



Construction of Immersive Art Space Using Mirror Display and Its Evaluation by Psychological Experiment

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Abstract. How art appreciation affects the human mind is an interesting question. Several studies have already been conducted on art's calming and inspiring effects on the human mind. As an extension of this, whether art can enhance people's creativity is a fundamental and interesting question. If art appreciation can enhance people's creativity, a new function of art will be discovered. It is well known that displaying media art, such as video art, in a large space can provide a deeply immersive experience, as with projection mapping. A deep sense of immersion can contribute to enhancing creativity. Therefore, it is desirable to research to evaluate whether creativity is aroused by displaying and viewing media art in a large space. One way to make a small space look vast is to construct a space using mirrors. We have designed and constructed an immersive space surrounded by mirror displays with the functions of both a mirror and a display. Firstly, this paper describes the specific method. In addition, using art created by one of the authors, we conducted a psychological experiment using 40 subjects to compare and evaluate her art and geometric figures displayed in the space. The results show that the immersive space and her art combination have characteristics that motivate people's minds and arouse creativity.

Keywords: Immersive Space · Art Space · Mirror Display · Psychological Evaluation

1 Introduction

Art can enrich people's minds, heal their hearts, and inspire them [1, 2]. Art can be considered the ultimate VR with the power to immerse people. Much emphasis has been placed on technological research to give people a sense of immersion in VR. However,

more research needs to be conducted on designing and constructing immersive spaces that combine art and VR and their evaluation.

We designed and constructed an immersive space suitable for art content to evaluate how art content affects the human mind. The video art of Naoko Tosa (hereafter “Tosa art”), one of the authors, will be used as art content. As described later, Tosa art uses technology to extract the beauty hidden in natural phenomena and transform it into video art characterized by its abstract and organic forms. Many people who have viewed Tosa art have commented that they feel like they are in outer space or feel a sense of floating. Therefore, the characteristics of Tosa art are best expressed when viewed in a vast space. To give viewers the feeling of being in an infinite space, we conceived the idea of constructing a space surrounded by mirror displays that function as both a mirror and a display and having viewers appreciate Tosa art in that space.

This paper describes the design and construction method of an immersive space constructed using a mirror display. In addition, we evaluated how combining the immersive space and Tosa art would affect people’s minds through a psychological experiment.

2 Related Studies and Activities

2.1 Research on Immersive Spaces in VR

The purpose of VR is to create a space different from reality and to give people an immersive feeling as if it were reality [3, 17]. VR space can be constructed by projecting images into an actual space using a projector or displaying images on an HMD (Head Mounted Display). In both cases, there is much research on adding the senses of touch, taste, and smell to increase the sense of presence. As these are primitive human senses, however, there is a problem that research progress takes time [4].

2.2 Fusion of VR and Art

Attempts to fuse art and VR occurred with the advent of VR and have continued until now. For example, William Latham of Goldsmiths, University of London, has been actively creating an art-expressed artificial life form called “Mutator VR” [5]. In the 1990s, there were many attempts to create an immersive space (CAVE is a typical example of such an immersive space [6]) using projectors, etc., and to display art in the space.

2.3 Construction of Immersive Space Using Mirrors

Mirrors are often used in art expression because it is relatively easy to create a seemingly endless space by using mirrors. One well-known example is Yayoi Kusama’s “Infinity Mirror Room,” in which she installed her art in a mirrored space [7].

3 Digital Art “Sound of Ikebana”

3.1 Concept of “Sound of Ikebana”

One of the authors, Naoko Tosa, discovered that by applying sound vibrations to a fluid such as paint and photographing it with a high-speed camera, the fluid creates a shape similar to that of a flower arrangement. Tosa further edited the resulting video to match the colors of the Japanese seasons and created a digital artwork called “Sound of Ikebana.” Fig. 1 shows a scene from the work. For the details of the art creation process, please refer to [8, 9, 13]. Although there have been various research on the visualization of sound, called “Cymatics,” (for example [18]), this is another way of sound visualization.

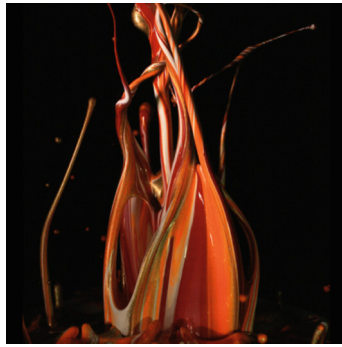


Fig. 1. A scene from “Sound of Ikebana.”

3.2 Effects of “Sound of Ikebana” on Human

When Tosa exhibited her digital art around the world with a focus on the “Sound of Ikebana,” many overseas art professionals pointed out that “Tosa’s digital art, which expresses beauty latent in physical phenomena in an abstract form, expresses beauty previously unnoticed by Westerners, and this is Japan’s consciousness and sensitivity.” Since then, “Sound of Ikebana” has taken on challenges in new directions, such as attempting to create new shapes by using the birth cries of newborn babies and the voices of Olympic athletes as sound sources and attempting to create art in the space age by creating works under microgravity [9]. Many people who have viewed Tosa art have commented that they feel their creativity is enhanced. A stimulating new art effect can be found if art appreciation enhances the viewer’s creativity. Such effects are apparent in a space with infinite expansion. This also led us to design and construct a space that gives a sense of infinite expansion and have visitors view Tosa art in that space to see if it improves creativity.

4 Design and Construction of Immersive Spaces Using Mirror Displays

4.1 Mirror Display

As mentioned in Sect. 2.3, using mirrors is appropriate for constructing a system that gives the impression of being in an infinite space. Here, we decided to use a “mirror display” with the functions of both a mirror and a display.

Several companies have commercialized mirror displays that combine the functions of a mirror and a display. We used a mirror display developed by AGC Corporation and commercialized under the name “Mirroria” [10]. The feature of this display is that it achieves a half-mirror reflectance of approximately 65%, the same level of reflectance as that of an ordinary mirror, by utilizing the company’s glass manufacturing technology.

4.2 Design and Construction of Immersive Spaces

Several psychological experiments we have conducted have confirmed that art content positively affects the human mind [11, 12]. Art content was displayed on large LED and mirror displays in these experiments. To take this further and confirm whether art content is effective in improving people’s creativity, placing people in a more immersive environment would be effective.

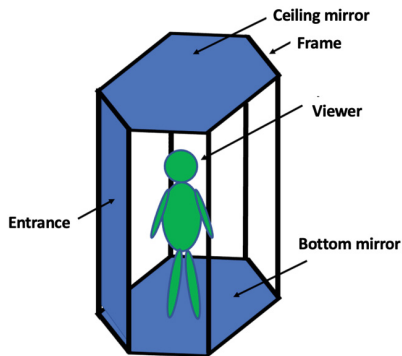


Fig. 2. Conceptual diagram of immersed space.

Therefore, we decided to construct an environment in which the space is surrounded by mirrors, and part of the mirrors are used as mirror displays, in which art contents are displayed. First, a hexagonal space surrounded by rectangular mirrors is constructed. The concept is shown in Fig. 2, where the hexagonal space comprises three sets of two mirrors facing each other. It is well known that mirrors create an infinite number of images by mutually reflecting each other. By having three sets of mirrors, the person inside feels as if he/she is surrounded by countless mirror images of himself/herself. Furthermore, by using the ceiling and floor as mirrors, one feels as if one is surrounded by an infinite number of images of oneself, both above and below.

The six mirrors that make up this hexagonal space are mirror displays and can display images. Since the vertical length of the mirrors is longer than the vertical length of the display, the display on which the images are shown forms part of the mirrors. At the same time, the position of the display is variable in the vertical direction (Fig. 3). This makes it possible to shift the position where the six mirrors display the image. Suppose the mirrors facing each other have the same position for displaying the images. In that case, the respective images will interfere with each other, reducing the sense of an endless series of images. Thus, by shifting the position of the image display, it is possible to create the effect of an endless series of images without having each image interfere with the other.

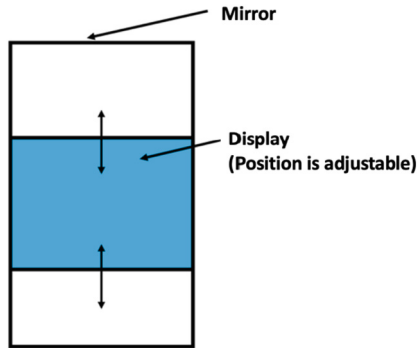


Fig. 3. Configuration of individual mirror displays.



Fig. 4. Exterior view of the immersed space (left: exterior view, right: door open).

The appearance of the constructed immersive space is shown in Fig. 4. Inside this device, even simple shapes can generate an environment of beauty by continuing back and forth, left and right, and up and down indefinitely (Fig. 5). Figure 6 shows several scenes where Tosa art is shown as an example of art content.

In this immersive space, preliminary experiments have confirmed that people can experience a sense of floating and liberation. Since a sense of liberation and floating

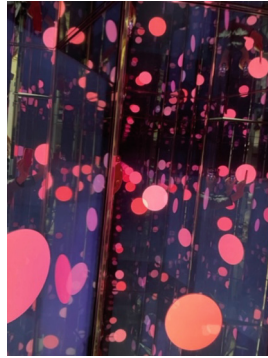


Fig. 5. Geometric figure (circle) displayed in the immersed space.

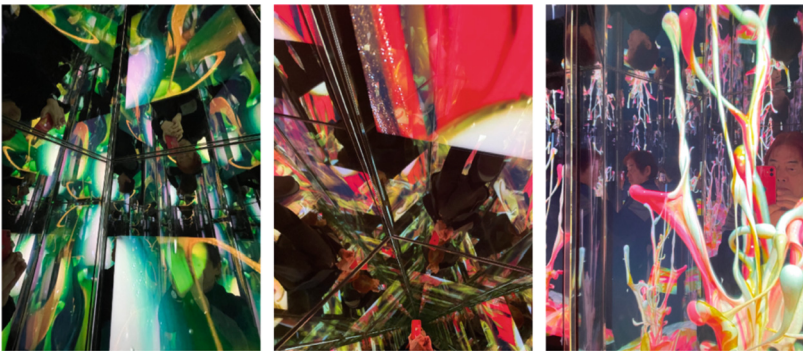


Fig. 6. Example of displaying Tosa Art in the immersive space.

are linked to creativity, people's creativity is expected to be aroused when art content is displayed in this immersive space. Then we can set the following hypothesis.

Hypothesis: The combination of the immersive space and Tosa art increases human creativity.

Next, we conduct psychological experiments to check this hypothesis.

5 Evaluation of Immersive Space by Psychological Experiments

5.1 Evaluation Concept

We evaluated the constructed immersive space. This immersive space gives people inside it the feeling of being in an infinitely expanding space. Therefore, when evaluating art in it, it is considered a good match with contemporary art, such as video art and media art. As mentioned earlier, there have been many attempts to combine VR and art, but art content can only demonstrate its actual value if viewed in a space suitable for it.

To evaluate this immersive space, we conducted a psychological experiment to compare and evaluate the impression subjects receive when art content and content to be

compared are displayed. As for the art content, we decided to use Tosa art. The reasons for this are as follows.

- (1) As mentioned, Tosa art is created by filming fluid phenomena with a high-speed camera. This indicates that Tosa art is based on physical phenomena. Therefore, it is more compatible with the scientific evaluation method than compared to art created by the artist's own hands.
- (2) Since it is based on fluid phenomena, various variations can be created by changing parameters, such as the type of fluid and the type of sound. In this respect, it is also compatible with the scientific evaluation method under different conditions.

5.2 Contents Used in the Experiments

(1) Art Content

For the reasons stated above, we decided to use Tosa art. Specifically, we used a 3-min video with the "Sound of Ikebana" as its primary content.

(2) Comparative Content

When conducting evaluation experiments using art content, preparing content for comparison with the art content is essential. We used simple geometric figures such as circles and squares as comparison contents. We conducted a preliminary experiment and evaluated several geometric figures through psychological experiments to determine the geometric figures to be compared with the art contents. The following three types of geometric figures were used in the preliminary experiment.

Geometric Fig. 1: The shape is a circle, and only the color changes with time.

Geometric Fig. 2: The shapes change to circles and squares in sequence along with the colors.

Geometric Fig. 3: The shape is a square, and the square rotates. The colors change with time, as in Geometric Figs. 1 and 2.

Here, the colors were set to be the same as the representative color of the art content, in synchronization with the time variation of the color of the art content, to create a similar impression as the art content. Preliminary experiments showed no significant differences among the three types of geometric shapes. As the degree of change for Geometric Fig. 2 is in the middle among the three types, we decided to use Geometric Fig. 2 (hereafter referred to as "Figure") for comparison with the art content. The details of the preliminary experiments are described in the literature [13] and can be found there.

5.3 Evaluation Items

Regarding the evaluation items, first, an evaluation item, "Impression factor," was established to determine what impression the subjects had. This has been used in several psychological experiments such as [14–16] and used by us for art evaluation.

In addition, since one of the purposes of this evaluation is to assess whether the combination of "immersive space + art content" arouses people's creativity, we decided to add an evaluation item regarding how it affects people's minds. As a result of discussions led by one of the authors, Michio Nomura, who specializes in psychology, we decided to evaluate the content in terms of whether it relaxes people's minds ("Relaxation factor"),

whether it inspires people's minds ("Motivation factor"), and whether it arouses people's creativity ("Creativity factor"). Specific evaluation items are shown in Table 1 below. Overall, there are 24 evaluation items, which is done on a 7-point scale. The difference in meaning between "immersed," one of the Motivation items, and "immersive," one of the Creative items, is subtle, but "immersed" corresponds to logical brain processing, such as "immersed oneself in studying." In contrast, "immersive" corresponds to sensory brain processing, such as "listening to music makes me immersive."

Table 1. Evaluation Items

<p>1. Impression factor (9 items) Comfortable - Uncomfortable Friendly - unfriendly Beautiful - Not beautiful Calm - Restless Interesting - Boring Warm - Cold Changeable - Not changeable Luxury - Sober Individual - Ordinary</p> <p>2. Relaxation factor (5 items) At ease - Not at ease Secure - Not secure Pleasant - Not pleasant Relaxed - Not relaxed Healed - Not healed</p>	<p>3. Motivation factor (5 items) Enthusiastic - Not enthusiastic Immersed - Not immersed Curious - Not curious Motivated - Not motivated Aroused - Not aroused</p> <p>4. Creativity factor (5 items) Associate - Do not associate Immersive - Not immersive Activated - Not activated Inspired - Not inspired In the zone - Not in the zone</p>
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5.4 Subjects

Forty male and female students (32 males and eight females) in their first through fourth year at Kyoto University were used as subjects.

5.5 Experimental Procedure

Below is the process of the experiment.

- (1) First, after briefly explaining the purpose and content of the experiment, a subject signed a consent form.
- (2) The subject moved into the immersive space.
- (3) Then the subject performed an initial evaluation before viewing Content 1 ("No content" condition). The subject brought his/her own smartphone into the space, and the evaluation was done using Google Forms.
- (4) Before Content 1 was displayed, a resting period (3 min) was taken to reset the subject's psychological state. During this time, the display was kept black.
- (5) Contents 1 was displayed (3 min).

- (6) After viewing Content 1, the subject was asked to complete a second evaluation.
- (7) Before Content 2 was displayed, a resting period (3 min) was taken to reset the subject’s psychological state. During this time, the display was kept black.
- (8) Contents 2 was displayed (3 min).
- (9) After viewing Content 2, the subject was asked to complete a third evaluation.
- (10) Then, the subject exited the immersive space.

Regarding the order of presentation of art and geometric figures, to ensure that order effects did not affect the results, the order was set randomly for each subject so that the total order of art → geometric figures and geometric figures → art was 20.

6 Evaluation Results

6.1 Results for Each Evaluation Factor

The average evaluation scores of 40 subjects for each Impression, Relaxation, Motivation, and Creativity factor are shown in Figs. 7, 8, 9, and 10. In these figures, the graphs show the differences in the evaluation scores for three different contents: while the display was kept black (“No content”), after viewing the geometric figures (“Figure”), and after viewing the art content (“Art”). Also, the results of the analysis of variance (ANOVA), which will be described later, are overlapped on these figures.

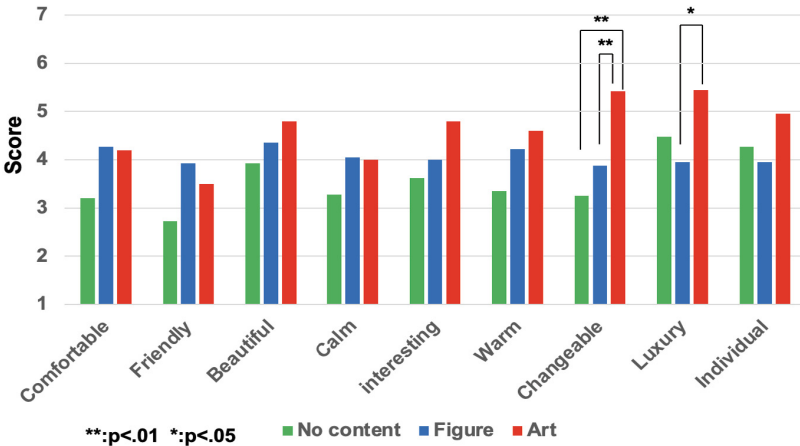


Fig. 7. Evaluation results for “Impression factor.”

In the individual evaluation results, for many of the evaluation items, the results were higher in the order of “No content < Figure < Art,” indicating the effectiveness of the “immersive space + Tosa art” approach.

6.2 Analysis of Variance (ANOVA)

In order to verify the significance of the differences in evaluation scores between each content in Sect. 6.1, an analysis of variance with the two factors (two-way ANOVA)

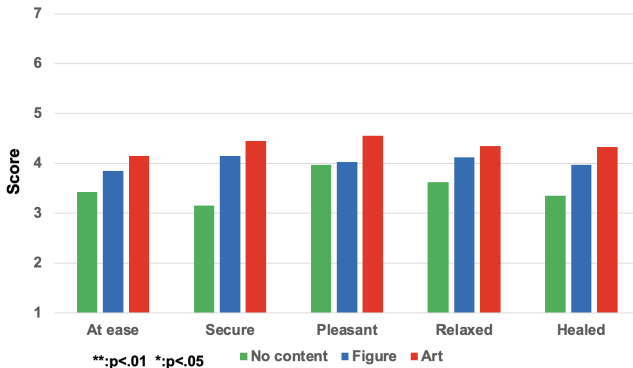


Fig. 8. Evaluation results for "Relaxation factor."

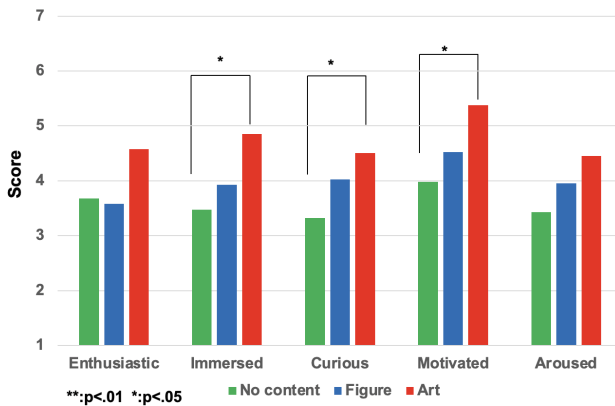


Fig. 9. Evaluation results for "Motivation factor."

was conducted for each of the Impression factor, Relaxation factor, Motivation factor, and Creativity factor. The two factors involved in the two-way ANOVA are "content" and "evaluation item." The results are shown in Fig. 11 (Impression factor), Fig. 12 (Relaxation factor), Fig. 13 (Motivational factor), and Fig. 14 (Creativity factor).

Also, multiple comparison was conducted on the individual assessment items for a more detailed analysis. The results are overlapped in Fig. 7 (Impression factor), Fig. 8 (Relaxation factor), Fig. 9 (Motivation factor), and Fig. 10 (Creativity factor).

6.3 Considerations

(1) ANOVA results by factor

A two-way ANOVA was conducted on the overall Impression, Relaxation, Motivation, and Creativity factors. The results showed that, except for the Relaxation factor, there were significant differences among "No content," "Figure," and "Art" (Figs. 11 through 14). Specifically, for the Impression factor, there was a significant difference at the 1% level among each combination of "No content," "Figure," and

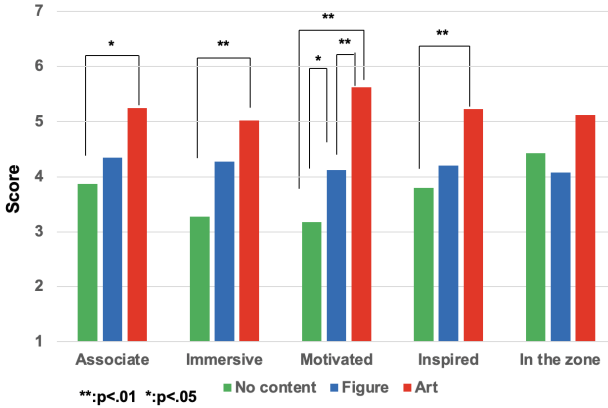


Fig. 10. Evaluation results for “Creativity factor.”

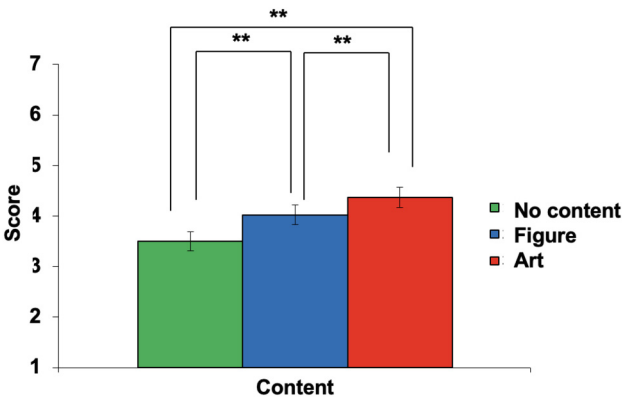


Fig. 11. ANOVA results for the overall “Impression factor.”

“Art” (Fig. 11). As for the Motivation and Creativity factors, there was a significant difference at the 1% level between “No content” and “Art” and between “Figure” and “Art.” Also, there was a significant difference between “No content” and “Figure” at the 5% level (Figs. 13 and 14).

For the Relaxation factor, we found a significant difference at the 1% level between “No content” and “Art” but no significant difference for the other combinations (Fig. 12).

(2) Multiple comparison results for individual evaluation items

Results of the multiple comparisons for individual assessment items showed the following.

For the nine items on the Impression factor, for the item “Changeable,” there were significant differences between “No content” and “Art,” and “Figure” and “Art” at the 1% level. For the item “Luxury,” there was a significant difference between “Figure” and “Art” at the 5% level.

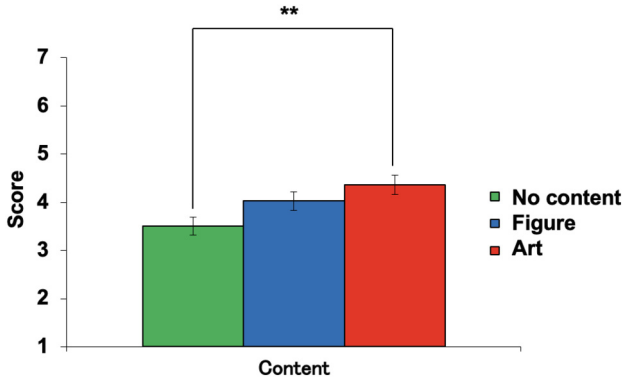


Fig.12. ANOVA results for the overall “Relaxation factor.”

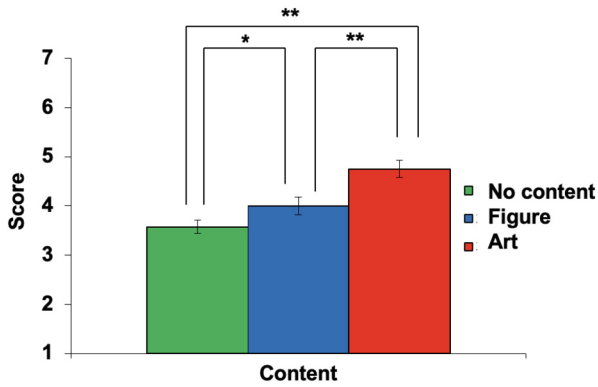


Fig. 13. ANOVA results for the overall “Motivation factor”

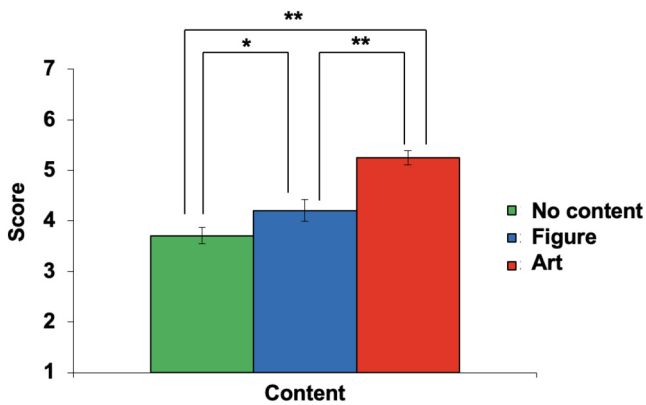


Fig. 14. Analysis of variance results for the overall “Creativity factor.”

There were no significant differences among “No content,” “Figure,” and “Art” on any of the five items of the Relaxation factor.

There was a significant difference for three of the five items on the Motivation factor. For the items “Immersed,” “Curious,” and “Motivated,” there were significant differences between “No content” and “Art” at the 5% level.

There were significant differences for four of the five items on the Creativity factor. For the item “Motivated,” there were significant differences between “No content” and “Art” and between “Figure” and “Art” at the 1% level. Also, there was a significant difference between “No content” and “Figure” at the 5% level. For the items “Immersive” and “Inspired,” there were significant differences between “No content” and “Art” at the 1% level. Also, for the item “Associate,” there was a significant difference between “No content” and “Art” at the 5% level.

These results indicate that Tosa art effectively motivates people and improves their creativity. Therefore, the hypothesis set at the beginning of this psychological experiment was supported.

7 Conclusion

Previous studies have shown that art has a calming and inspirational effect on the human mind [1, 2]. Through several psychological experiments, we have also found that art has a relaxing and inspiring effect on the human mind [12, 13]. In addition to this, we hypothesize that art has the effect of increasing a person’s creativity. This is because when we exhibited video art created by Naoko Tosa, one of the authors, in various parts of the world, many people commented that they “felt a life force” and “felt Japanese beauty.” In contrast, others said they “felt a sense of levitation” and “their creativity was aroused.” If art appreciation increases people’s creativity, then a new benefit of art can be found. This study was conducted to confirm this through a psychological experiment.

In this paper, we first described designing and constructing an “immersive art space” suitable for art appreciation. The fact that projection mapping using art images is used in many situations means that displaying art in a vast space increases the sense of immersion. In this study, we proposed and constructed a hexagonal immersive space using a mirror display that functions as both a mirror and a display to create a sense of being in a vast space. In this space, three sets of mirrors facing each other create the impression of an infinite space. By displaying art images in the mirrors, it is possible to give people the feeling of being in an infinite space surrounded by art images.

In the latter half of this paper, we described the results of an experiment to confirm whether displaying art in the constructed space enhances creativity through psychological evaluation. The art used for the evaluation was the video art by Naoko Tosa described above. Geometric figures were used as the content to be compared with the art content. Based on the results of an experiment to compare multiple types of geometric figures with different shapes and movements [13], one of them was selected and used in this study.

We asked 40 subjects to rate on a 7-point scale how they felt when viewing the three types of content, “No content,” “Figure,” and “Art,” using 24 items in four groups related to “Impression,” “Relaxation,” “Motivation,” and “Creativity.” The results revealed the following.

First, a two-way ANOVA was used to test whether there were statistically significant differences between the ratings of the three types of content for the four groups of “Impression,” “Relaxation,” “Motivation,” and “Creativity.” The results showed that the main effects for “Impression,” “Motivation,” and “Creativity” were significant among all combinations of “No Content,” “Shapes,” and “Art.” For “Relaxation,” the main effect was significant only between “No content” and “Art.”

Multiple comparison was conducted for a more detailed analysis. The results showed significant differences between the contents for two of the nine “Impression” items. Regarding “Motivation,” three out of five items showed significant differences among the contents. In addition, significant differences were found in 4 out of 5 items for “Creativity.” Among the “Creativity” items, significant differences were found for “Motivated” in all combinations of “No content,” “Figure,” and “Art” among the contents. These results indicate combining “immersive art space” and “Tosa art” contributes to creativity.

There are several possible directions for future research. One is to see if the results of this study are generalizable by using art other than Tosa art as content. Another is to verify whether or not similar results can be obtained by measuring physiological data and psychological evaluation. We want to continue these studies in the future.

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