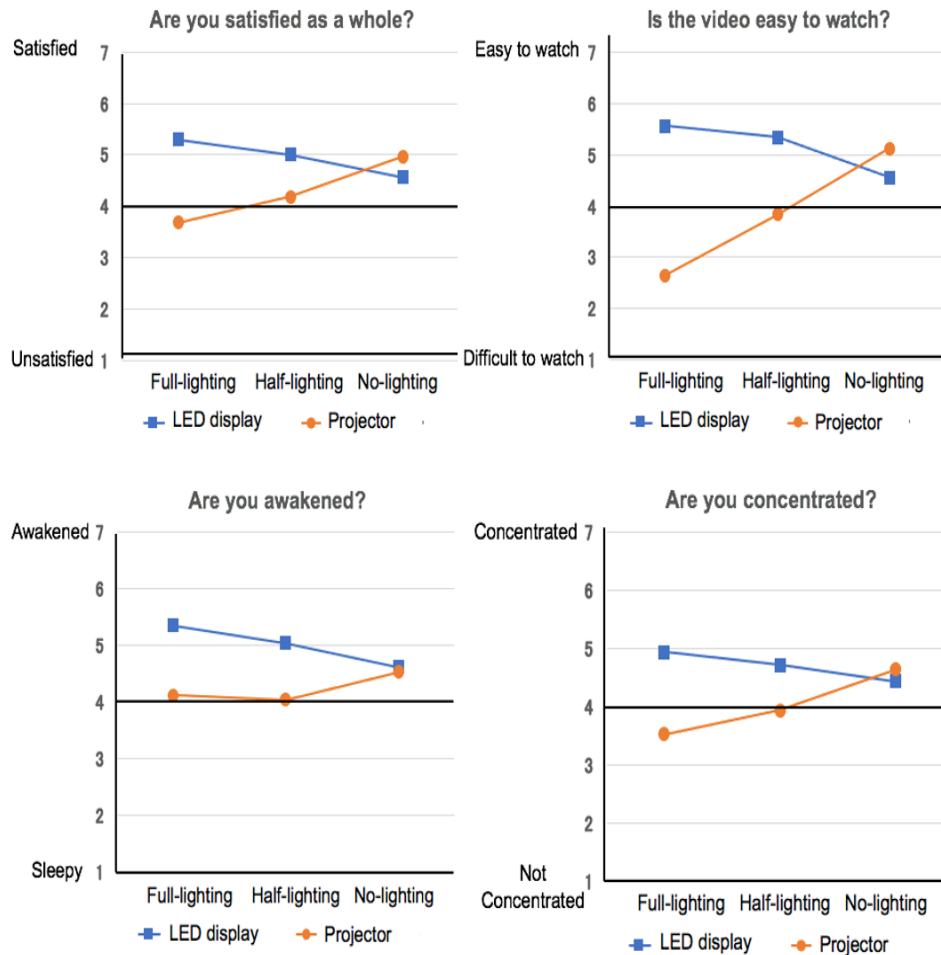
As mentioned above, the content is presented as shown in Fig. 4 under 6 kinds of experimental conditions given in random order. During 20 minutes of viewing, an intermediate evaluation was done at the middle of 10 minutes and the final evaluation was done after watching. As there was no evaluation difference between these two evaluations, the final evaluation result was used for the analysis.

Table 1. Subjective evaluation item

Satisfied - Unsatisfied
 Easy to watch - Difficult to watch
 Awakened - Sleepy
 Concentrated - Not concentrated
 Motivated - Not motivated
 Want to watch longer – Don't want to watch longer

4 Results and discussion

4.1 Average value of subjective evaluation items



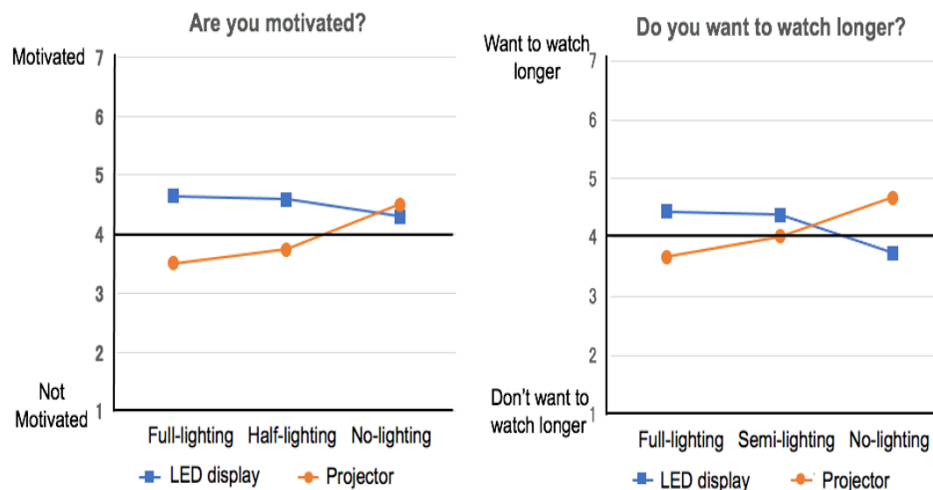


Fig. 5 Results for each evaluation item

Six types of experimental conditions were compared for each subjective evaluation item. Figure 5 shows a comparison of two display methods and three lighting conditions for the six evaluation items.

4.2 Consideration of the average value of subjective evaluation items

(1) Regarding overall satisfaction

The evaluation score of the LED display decreased as it got darker, while the projector increased. The LED display has a high score of 5.29 for full lighting condition, but it decreases to 5 for half lighting and 4.56 for no lighting. In a comparison experiment between art content and text-based content, the darker the LED display, the higher the evaluation [6], but in this experiment, the evaluation score decreases as the illuminance decreases. In the case of art content, lowering the illuminance had the effect of making details look clearer. But in the case of content such as lectures and presentations, when the illuminance is lowered, probably the contrast between the text and the background is strongly felt. On the other hand, in the case of a projector, the average score is 3.68 for full lighting, but for half lighting it is 4.18, which exceeds the center value, and when the lights are off, the evaluation score is 4.97, higher than LED display.

From these, it is necessary to pay attention to the following when displaying contents on a large screen in the case of presentations and lectures.

- LED display is excellent under the condition of the brightness of 200 lux or more.
- However, it is desirable to adjust the brightness of the LED display in dark conditions.
- It is desirable to use the projector under conditions where the lights are turned off as much as possible.

- Under the condition of the brightness of 200 lux or more, it is necessary to use the projector with high brightness.

(2) Regarding other evaluation items

For the other evaluation items, similar results as the overall satisfaction were obtained for all the evaluation items. In particular,

- All evaluation items show that the evaluation score of the LED display decreases as the illuminance decreases, and conversely the evaluation score of the projector increases.
- In the case of full lighting and half lighting, the LED display always gets a higher evaluation score than the projector.
- When the light is off, the evaluation values of the LED display and the projector are close to each other, or for several evaluation items, the scores are reversed.

The tendency of the score of each evaluation item shows almost the same tendency as the result of overall satisfaction. However, concerning "whether the video is easy to watch", the result is that the value of the projector changes greatly. It is a low value of 2.65 for full lighting, but it is 3.84 for half lighting, and 5.12 for no lighting, which exceeds that of the LED projector. Probably this is because the evaluation item "whether the video is easy to watch" is not an emotional evaluation item but a quantitative evaluation item so that the effect of illuminance on the projector is directly exerted.

4.3 Two-way analysis of variance (Two-way ANOVA)

Factors affecting the results of this experiment include two conditions related to the display method (LED display/projector) and three conditions related to the lighting conditions (full-lighting/half-lighting/no-lighting). Therefore, to perform a more detailed analysis, two-way ANOVA (analysis of variance) was performed. Table 2 shows a summary of the results of two-way ANOVA.

Since it is considered that the results related to the total satisfaction are representative one from Fig. 5, the results of the two-way ANOVA regarding the total satisfaction will be mainly described.

The results showed that the main effect on lighting conditions ($F(2,66)=1.27$, $p=.289$) was not significant, whereas the main effect on display method ($F(1,33)=15.75$, $p<.001$), the interaction between the display method and the lighting conditions ($F(2,66)=23.50$, $p<.001$) was found to be significant.

The result of the simple main effect is that the simple effect of the lighting condition when using the LED display ($F(2,132)=5.09$, $p=.007$) and also the simple effect of the lighting condition when using the projector ($F(2,132)=15.83$, $p<.001$) were significant. Regarding the lighting conditions, the simple effect for full-lighting ($F(1,99)=44.55$, $p<.001$) and the simple effect for half-lighting ($F(1,99)=11.55$, $p=.001$) are significant. However, the simple effect ($F(1,99)=2.89$, $p=.092$) for no lighting was off was not significant.

Table 2. Results of two-way ANOVA

		Are you satisfied?	Is it easy to watch?	Are you awakened ?	Are you concentrated?	Are you motivated ?	Do you want to watch longer?
Main effect	Display method	**	**	**	**	**	ns
	Lighting condition	ns	**	ns	ns	ns	ns
Interaction	Display method×Lighting condition	**	**	*	**	**	**
Main effect of a factor for each level of another factor	Display method at full-lighting	**	**	**	**	**	*
	Display method at half-lighting	**	**	**	**	**	ns
	Display method at no-lighting	ns	*	ns	ns	ns	**
	Lighting condition display = LED	**	**	*	ns	ns	*
	Lighting condition at display = Proj	**	**	ns	**	**	**
Multiple comparison	Full-lighting: LED - Proj	**	**	**	**	**	*
	Half-lighting: LED - Proj	**	**	*	*	**	ns
	No-lighting: LED - Proj	ns	*	ns	ns	ns	*
	LED: Full - Half-lighting	ns	ns	ns	ns	ns	ns
	LED: Full - No-lighting	*	**	*	ns	ns	*
	LED: Half - No-lighting	ns	**	ns	ns	ns	ns
	Proj: Full - Half-lighting	*	**	ns	ns	ns	ns
	Proj: Full - No-lighting	**	**	ns	**	**	**
	Proj: Half - No-lighting	*	**	ns	*	**	ns
**: p<.01, *: p<.05, ns:Not statistically significant							

For the multiple comparisons using the Holm method, when using the LED display, the comparison between full-lighting and no-lighting ($p = .012$) is significant, but the comparison between full-lighting and half-lighting and between half-lighting and no-lighting are not significant. When using a projector, the comparison between full-lighting and no-lighting ($p < .001$) is significant, but the comparison between full-lighting and half-lighting ($p = .044$) and between half-lighting and no-lighting ($p = .014$) were significant. Figure 6 shows the result of total satisfaction including these results.

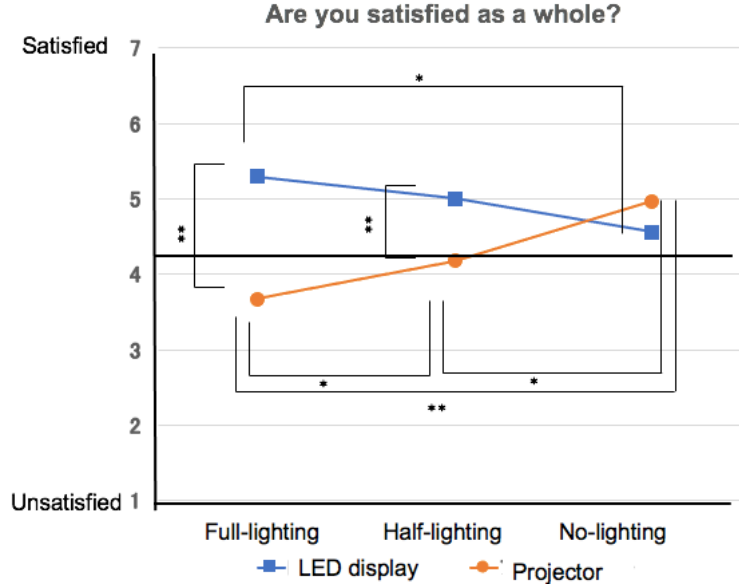


Fig. 6. Overall satisfaction including the results of the multiple comparisons.

5 Conclusion

Which is more advantageous, LED display or projector when displaying content on a large screen is an important issue, as showing contents using large display is becoming popular in many occasions including entertainment. But few experiments have been reported so far that directly compare the projector and the LED display under various conditions.

We are approaching this problem by using a 200-inch LED display and a 200-inch screen + projector. In the previous research [6], we conducted an evaluation experiment on what kind of environmental conditions are suitable while comparing art content with text content. As a result, based on the average score and the result of multiple comparisons, "art content x LED x no-lighting" gives a very high score.

However, LED displays and projectors are mainly used for presentations at academic conferences, lectures, etc. In such cases, there are many situations where images and videos are used together with text. Conventionally, projectors have often been used in such situations, but as large LED displays have become cheaper, there are increasing opportunities for LED displays to be used. As it is useful to compare the LED display and the projector in such a situation, we conducted a comparative experiment in such an environment.

In this research, the content was displayed under a total of 6 environmental conditions that combined the conditions of a 200-inch LED display/200-inch screen + projector, and full-lighting/half-lighting/no-lighting. The SD method was applied to 34 subjects. As the content, we assumed the scene of lectures and presentations and

considered avoiding the influence of the content by using multiple contents. As a result, lecture videos covering a wide range of fields such as science, engineering, medicine, psychology, philosophy, and art were selected from the lecture videos by Kyoto University faculty members and used in the experiments.

As a result, we obtained an interesting result that the evaluation score decreases as the lighting conditions become darker when using an LED display, whereas it increases as the lighting condition becomes darker in the case of a projector. In addition, the LED display obtained a higher evaluation score than the projector under bright conditions, but the difference between the two became smaller as the lighting became darker, and the results were the same under the no-lighting condition, or the evaluation score of the projector was higher than LED display.

Furthermore, by performing two-way ANOVA, detailed results were obtained on how each factor interacts with other factors and influences the evaluation score under various conditions. We believe that we have obtained guidelines for using LED displays and projectors when giving lectures and presentations.

In this experiment, the subjects were students in their 20s, and it is thought that the sensibilities of the young generation are reflected in the results. As our future research, it is necessary to conduct experiments using subjects of other generations.

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