Evaluation of High Presence Sensation based on Biological Information

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***Abstract*—Various kinds of high presence displays are developed and used in recent years. However, it is difficult to quantitatively evaluate the "presence". In this study, we tried to define the word of presence operationally by measuring the biological information of the users. In the experiment, the conditions of 2D/3D images, viewing angles, and resolutions of the displayed images were changed. And the electrocardiogram, facial skin thermogram, and eye movement of the users were measured when they were looking at the displayed images. From the result, it was shown that the RRV value decreases, the nose skin temperature did not decrease, and the frequency of eye movement increased, when the user were looking at the high presence image. This situation means the state where the user is concentrating his mind, feeling relax, and being interest in the displayed image. From the results, we proposed the index value of the word of presence by using the RRV value, the nose skin temperature, and the frequency of high presence sensation.**

Keywords-high presence sensation; biological information; electrocardiogram; facial skin thermogram; eye movement

I. INTRODUCTION

Recently, various high presence display systems such as 4K3D display and dome display are developed and used. Moreover, several research projects about display technology and image generation technology that aim at generating higher presence sensation are performed. However, it is difficult to quantitatively evaluate the sense of "presence" based on the objective criteria, because the word of presence is usually used to represent the subjective feeling which depends on the personal impression and emotion. For example, we cannot answer the following questions clearly: "What is the presence ?", "How high is the presence of this system?", or "What should we do to improve the presence?".

The purpose of this study is to define the concept of "presence" quantitatively so that it can give the guideline for the development of various kinds of high presence displays. Particularly, in this study, we focused on the change of biological information when the user is looking at the high presence image, and tried to construct the index value of the high presence sensation that can be used to evaluate various display systems. This paper describes the relationship between the presence sensation and the biological information, the experiment on measurement of biological information of the user who is experiencing various kinds of high presence displays, and the proposition of the index of the presence based on the experimental results.

II. PRESENCE AND BIOLOGICAL INFORMATION

In general, it is difficult to define the meaning of the word "presence". If the word of presence were defined conceptually, the explanation of "sensation as if facing on the occasion" would be given, and it is difficult to evaluate this concept objectively and quantitatively. This study aims at introducing the objective index for the evaluation of the word presence of which the conceptual definition is difficult.

In the previous works which tried to define the word of presence, the factor analysis based on the semantic differential method was proposed [1]. But, this method is thought to be an objective evaluation. Although the brain activity when looking at the image was measured using fMRI as an objective index, the measurement was limited to the display system that can be taken into the equipment of fMRI [2]. Moreover, though the research on the relationship between center of gravity agitation and displayed image was conducted, the evaluated element was limited to the screen size.

In this study, several biological information of the human being when experiencing the high presence image is used as an objective index. In this case, it is desirable that the biological information can easily be measured in various display environments. Therefore, in this study, electrocardiogram (ECG), facial skin thermogram (FST), and eye movement were used. In the electrocardiogram, it is known that RRV value which is the variance of the intervals between R-wave and R-wave decreases when the human concentrates his mind [4]. As for the facial skin thermogram, it is said that the nose skin temperature decreases when the human feels the mental stress [5][6]. Moreover, it is thought that the frequency of the movement of view direction indicates the degree of interest in the displayed image, because we tend to look at the object of interest [7]. This study estimated the sense of presence that was felt by the subjects when they looked at the image in various display environment based on these biological information.

The method of defining the presence based on the biological information of the user when he looks at the image is considered to be a kind of operational definition of the concept of presence. Operational definition is a way of defining the meaning of word based on not the abstract

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concept but the concrete operation or procedure, and it is often used in the field of scientific philosophy. For example, though it is very difficult to define the word "intelligence" conceptually, it can be defined as "intelligence is an ability measured by intelligence test" based on the operation.

In this study, the abstract and subjective concept of "presence" is defined operationally based on the objective data of the biological information by measuring it when the human is looking at the high presence image.

III. Experiment on Presence and Viewing Angle

In this study, we first took up the viewing angle of the displayed image as an element of the high presence sensation and measured the relationship between the viewing angle and the biological information of the user. As display systems used in the experiment, an inclined-type dome display in National Museum of Emerging Science and Innovation (viewing angle is about 180 degrees), a 180-inch large screen display for 4K projector (viewing angle is 36 degrees), and a 42-inch liquid crystal television (viewing angle is 16 degrees) were used.

As biological information, electrocardiogram, facial skin thermogram, and eye movement were measured. From the electrocardiogram data, RRV value which is the variance of R-R intervals was calculated. RRV has correlation with the user's concentration, and it is known that the RRV value decreases when the user concentrates his mind. Biological signal measuring device NeXus-4 and monitoring software BioTrace+ of HumanKarigar were used for the measurement of electrocardiogram.

From the facial skin thermogram, the change of the nose skin temperature was used. In this case, since the facial skin temperature is influenced by the change of the room temperature, the difference of skin temperatures between forehead and nose was measured and used. It is known that the nose skin temperature decreases according to the increase of the mental stress, and it can be used to measure the user's mental stress. Infrared thermal camera TVS-500EX of Nippon Avionics Co., Ltd. was used for the measurement of the facial skin thermogram.

As for the eye movement, the number of times of the movement of view direction per second was measured. It is thought that the user's view direction moves frequently when he has an interest in the displayed image contents, since the human has a tendency to move his view direction to the object of interest. In order to measure the user's view direction, mobile type eye mark recorder EMR-9 of NAC Image Technology Inc. was used.

In the experiment, these data of the biological information were measured when the subjects were seeing the images that were displayed on each display system [8]. As image contents used in the experiment, the image of the educational animation movie "Encounter with Earth" which was created for dome display was displayed for twelve minutes [9]. In each experiment, quiet time for three minutes in which the displaying image was stopped was given before and after displaying image. Figure 1 shows the experimental scene in the condition of using the dome display environment. Figure 2 shows the example of the displayed image.

Figure 1. Experimental scene in dome display environment

Figure 2. Example of the image projected on dome display

Figures 3-5 show each result of the RRV value, the nose skin temperature, and the frequency of eye movement for five subjects. As for the RRV value, we can see that the viewing angle was significant at 1% level ($p=0.000$) from the analysis of variance, and there was significant differences between 42-inch small monitor and 180-inch large screen ($p=0.000$) and small monitor and dome screen ($p=0.001$) respectively from the analysis of multiple comparison. As the results of nose skin temperature, viewing angle was also significant at 1% level, and there were significant differences between small monitor and large screen ($p=0.000$) and small monitor and dome screen ($p=0.000$). On the other hand, as for the frequency of eye movement, viewing angle was significant at 1% level ($p=0.000$) in the analysis of variance, and there were significant differences between small monitor and large screen ($p=0.000$) and large screen and dome screen ($p=0.000$) respectively in the multiple comparison.

From these results, we can see that the RRV value decreases, the nose skin temperature does not decrease, and the frequency of eye movement increases when the wide field of view image was displayed. This means that the user concentrated his mind, felt relax with little mental stress, and

had a lot of interest in the displayed image, and it is a characteristic of the biological information for the sense of presence.

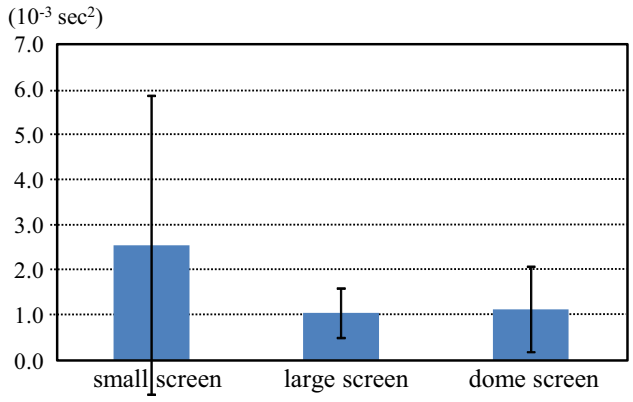

Figure 3. RRV values for each display

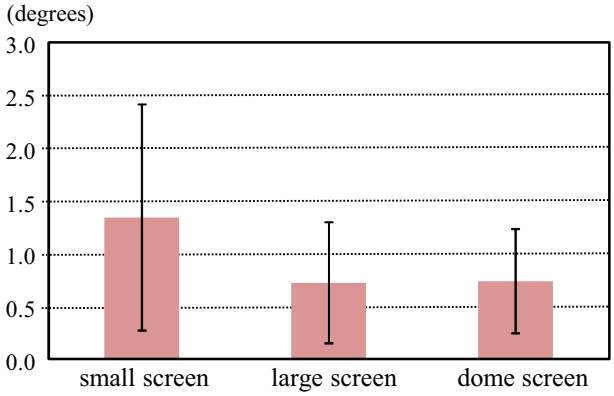

Figure 4. Nose skin temperature for each display

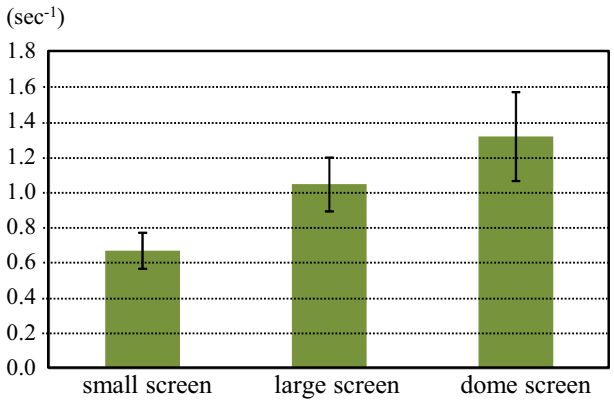

Figure 5. Frequency of eye movement for each display

IV. Experiment on Presence and Various Images

Next, in order to examine the elements of the display system that influence the sense of presence, we conducted an experiment by considering three kinds of elements, such as stereo vision, viewing angle, and resolution. In the experiment, the conditions of 3D image and 2D image, 36 degrees viewing angle and 16 degrees viewing angle, and 4K image (4096x2160) and full HD image (1920x1080) were selected for each element, and the experiment in total of eight kinds of conditions was conducted.

As display devices, SONY SRX-S110 projector was used to project 4K image onto 180-inch screen, and 42-inch plasma television of Panasonic 3D VIERA TH-P42GT3 was used to display full HD image, respectively. As 3D image generation, polarization method and frame sequential method were used for SRX-S110 and 3D VIERA, respectively. Moreover, in order to realize the viewing angles of 36 degrees and 16 degrees, the subjects sat at the distances of 6.2m and 12.9 from the 180-inch screen, and at the distances of 1.4m and 3.3m from the 42-inch television, respectively

As biological information, electrocardiogram, facial skin thermogram, and eye movement were measured in the same way as the previous experiment. Movie content "Light Connect" that was created as 4K 3D image in collaboration with NHK Media Technology was used in the experiment. The running time of the movie was 12 minutes, and the quiet time of 3 minutes were given before and after running the film. Figure 6 shows measuring the biological information, and figure 7 shows the example of the displayed contents.

Figure 6. Measurement of biological information

Figure 7. Example of the image projected on 180-inch screen

Figures 8 to 10 show the results of the RRV value, the nose skin temperature, and the frequency of eye movement for five subjects. In the three-way ANOVA for the result of RRV values, the stereo vision (p=0.013), the viewing angle (p=0.000), and the resolution (p=0.044) were significant, respectively. Figure 8 shows the RRV value for each condition. The RRV values for 3D image, wide viewing angle, and 4K 3D image were smaller than the RRV values for 2D image, narrow viewing angle, and full HD image.

From the result of three-way ANOVE for nose skin temperature, though the viewing angle (p=0.003) was significant, the stereo vision (p=0.546) and the resolution (p=0.255) were not significant. The nose skin temperature for the image of wide viewing angle was not reduced much, and it means that the subject felt little stress. Moreover, from the result of the frequency of eye movement, though the stereo vision (p=0.047) and viewing angle (p=0.000) were significant, the resolution (p=0.836) was not significant. The frequency of eye movement for 3D image was larger than 2D image, and it means that the subjects had more interest in the 3D image. And the frequency of eye movement for wide viewing angle image was larger than narrow viewing angle image.

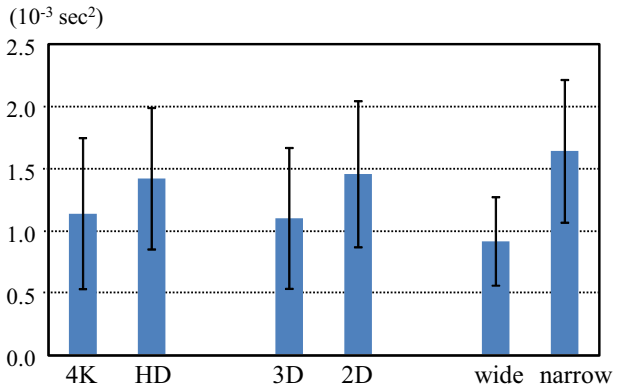

Figure 8. RRV values for each condition

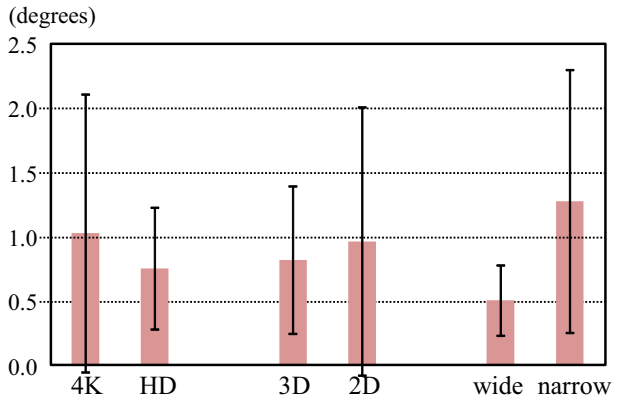

Figure 9. Nose skin temperature for each condition

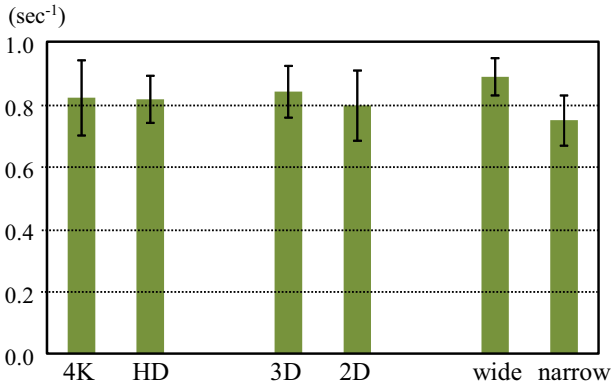

Figure 10. Frequency of eye movement for each condition

From the results of the experiment, we can understand that the viewing angle of the displayed image affects the concentration, relaxation, and interest of the user, the 3D image affects the concentration and interest, and the resolution affects the concentration. On the other hand, we asked the subjects who participated in the experiment to make subjective ranking about the presence felt from each image. Table 1 shows the result. This result shows that the presence is affected by the elements of the displayed image in order of viewing angle, resolution, and 3D. By comparing these results, we can see that the influence of the viewing angle was largest in both cases, but the order of the influence of 3D and resolution was different. We can consider that this difference is caused by the distance between the subject and the screen. In the experiment, the influence of the resolution was reduced because the high resolution image with narrow viewing angle was seen from the distant position. In the next step, it is necessary to conduct the experiment which examines the influence of the resolution by considering the distance between the subject and the screen.

Table 1. Order of subjective evaluation of presence

order	viewing angle	resolution	stereo
1	wide	4K	3D
2	wide	4K	2D
3	wide	4K	3D
4	wide	4K	2D
5	narrow	HD	3D
6	narrow	HD	2D
7	narrow	HD	3D
8	narrow	HD	2D

V. INDEX VLUE OF PRESENCE

From the results of these experiments, it was shown that when the user experienced the 3D, wide viewing angle, and high resolution image that can be considered as high presence image, the RRV value decreased, the nose skin temperature did not decrease, and the frequency of eye movement increased. This means that the user is

concentrating his mind, but feeling little mental stress, and being interested in the image when he is experiencing the high presence image. Namely, the subjective sense of presence can be defined operationally by using these data of the biological information.

In this study, three kinds of biological information of RRV, nose skin temperature, and frequency of eye movement are proposed as an index value of high presence sensation. Since the concrete value of the biological information includes individual difference, it is normalized by the maximum and minimum values. For example, the index value of the presence for the 4K3D image with wide viewing angle was calculated as (0.77, 0.84, 0.72) from the average values of the RRV, nose skin temperature, and eye movement. Moreover, though the index values for the 3DHD and 4K2D images with narrow viewing angle are (0.36, 0.72, 0.30) and (0.28, 0.00, 0.06), they are greatly increased as (0.62, 0.91, 0.61) and (0.64, 1.00, 0.63), respectively by combining them with wide viewing angle.

VI. CONCLUSIONS

In this study, the relationship between the presence felt by the user and the biological information of electrocardiogram, facial skin thermogram, and eye movement was measured experimentally. From the result, we found that though the RRV value decreased, the nose skin temperature did not decrease and the frequency of eye movement increased, when the user looked at the high presence image. This means the state of concentrating the mind, feeling relax, and being interested in the image. Thus, these data of biological information can be considered as an index value of the presence sensation.

Although the relationship between the characteristics of the visual display and the biological information of the user was examined in this study, the influences of other elements such as the auditory information and the displayed content itself are also important. Future work will include examining these elements to develop the higher presence display systems.

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