"Super Hi-Vision" – an ultra-high definition television– and its human factors

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Abstract
The ultra-high definition TV system nicknamed "Super Hi-Vision" is a television system with 4000-scanning-line video and 22.2 multichannel sound. NHK has been developing it with the aim of creating a broadcasting system conveying a strong sensation of presence. We believe that it is important to design the system by taking into account human factors such as human visual system characteristics. This paper describes the psychological and physiological experiments on the visual effects of "Super Hi-Vision".

1. Introduction
Research and development continues on an ultra high-definition television at NHK Science and Technical Research Laboratories [1]. We have named this system 'Super Hi-Vision'. Our work will explore future media beyond the confines of HDTV. One desirable future media could be described as one that allows users to be "absorbed" in an environment created by an audio/visual presentation, where they would feel as if the subject being presented were actually at their location. In other words, it would give a strong sensation of reality, or presence (hereafter sensation of presence). Such a media would at least require large, wide-screen images that are beyond the capability of current HDTV to produce (Figure 1).

A thorough knowledge of human factors, especially the response of the human visual system to such a system, will be indispensable to the design of the system. We consider that our research scheme should embody the following aspects. Firstly, subjective evaluations are indispensable when we design the system. Secondly, objective (physiological) evaluations are useful as a complement to subjective ones because subjective evaluations may be time-consuming. Furthermore, physiological evaluations would provide us with a useful perspective for studying the human visual system in regard to the design of such a futuristic audio-visual system. Thirdly, negative effects such as motion sickness induced by video should be taken into account when designing the system.

This paper briefly introduces the Super Hi-Vision system and the researches being conducted at NHK STRL from the three aspects mentioned in the previous paragraph.

Figure 1 Super Hi-Vision conceptual image

2. "Super Hi-Vision" prototype system
When a new video format is being developed, it is important to learn how the size and resolution of the display affect the perception of someone watching a video presentation. It was from this viewpoint that the initial HDTV research and development took place more than 40 years ago, with studies on various video formats and on subjective picture-quality for high-resolution TV (the present HDTV) [2]. The results were used to make important decisions on the most appropriate format. These fundamental studies measured the perceived sensation of presence from wide-screen images by using psychophysical techniques. One example was an experiment that evaluated the subjectively induced tilt angle of the coordinate axes when a subject was presented with a tilted stimulus images on a semi-spherical screen. It was found that a larger induced angle indicates the image presented a stronger sensation of presence. The

inducing effects start to appear around 20 arc-degrees and reach plateau at from 80 degrees to 100 degrees [3].

Based on these research findings, we constructed a prototype advanced broadcasting system conveying a strong sensation of presence to the viewer. We named it Super Hi-Vision. It is capable of displaying images with horizontal viewing angles of up to 100 degrees. In consideration of the standard viewing distance*, a 100-degree viewing angle requires approximately 8,000 pixels in the horizontal direction. Interoperability with the present HDTV system would also be desirable, and sharing commercially available HDTV equipment would make system implementation easier. These considerations led us to choose parameters appropriate for four times the number of pixels of HDTV, both horizontally and vertically, a progressive scanning scheme at a 60Hz frame frequency, and an aspect ratio of 16:9.

* The distance at which the scanning line structure of a display starts to become unrecognizable by a standard observer (a person with 20/20 vision). Since 20/20 vision is the ability to distinguish a viewing angle of one arc-minute, the viewing angle needed to see a single scanning line or a single pixel is calculated as one arc-minute. Therefore, standard viewing distance is determined by the number of scanning lines in an image, represented by the multiples of the display height H. This means 3H for HDTV, and 0.75H for Super Hi-Vision.

3. Research from the aspect of human factors

It is important to clarify the target specifications and performance to develop such a system that conveys a strong sensation of presence to the viewer. Hence, we are researching the relationship between human information reception characteristics and the system configuration by using the Super Hi-Vision prototype described in the previous section.

Figure 2 Display of Super Hi-Vision prototype

3.1 Subjective evaluation of the sensation of presence

A subjective evaluation of the sensation of presence was conducted [4]. It consisted of two experiments in which the viewing angle of the displayed images was manipulated as a between- or within- subjects factor. These experiments were intended to investigate a contrast effect, i.e. any bias caused by comparing different viewing angles in the within-subjects evaluation.

Two hundred adults (98 female, 102 male) participated in both experiments. The subjects of the between-subjects experiment were divided into five groups for evaluating each viewing angle. The Super Hi-Vision prototype with a 450-inch screen was used. (Figure 2), and the still scenery pictures shown in Figure 3 were used in both experiments. These were photographed with a 4-inch x 5-inch large-format camera and then digitized with a drum scanner. The subjects viewed the evaluation image for 10 seconds, followed by 10-second gray homogeneous image. Then they evaluated the sensation of presence using

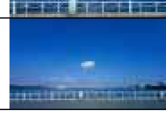
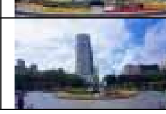
Picture angle [deg.]	'bay'	'path'	'warehouse'	'statue'
60				
100				

Figure 3 Test materials

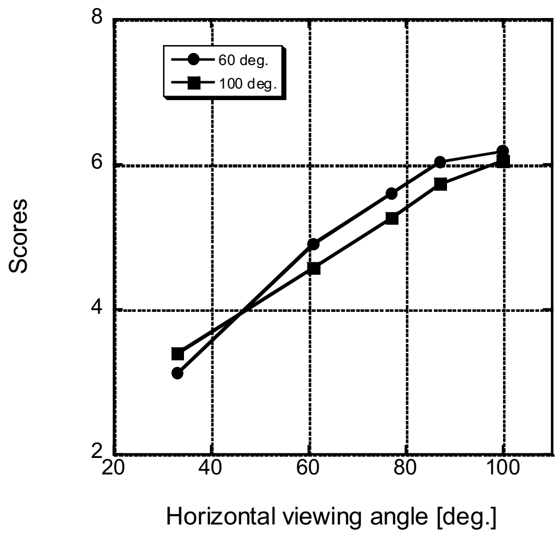


Figure 4 Evaluation results: within-subject

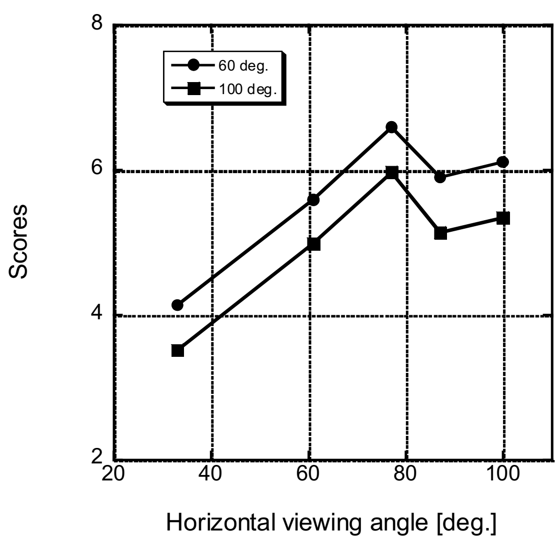


Figure 5 Evaluation results: between-subject

10-cm visual analog scales ranging from a low extreme of "I didn't feel a sensation of presence at all" to high of "I felt an extremely strong sensation of presence ".

Figure 4 shows the mean scores of the sensation of presence for picture "statue" used in the within-subjects-factor experiment. The results show that the scores of the sensation of presence increase monotonously as the viewing angle becomes wider. They show significant differences between viewing angles except the case of 87.3 and 100 degrees for the image with a camera picture angle of 60 degrees. Figure 5 shows the mean scores of the sensation of presence for the picture "statue" used in the between-subjects-factor experiment. The results differ from the ones of the within-subjects-factor experiment as they level off at a viewing angle of around 80 degrees. They show significant differences between the viewing angle of 33.2 degrees and larger viewing angles. There were no significant differences between the viewing angles from 61.6 to 100 degrees.

3.2 Physiological index - body sway -

We measured the viewer's body sway while they were viewing still images presented by the Super Hi-Vision system [5]. It was assumed that the smaller the difference between the real world and the scene presented by video systems becomes, the smaller the difference in the response of human equilibrium would be between viewing the real world and viewing the scene presented by the system.

Twenty one adults participated in the experiment. A Super Hi-Vision prototype with 320-inch screen displayed three scenery images as the test materials. Viewers stood for 120 seconds on a force platform with the inner sides of their feet in contact, which is called the Romberg foot position. The total body sway distances were calculated by summing the locus of body sway from 30 seconds to 90 seconds during one measurement session.

The result of body sway measurement is shown in Figure 6. It shows the differential length of total body sway between for a viewing angle of 33.2 degrees and the others. The wider the viewing angle is, the shorter the total body sway becomes. A repeated measurement ANOVA with two factors (picture and viewing angle) showed that the main factor of viewing angle was significant ($p=0.046$), that the main factor of picture was not significant ($p=0.313$), and that their interaction had a tendency of significance ($p=0.061$). Helmert contrasts within subjects were performed to test whether the stabilizing effect saturates or not when the viewing angle increases. The results showed a significant difference between 33.2 and more than 61.6 degrees ($p=0.002$). They didn’t show a significant difference between 61.6 and 76.9 degrees ($p=0.516$). These results are almost the same as those of our previous

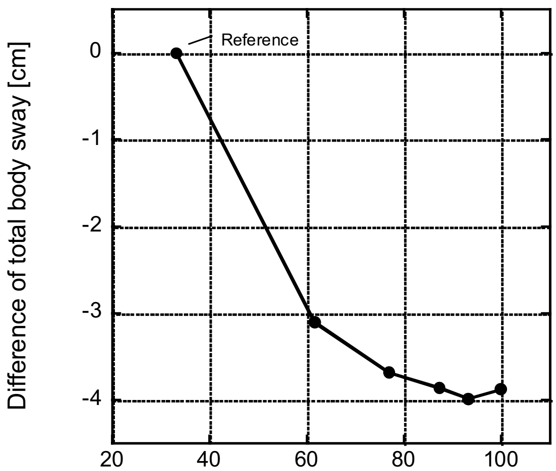


Figure 6 Measured results of body sway

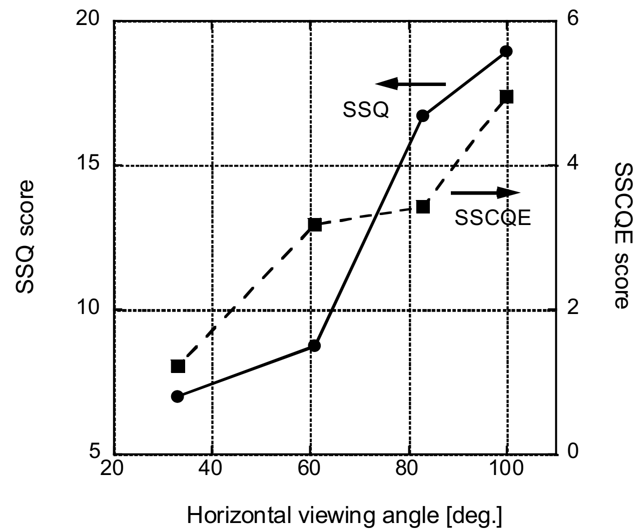


Figure 7 SSQ and SSCQE

report [6] except for the significance of the difference between 61.6 and 76.9 degrees.

3.3 Visually induced motion sickness

Wide-field-of-view video may induce motion sickness in viewers as a result of a strong visual stimulus from a large screen. It is important to take this effect into account when designing such a system [7].

We evaluated the effects of viewing angle on the visually induced motion sickness by using both subjective and physiological indices [8]. The Simulator Sickness Questionnaire (SSQ) and the Single stimulus continuous quality evaluation (SSCQE) were used as subjective indices. SSQ is a method developed by Kennedy to evaluate simulators [9]. It uses 16 symptoms categorized into one or two of three items, oculomotor, disorientation, and nausea. The SSQ scores are obtained by summing these items after weighting. SSQ tests were conducted before and after viewing the test stimuli. SSCQE is a method for subjective evaluation of picture quality that was standardized by International telecommunication union radio sector (ITU-R). It is used to evaluate time-varying picture quality [10].

We measured heart-rate variability. A change in the balance of sympathetic and parasympathetic nerves is considered to be a sign of motion sickness. It is

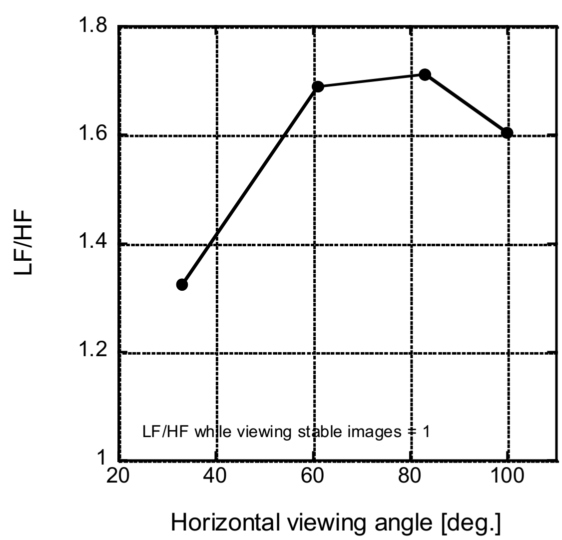


Figure 8 LF/HF of heart rate variation

known that low-frequency component of heart rate variation is affected by both the sympathetic and parasympathetic nerves but high-frequency component is affected by only the parasympathetic nerve. Therefore, LF/HF can be used as an index of the balance state of the autonomic nervous system.

Fifteen adults (14 female, 1 male) participated in the experiments. The Super Hi-Vision prototype had a 450-inch screen and it displayed motion images shot from a car running on freeway. Motion vectors of the original images were applied to produce stable and unstable test stimuli from the original one. After 15-minutes of quiet time, the subjects watched 5-minutes of stable images with viewing angle of 100 degrees then they watched 10 minutes of unstable images with one of four viewing angles.

The results are shown in Figures 7 and 8. The SSQ scores increase as the viewing angle becomes wider, and they level off slightly around 83 degrees. SSCQE is worse for the unstable images, and there is no significant difference between viewing angles in this case. LF/HF also increases for unstable images, and again, there is no significant difference between viewing angles.

4. Conclusion

This paper described the study of an ultra-high definition television called "Super Hi-Vision" focusing on its human factors. One of the principal features of Super Hi-Vision is its widened viewing angle of displayed images. Hence, we first investigated the psychological and physiological effects of wide viewing angle. The research included subjective evaluation of the sensation of presence, measurement of body sway as an objective index for the sensation of reality, and subjective and physiological evaluation of visually-induced motion sickness. These results would be the basis for the determination of the standard viewing condition and signal format of Super Hi-Vision. We will continue the study on remained items such as frame frequency so that the results are reflected when determining the signal format from the aspect of human factor.

It can be said that video media expands human vision, and thus a wider and larger screen would satisfy the basic human desire to receive as much information as possible. The development of an actual system capable of fulfilling this desire will span many fields and will flourish in the future. Our work will essentially aim at realizing a media that is provocative yet pleasing to the senses, and the concept that these media should be designed on the basis of human visual system, as described in this paper, will be the foundation of this effort.

5. References

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