

# Construction of Immersive Art Space and Its Evaluation Using ECG Data

Ryohei NAKATSU, Naoko TOSA, Yoshiyuki UEDA, Michio NOMURA  
Kyoto University  
Sakyo, Kyoto 606-8501, Japan

Yasuyuki URAOKA, Akane KITAGAWA, Koichi MURATA, Tatsuya MUNAKA, Masafumi FURUTA  
Shimadzu Corporation  
Seika-cho, Soraku-gun, Kyoto 619-0237, Japan

## ABSTRACT

Many previous studies have shown that art appreciation relaxes the human mind and reduces stress. We also hypothesized that art appreciation positively affects viewers' motivation and creativity and started research to confirm this. Firstly, based on the idea that viewing art in an immersive environment that provides a sense of endless space can maximize the effects of art appreciation, an immersive environment was constructed using a mirror display that functions as both a mirror and a display. As a next step, we measured and analyzed physiological data to support our hypothesis. In this paper, after briefly describing the configuration of the immersive environment, we report on the results of the measurement and analysis of electrocardiographic (ECG) data when art content is compared with geometric figure content and no content using the environment.

**Keywords:** Immersive Space, Media Art, Physiological Data Evaluation, ECG Data, Creativity

## 1. INTRODUCTION

Art can enrich people's minds, heal their hearts, inspire them, etc. In addition, we hypothesize that art appreciation has the effect of higher-order effects, such as increasing creativity. In order to measure the higher-order effects of art appreciation, such as the improvement of creativity, it is necessary to construct an immersive space suitable for art appreciation and have the subjects appreciate the art in the space.

It is expected that the complex process of art appreciation will be better understood by using two evaluation methods, psychological evaluation, and physiological data measurement, and examining the relationship between them rather than using only one method. This study aims to clarify how people experience art appreciation in an immersive environment by measuring and analyzing physiological data. Since we have already presented the psychological evaluation results at several international conferences, this paper focuses on analyzing physiological data, specifically electrocardiographic (ECG) data, and describes the process and results.

## 2. RELATED RESEARCH

### 2.1 Art viewing and human psychology

It is well known that art has a significant influence on human psychology. Many studies have been conducted on the relationship between visual art (e.g., paintings), auditory art (e.g.,

music), and psychology [1]. It has been reported that visiting art museums and viewing paintings lowers blood pressure and reduces stress [2]. Art appreciation is also reported to be effective in preventing and recovering from dementia [3]. Using this, a project to prevent or alleviate dementia by having patients with dementia systematically visit art museums has been conducted [4].

### 2.2 Physiological data regarding art viewing

An example of physiological data measurements regarding how art appreciation affects people is the study by Angela Clow and Cathrine Fredhoi [5]. They measured salivary cortisol, which reflects stress, in London workers before and after their viewing artwork in an art gallery. The initially high cortisol levels returned to normal after viewing, indicating that art viewing effectively reduces stress.

Michael Law et al. [6] collected 3,882 articles, checked them, and selected 14 articles for inclusion in their review. The viewing locations ranged from art galleries and museums to laboratories and hospitals. The most common physiological data measured were cortisol levels and heart rate. Moreover, some used blood pressure and skin electrification. In many of them, psychological evaluation was also conducted along with physiological data measurement.

Many previous studies on psychological and physiological methodologies have been conducted, as described above. However, most of them have focused on stress reduction and its related effects on art appreciation, and few studies have focused on the relationship between art viewing and creativity.

## 3. DIGITAL ART “SOUND OF IKEBANA”

One of the authors, Naoko Tosa, has 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 Ikebana, a Japanese flower arrangement. This is art production utilizing fluid phenomena.

Using this environment, she confirmed that various fluid shapes could be generated by changing the sound's shape, frequency, type of fluid, and viscosity [7]. She further edited the resulting video to match the colors of the Japanese seasons and created a digital artwork called Sound of Ikebana (hereafter “Tosa art”). Figure 1 shows a scene from the work.



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

Many people who have viewed Tosa art have commented that they feel their creativity is enhanced. If art appreciation leads to increased creativity in the viewer, then an exciting benefit of art can be found. Such an effect is more likely to be demonstrated in a space that provides a sense of infinite immersion, which led to this study to design and construct a space that provides a sense of infinite immersion and to have visitors view Tosa art in that space to see if it leads to an increase in creativity.

#### 4. DESIGN AND CONSTRUCTION OF IMMERSIVE SPACE USING MIRROR DISPLAYS

Mirrors are suitable for constructing a system that gives the impression of infinite space. At the same time, a display system is necessary to display images. Here, we decided to use a mirror display [8] that functions as both a mirror and a display.

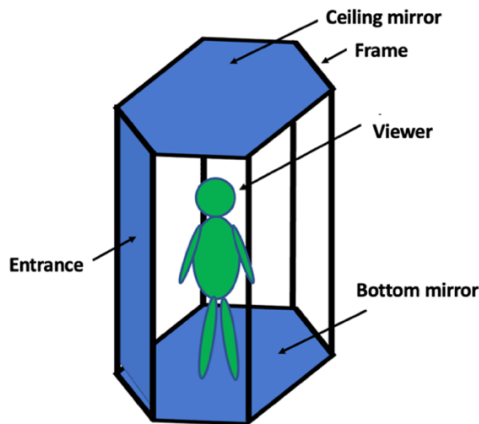


Fig. 2. Conceptual diagram of immersive space.

A hexagonal space surrounded by rectangular mirrors was constructed. Its concept is shown in Fig. 2, where the hexagonal space comprises three sets of mirrors facing each other. It is well known that mirrors facing each other create infinite images by mutually reflecting each other. By having three sets of mirrors, a 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 busts of oneself, both above and below. The six mirrors that make up this hexagonal space are the mirror displays described above and can display images. The appearance of the constructed immersive space is shown in Fig. 3.



Fig. 3. Exterior view of the immersive space (Left: exterior view, Right: door open)

Inside this system, even a simple figure can generate a feeling of beauty by continuing back and forth, left and right, and up and down indefinitely, as is shown in Fig. 4-Left. Figure 4-Right shows an example of displaying Tosa art.

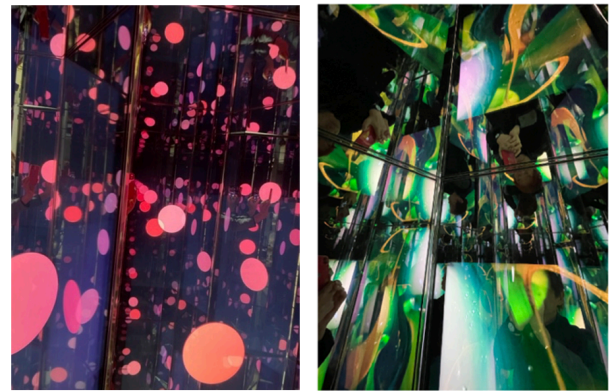


Fig. 4. Examples of geometric content (left) and art content (right) visible within the immersive space.

In this immersive space, preliminary experiments have confirmed that people can experience a sense of liberation and floating. Since a sense of freedom and floating are related to creativity, creativity is expected to be enhanced when art contents are displayed in this immersive space.

#### 5. CONTENT EVALUATION IN THE IMMERSIVE SPACE

##### 5.1 Evaluation concept

We used the artwork of Naoko Tosa, one of the authors, as the art content to be shown in the immersive space and to be evaluated. The reasons for this are as follows.

- (1) Tosa art uses a high-speed camera to capture fluid phenomena as its generation method. In other words, it is based on physical phenomena. Therefore, it is more compatible with the scientific evaluation method than art created manually by artists.
- (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 of conducting various experiments by changing conditions.

### 5.2 Measurement of physiological data

This research is conducted in collaboration with Kyoto University and Shimadzu Corporation. We used a device called HuME (Human Metrics Explorer) [9] from Shimadzu Corporation to measure physiological data. HuME is a physiological measurement system that integrates various types of wearable devices. In this research, we measured electrocardiogram (ECG) with the HuME device, electroencephalogram (EEG), and electrodermal activity (EDA) with commercial equipment. This paper focuses on measuring ECG data and its analysis.

### 5.3 Contents

#### Art Content

Among the many art contents available, Tosa art was selected for the reason mentioned in 5.1.

#### Geometric figure contents for comparison

We have selected three types of geometric figures to compare geometric figures with the art content. These geometric figures have the following characteristics.

**Geometric Figure 1:** The shape is a circle and only the color changes over time.

**Geometric Figure 2:** The shape changes to a circle and a square in sequence, along with colors.

**Geometric Figure 3:** The square shape rotates, and the color changes with time.

Preliminary psychological experiments have revealed no significant differences in comparisons between these geometric figures. Based on these results, we selected Geometric Figure 2 (hereafter “Figure”) to be compared with the art content.

### 5.4 Subjects

Forty Kyoto University students were used as subjects. The students were given a thorough explanation of the experiment and were asked to sign a consent.

### 5.5 Experimental Procedure

The following is the procedure for measuring each subject's physiological data. (At the same time, a psychological evaluation was conducted.)

**Move-in:** A subject moves into the immersive space.

**Evaluation 1:** The subject completes an initial psychological evaluation.

**Rest 1:** No content is displayed to reset the subject's state. Physiological data measurement is performed.

**Content 1:** Art (Tosa art) or Figure is displayed. Physiological data measurement is performed at the same time.

**Evaluation 2:** The subject completes a second psychological evaluation.

**Rest 2:** No content is displayed to reset the subject's state. Physiological data measurement is performed.

**Content 2:** Art or Figure is displayed. If Content 1 is Art, Figure is displayed; if Content 1 is Figure, Art is displayed. Physiological data measurement is performed at the same time.

**Evaluation 3:** The subject completes a third psychological evaluation.

**Move out:** The subject exits the immersive space.

## 6. RESULTS OF ECG DATA ANALYSIS

### 6.1 Physiological data used for this research

Forty subjects were measured for physiological data (ECG, EEG, and EDA), but only 22 could successfully measure all three data types. Since we want to analyze the relationship between the ECG, EEG, and EDA, we decided to focus on the 22 subjects for whom all three data types could be measured. In this paper, we focus on the ECG data.

### 6.2 Analysis methods for ECG data

Figure 5 shows the basic shape of the ECG data.



Fig. 5. Shape of ECG.

Heart rate variability, the periodic interval fluctuation between adjacent R waves (RRI) obtained from this, reflects autonomic nervous system activity. We focused on the following heart rate variability indices obtained from the ECG data of 22 subjects.

**RRI:** RR interval

**SDNN:** Standard deviation of RR interval.

**RMSSD:** Root mean square of the difference between adjacent RR intervals.

**pNN50:** Ratio of difference between adjacent RRIs exceeding 50 msec.

**LF:** Low-frequency component obtained from frequency analysis of RR interval data.

**HF:** High-frequency component from frequency analysis of RR interval data.

**LF/HF:** Ratio of low-frequency component to high-frequency component.

SDNN, RMSSD, pNN50, and HF are used as indices of parasympathetic activity, while LF/HF is used as an index of sympathetic activity. All of these can be obtained as time series data. However, in this study, averaged data values during 3 minutes (Figure, Art, Rest 1: no content corresponding to Rest 1, Rest 2: no content corresponding to Rest 2) were compared, as well as the result of analysis of variance (ANOVA) to see if the differences between them were significant.

### 6.3 Results of ECG data analysis

Graphs comparing the Figure, Art, Rest1, and Rest2 for each of the five heart rate variability indices, SDNN, RMSSD, pNN50, HF, and LF/HF, are shown in Fig. 6 through Fig. 10. ANOVA was also performed to see if the differences between Figure, Art, Rest1, and Rest2 were significant. The ANOVA results are

overlapped in Fig. 6 through Fig. 10. From these figures, we can see the following.

**Figure 6:** For SDNN, the value of Art is low, indicating that parasympathetic activity is suppressed. ANOVA also showed a significant main effect for content ( $F(3, 63)=5.87, p=.002$ ). Multiple comparisons revealed significant differences between Art and Rest1, Rest2, at 5%.

**Figure 7:** Similar to Fig. 6, the value of Art is low for RMSSD, indicating that parasympathetic activity is suppressed. ANOVA results show that the main effect for content is insignificant ( $F(3, 63)=3.23, p=.064$ ). As p is low, multiple analyses were conducted. For the differences between the content, a low value of  $p=.047$  is obtained for the difference between Art and Rest1 and  $p=.033$  for the difference between Art and Rest2.

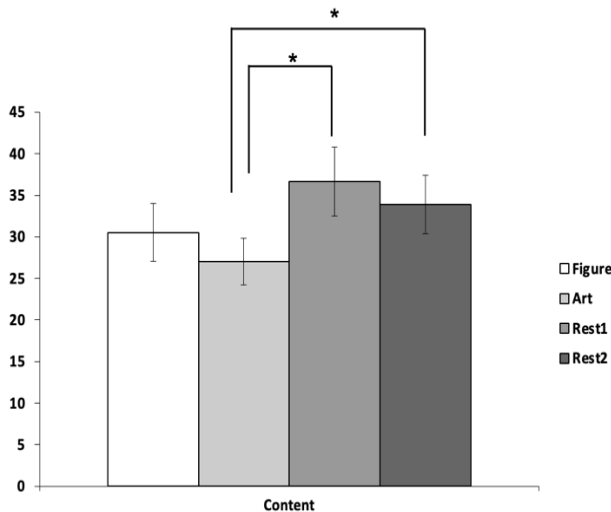
**Figure 8:** Concerning pNN50, the value of Art is low, indicating parasympathetic activity is suppressed. ANOVA results show that the main effect regarding content is significant ( $F(3, 63)=3.11, p=.043$ ). However, the multiple analysis results show no significant differences among the contents due to the large variance.

**Figure 9:** For LF, the trend is similar to Fig. 6 through Fig. 8. However, the main effect regarding content is insignificant ( $F(3, 63)=1.81, p=.165$ ).

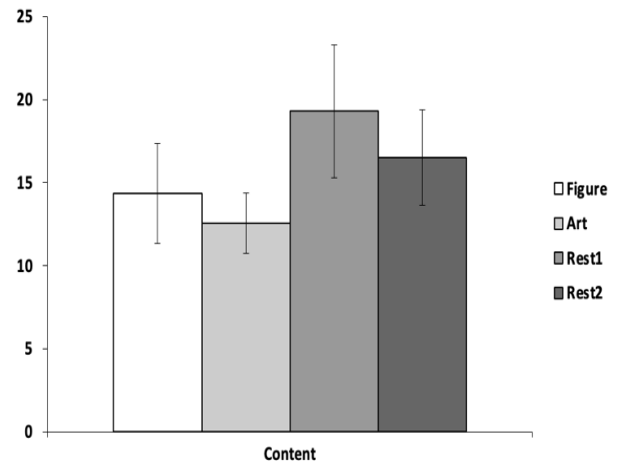
**Figure 10:** The following results were obtained for LF/HF (Fig. 11).

Rest1 (first rest): The low LF/HF values indicate that sympathetic activity is suppressed. This means that the subject was in a relaxed state. During Art viewing: LF/HF values are slightly higher than in Rest1. This indicates that viewing Art induces a state of arousal and excitement similar to the resting state in the subject. When viewing Figure: LF/HF values are higher than when viewing Art, indicating that sympathetic activity is stronger than when viewing Art. Rest2 (second rest): LF/HF values are higher than Rest1. This indicates that the anticipation and excitement for the following content continues even after the content presentation ends, suggesting that sympathetic activity continues.

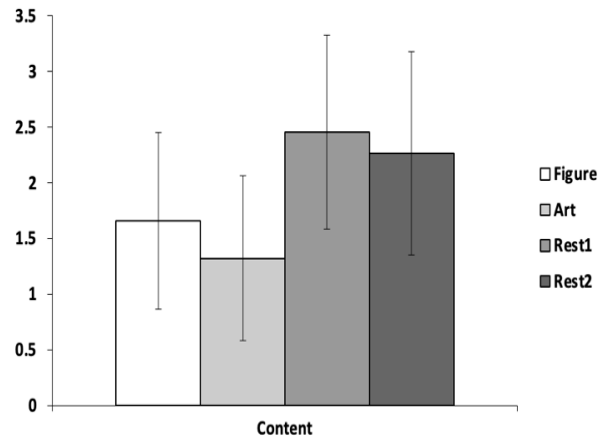
The ANOVA results show that the main effect of content is significant ( $F(3, 63)=3.41, p=.028$ ). However, the multiple analysis results show no significant differences in content, which may be due to the significant variance.



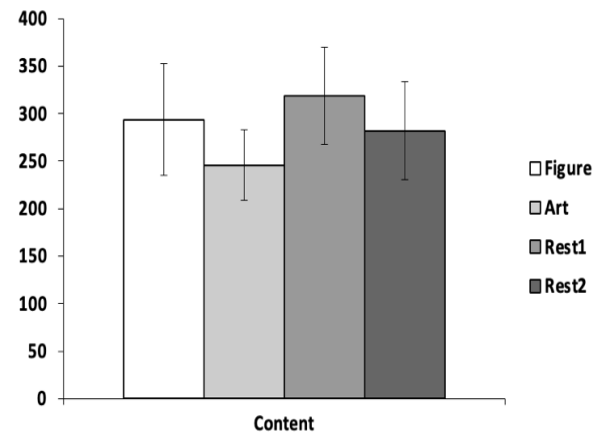
**Fig. 6.** Mean values and ANOVA results for the four content types for SDNN.



**Fig. 7.** Mean values and ANOVA results for the four content types for RMSSD.



**Fig. 8.** Mean values and ANOVA results for the four content types for pNN50.



**Fig. 9.** Mean values and ANOVA results for the four types of content for HF.

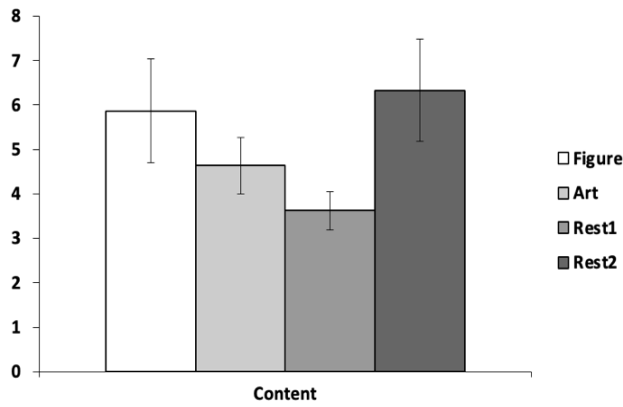


Fig. 10. Mean values and ANOVA results for the four content types for LF/HF.

In summary, Figures 6 through 10 can be interpreted as follows. Figures 6 through 9 show that parasympathetic activity decreased during art appreciation. Figure 10 shows that sympathetic activity was also suppressed during art appreciation, with a slight increase compared to the resting state. In other words, sympathetic and parasympathetic activities were suppressed during art appreciation. Since sympathetic and parasympathetic activities usually move in opposite directions, the combination of low activity of either nervous system indicates low activity of both autonomic nervous systems. This is seen, for example, during deep sleep or in the presence of certain neurological disorders. It is usually interpreted that in this state, overall autonomic regulation may be reduced, and various functions of the body may not be adequately coordinated. In contrast, the results obtained in this study were obtained under conditions in which healthy subjects viewed art in the immersive space. The results suggest that art appreciation may induce a particular condition in people.

#### 6.4 Analysis results focusing on the rate of change from Rest

There are individual differences in heart rate at rest (corresponding to Rest1 and Rest2 in this experiment). Therefore, looking at the change from the immediately preceding Rest is better than using the value itself. Therefore, we compared Figure and Art using the rate of change from the previous Rest for HF and LF/HF. As the rate of change,  $(Figure - Rest)/Rest$  or  $(Art - Rest)/Rest$  was used. The same analysis as in 6.3 was performed using this rate of change. The results for the averages are shown in Figs 11 and 12. At the same time, an analysis of variance (ANOVA) was performed to see if there was a significant difference between Figure and Art.

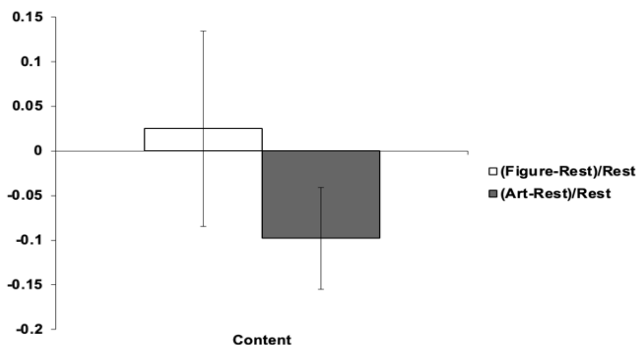


Fig. 11. Results for the rate of change from Rest for HF

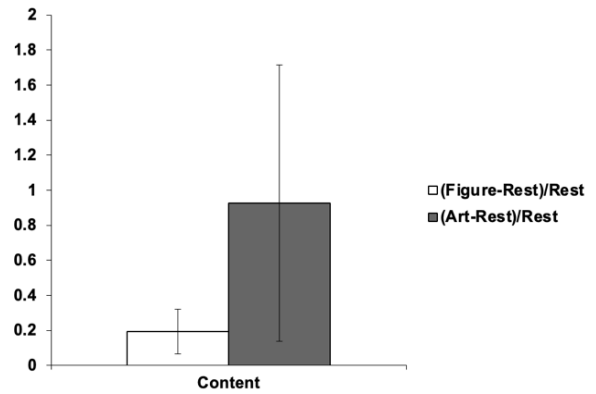


Fig. 12. Results for the rate of change from Rest for LF/HF

Although there appears to be a difference between Art and Figure in Figs. 11 and 12, the ANOVA result shows that there is no significant difference between the two. This may be due to the significant variance in both cases.

Furthermore, a similar analysis was conducted for RRI (RR time interval), and the results are shown in Fig. 13. In this case, there appears to be a difference between Art and Figure. However, the ANOVA result shows no significant difference between the two. This may also be due to the significant variance.

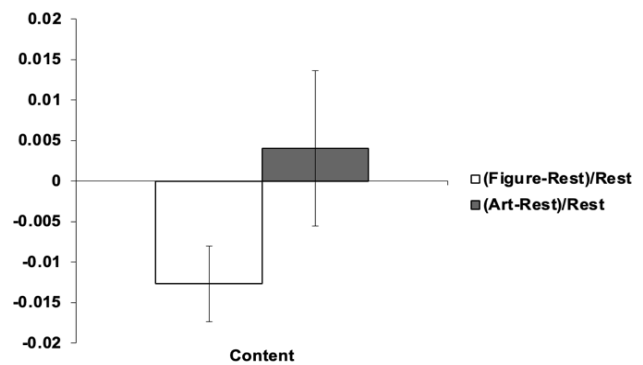


Fig. 13. Results for the rate of change from Rest for RRI

Figures 12 and 13 show that the variance is enormous for Art. This indicates significant individual differences concerning the effect of art viewing on the ECG. This suggests that a detailed analysis of each individual may provide insight into how the effects of art viewing vary from person to person. Future analyses will focus on this point.

## 7. CONCLUSION

Previous research has confirmed that art can calm and inspire people. At the same time, it is expected that art can have further effects, such as enhancing people's creativity, and we sometimes receive such comments from the audience at the exhibits of video art of Naoko Tosa. We are interested in clarifying whether or not there are such effects. Based on the feedback from people who say that her artworks give them a sense of levitation and liberation, they should be viewed in an immersive space that gives people a sense of infinite expanse. To realize this, we designed and constructed an immersive space consisting of mirror displays that function as both a mirror and a display.

Our research aims to investigate how viewing Tosa art in such an immersive space affects the subjects. We conducted psychological experiments and physiological data measurements simultaneously, aiming to analyze the relationship between them to clarify the effects of art viewing on people's psychology and physiology. Using the data obtained, an analysis of the psychological evaluation results has already been conducted, with exciting results showing that viewing Tosa art in an immersive space inspires people's minds and stimulates their creativity [10].

Since physiological data measurement was conducted simultaneously with a psychological evaluation, the next step is to clarify the effect of Tosa art appreciation on the focus on physiological data. In this paper, we focus on the electrocardiogram (ECG) and analyze the heart rate variability under four conditions: when art content is presented, when geometric figure content is presented, and when no content is presented twice. The results were analyzed in terms of mean and variance analysis results. The results showed that sympathetic activity was less active, and parasympathetic activity was suppressed during art presentation. Neither sympathetic nor parasympathetic activity is active during deep sleep or in the presence of certain neurological disorders, which have been considered abnormal. In contrast, this experiment, in which healthy subjects viewed art in an immersive space, revealed the possibility that art viewing may have a unique effect on people's minds and bodies. This point should be further investigated in the future.

The results also revealed substantial interindividual differences. This indicates that a detailed analysis of the data for each subject is needed. Based on the results obtained in this study, we will conduct a further detailed analysis of the ECG data. At the same time, we will examine the relationship between the psychological evaluation results and the ECG data analysis results. We will also analyze the EEG and skin potentials measured along with the ECG data to clarify the effects of art appreciation on the human mind.

## REFERENCES

- [1] Ellen Winner, "How Art Works: A Psychological Exploration," Oxford University Press (2018).
- [2] Stefano Mastandrea, Fridanna Maricchiolo, Giuseppe Carrus, Ilaria Giovannelli, Valentina Giuliani, Daniele Berardi, "Visits to figurative art museums may lower blood pressure and stress," *Arts and Health*, Vol.11, No.2, pp.1213-132 (2019).
- [3] R. L. Beard, "Art therapies and dementia care: A systematic review," *Dementia*, Vol.11, pp.633–656 (2012).
- [4] Arthur Schall, Valentina A Tesky, Ann-Katrin Adams, Johannes Pantel, "Art museum-based intervention to promote emotional well-being and improve quality of life in people with dementia: The ARTEMIS project," *Dementia*, Vol.17, No.6, pp.728–743 (2018).
- [5] Angela Clow, Cathrine Fredhoi, "Normalisation of salivary cortisol levels and self-report stress by a brief lunchtime visit to an art gallery by London City workers," *Journal of Holistic Healthcare*, Vol. 3, No. 2, pp. 29-32 (2006).
- [6] Mikaela Law, Nikita Karulkar, Elizabeth Broadbent, "Evidence for the effects of viewing visual artworks on stress outcomes: a scoping review," *BMJ Open* (2021).
- [7] Yunian Pang, Liang Zhao, Ryohei Nakatsu, Naoko Tosa, "A Study of Variable Control of Sound Vibration Form (SVF) for Media Art Creation," 2017 International Conference on Culture and Computing (2017).
- [8] *Mirroria* (<https://www.asahiglassplaza.net/products/mirroria/>)
- [9] Akane Kitagawa, Yasuyuki Uraoka, Masafumi Furuta, Tatsuya Munaka, "Human Metrics Explorer System for Multi-Device Physiological Measurements in Emotion Estimation," *SII 2024*, pp.184–189 (2024).
- [10] Ryohei Nakatsu, Naoko Tosa, Yunian Pang, Satoshi Niiyama, Yasuyuki Uraoka, Akane Kitagawa, Koichi Murata, Tatsuya Munaka, Yoshiyuki Ueda, Masafumi Furuta, Michio Nomura, "Construction of Immersive Art Space Using Mirror Display and Its Evaluation by Psychological Experiment," *EAI ArtsIT 2023* (2023.11).