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National Comparison of Influence on Subjective Impression by Images in Different Resolutions

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Abstract: The development of imaging technologies and display enable the performance of 4K (3840×2160px) and 8K (7680×4320px) contents. To provide attractive 4K video content, it is important to design and manage services based on users' quality of experience (QoE). To establish a "comprehensive QoE evaluation technology" previous studies have considered various aspects media quality, user attributes, the purpose of use, usability, service attributes and others. However, regional differences have largely not been investigated. In this paper, we measured the impression of images in different resolutions by SD (Semantic Differential) Method and analyzed subjective data by factor analysis, followed by a comparison between Chinese and Japanese test subjects. Results demonstrate that "the feeling of details clarity" is strongly related to changes in image resolution, while "the feeling of naturalness" and "the feeling of impact" are related to the material used. The understanding of contents and the adjective pairs "Strong contrast - Weak contrast", "Clearly - Fade" belonged to 1st factor "the feeling of details clarity" were found to be dependent on the viewer's region.

Keywords: 4K, Subjective impression, QoE, Regional difference

1. INTRODUCTION

Terrestrial digital broadcasting has developed significantly, together with Blu-ray technology and 4K television. The revolution in storage and image processing technology has greatly enhanced TV transmission.

HDTV has achieved worldwide popularity. In Japan, HDTV is already available from sources such as terrestrial broadcasting, satellite broadcasting, cable TV, Internet broadcasting and package media. The next generation of broadcasting and television technology is now already in research and development. It is called SUPER Hi-VISION (SHV) and is being promoted by Nippon Hoso Kyokai (NHK: Japan Broadcasting Corporation) [1]. In 2014, Japan begun the experimental 4K broadcasting of the opening of the World Cup held in Brazil, and NHK is conducting research and development with the aim of starting experimental 8K broadcasting of the opening of the 2016 Rio de Janeiro Olympics and the 2020 Tokyo Olympics [2].

Design and management of services based on viewers' quality of experience (QoE) is crucial in providing engaging, high-quality content. Therefore, the International Telecommunication Union (ITU) has formulated a series of international standards related to subjective assessment methodology, and had defined QoE in the following Recommendation p.10/G.100 [3]:

Quality of Experience (QoE)

The overall acceptability of an application or service, as perceived subjectively by the end-user.

NOTES

(1) *The quality of experience includes the complete end-to-end system (client, terminal, network, services infrastructure, etc.).*

(2) *User expectations and context may influence overall acceptability.*

A lot of studies have been conducted in order to establish a "comprehensive QoE evaluation technology" [4,5]. The subjective senses, in addition to media quality, have also been considered by researchers [6]. Moreover, for the purpose of providing contents which can satisfy individual users, it is necessary to take into consideration individual (personal) characteristics for quality control [7].

It is certainly obvious that SHV technology would provide users with access to better quality multimedia. What remains under question is the prospect of matching resolution between the signal source and the signal receptor, because users nowadays are using a wide variety of devices and various screen resolutions. A lot of researches have been focused on the impression of images in different resolutions, for example, In [8], a subjective assessment was performed to test the high-resolution effect of NLSP (non-linear signal processing), and in [9], the effect of display resolution on physiological and psychological state while viewing video content at 4K and

2K was experimentally evaluated, the result showed that, viewing material at 4K causes psychological elation. All of these research showed impressive differences between different resolutions. However, until now, no research has been focused on the variations from regional impressions.

The focus of this study is to examine the influence on the subjective impression by images at different resolutions and discuss regional differences. We measured the impression of images in various resolutions by SD (Semantic Differential) Method and analyzed these subjective data by Factor analysis, then conducted a comparison between Chinese and Japanese subjects. As a result, three factors were identified which will be described later. The results of this study will show that the feeling of detail clarity is related to the change of resolution. Furthermore, we demonstrated that there are differences in the impression of images for people of different nationalities.

2. EXPERIMENTAL METHODOLOGY

For our experiments, we have used the Semantic Differential (SD) method to acquire the impression of images.

2.1 Evaluation Criteria Selection

One of the best methods for evaluating the impression of a picture has been proposed by Kansei Engineering, specifically the SD method, which has been used in many image quality assessments conducted by Kansei Engineering, as reported in previous studies [10, 11]. Before proceeding with the SD method, it is necessary to prepare a selection of evaluation criteria that can characterize the Kansei feelings from an image.

In our experiments, we have used adjective pairs that were previously selected by questionnaire for use in the SD method. Figure 2 showed the flow of evaluation criteria selection. At first, we aggregated 130 adjective pairs from past studies [6, 10], as well as included some new words.

As we know, images appeared to contain three attributes: color, texture, and shape. Therefore, in this research, we asked test subjects to select all adjective pairs that they thought suitable for assessing respective attributes. A total of 16 subjects participated in the subjective test using a questionnaire. The top 10 most-selected adjective pairs for each property were then used as the evaluation criteria. At last, we choose 11 adjective pairs with factor loadings over 0.8 by conducted factor analysis which will be described later. The adjective pairs finally used in the experiment are shown in Table 1, all experiments were carried out in subjects' native languages.

Table 1: Evaluation criteria

Attribute	Adjective-pairs
Color	Clean – Dirty (綺麗な – 汚い) (干净的 – 脏的)
	Transparent – Opaque (透き通った – 濁った) (通透的 – 污浊的)
	Distinct – Light (はっきりした – 淡い) (清晰地 – 色浅的)
	Strong contrast – Weak contrast (コントラストが強い – コントラストが弱い) (对比度强的 – 对比度弱的)
	Whitish – Blackish (白っぽい – 黒っぽい) (发白的 – 发黑的)
Texture	Clean – Dirty (綺麗な – 汚い) (干净的 – 脏的)
	Clearly – Fade (鮮鋭な – ぼけた) (鲜锐的 – 模糊的)
	Natural – Artificial (自然な – 人工的な) (自然的 – 人工的)
	Strong – Light (硬い – 柔らかい) (坚硬的 – 柔软的)
Shape	Natural – Artificial (自然な – 人工的な) (自然的 – 人工的)
	Strong – Light (硬い – 柔らかい) (硬的 – 柔软的)

2.2 Test Subjects

In this experiment, we used a total of 46 subjects, non-experts (people who are not routinely involved in work relating to the quality of TV pictures and who have limited experience in assessment tests [12]). The 46 participants were 23 Chinese, 23 Japanese and ranged in age from 20 to 29 years old, all with a visual acuity around 2.0 on the Japanese scale.

2.3 Experimental Conditions

Pictures were shown on a 4K display (55inch LCD, 3840×2160 [pixels]). A total of 10 images was used (Figure 1).

Figure 1: Evaluation images

Figure 2: Flow of Evaluation Criteria Selection

Figure 3: Viewing distance

The first two CG images were provided by NICT free of charge [13], five of images are Standard Color Image [14], and the last three photos of Toyama city were shot by our team. In this way, we collected various types of images for the experiment, so as to acquire results that are more accurate.

Each image was used at four resolution levels: 4K (3840×2160 [pixel]), FHD (1920×1080 [pixel]), HD (1280×720 [pixel]) and FWVGA (854×480 [pixel]). As we still have to display all images on the same 4K screen, images in FHD, HD, and FWVGA resolutions have been enlarged to 4K size.

The experiment has been conducted in a dark room without any illumination. Subjects viewed images at a distance of $1.5H$, as suggested previously [2], where H is monitor height (Figure 3).

2.4 Experimental Procedure

As shown in Figure 4, for the SD method - subjects looked at the assessment image for 10 seconds, followed by evaluation and voting on a seven-grade quality. There was no time limit for voting. We continued with a 3 seconds interval of gray display, in order to minimize or reduce completely the impact of previous images. Considering the counter-balance, the images were displayed randomly. After the experiment, we calculate the average of each image and all adjective-pairs. Following, we conducted a factor analysis (major factor method, varimax rotation) based on the mean value. We then conducted a Friedman test to find whether there

Figure 4: Flow of image reference

were significant differences in the assessment scores of each adjective-pairs between different resolutions, and Wilcoxon Signed-rank test was also conducted to check whether the difference between Chinese and Japanese was significant. Comparisons were statistically significant at the 95% level in this paper, $p < 0.05$.

3. RESULTS

3.1 Results of all subjects

As a result of the experiment, three factors have been extracted, as detailed in Table 2. The adjective pairs in the same group were similar to each other, therefore we named the three factors based on the adjective pairs with the highest factor loading, based on the experience of previous studies [6, 11].

The first factor has the adjective-pairs of “Clean – Dirty (Texture)”, “Clearly – Fade (Texture)”, “Clean – Dirty (Color)”, all of which are descriptive of the quality of images, thus we named it “Feeling of Detail clarity”.

The second factor has the adjective pairs of “Natural – Artificial (Texture)”, “Natural – Artificial (Shape)”, “Whitish – Blackish (Color)”, all of which are descriptive of the naturalness of image, thus we named it “Feeling of Naturalness”.

The third factor contains adjective-pairs of “Strong – Light (Shape)”, “Strong – Light (Texture)”, all of which are descriptive of the impact an image has, thus we named it “Feeling of Impact”. The result of Friedman test, except the adjective pair: “Strong – Light (Texture)”, the others all showed significant differences in the assessment scores between different resolutions.

3.2 Results of Chinese subjects only

Results of the same three factors are detailed in Table 3. The first factor has adjective-pairs of “Clearly – Fade (Texture)”, “Strong contrast – Weak contrast (Color)”, “Distinct – Light (Color)”, same with all subjects, named “Feeling of Detail clarity”. The second factor has the same adjective pairs with the outcome of all subjects, “Natural – Artificial (Shape)”, “Whitish – Blackish (Color)”, “Natural – Artificial (Texture)”, named “Feeling of Naturalness”. The third factor includes “Strong – Light (Texture)”,

“Strong – Light (Shape)”, same with the results of all subjects, named “Feeling of Impact”. The result of Friedman test, there were significant differences in the assessment scores between different resolutions of adjective pairs below: “Clear – Dirty (Color)”, “Clear – Dirty (Texture)”, “Strong contrast – Weak contrast (Color)”, “Distinct – Light (Color)”, “Natural – Artificial (Texture)”, “Clearly – Fade (Texture)”, “Transparent – Opaque (Color)”, “Whitish – Blackish (Color)”. The adjective pairs: “Strong – Light (Shape)”, “Strong – Light (Texture)”, “Natural – Artificial (Shape)” showed no significant difference.

3.3 Result of Japanese subjects only

Results of the same three factors are detailed in Table 4. In the same way as with Chinese subjects only, there were three factors extracted, with the same adjective pairs for each factor. The first factor has adjective-pairs of “Clean – Dirty (Texture)”, “Clean – Dirty (Color)”, “Distinct – Light (Color)”, named “Feeling of Detail clarity”. The second factor has adjective-pairs of “Strong – Light (Shape)”, “Strong – Light (Texture)”, named “Feeling of Impact”. The third factor included “Natural – Artificial (Texture)”, “Natural – Artificial (Shape)”, “Whitish – Blackish (Color)”, named “Feeling of naturalness”. The result of Friedman test, there were significant differences in the assessment scores between different resolutions of adjective pairs below: “Clear – Dirty (Color)”, “Clear – Dirty (Texture)”, “Strong contrast – Weak contrast (Color)”, “Distinct – Light (Color)”, “Clearly – Fade (Texture)”, “Transparent – Opaque (Color)”, “Strong – Light (Shape)”, “Natural – Artificial (Texture)”. The adjective pairs: “Strong – Light (Texture)”, “Natural – Artificial (Shape)” and “Whitish – Blackish (Color)” showed no significant difference.

3.4 Factor Scores of All Subjects

According to the results of factor analysis, there are three factors extracted – “feeling of detail clarity”, “feeling of naturalness” and “feeling of impact.”

To analyze the relationship between the first factor (feeling of detail) and the second factor (feeling of naturalness), we plotted the factor scores of each image used (Figure 5). The horizontal axis is the score of the first factor, and the vertical axis is the score of the second factor. Plot 1 is the 4K image A, plot 2 is the FHD image A, plot 3 is the HD image A, plot 4 is the FWVGA image A, and plot 5 is the 4K image B. In this way, we numbered each image in order of 4K, FHD, HD and FWVGA from 1 to 40. The red dots represent the images in 4K resolution. From the figure, we can see that, except

Table 2: Factor loadings (All subjects)

	1 st factor	2 nd factor	3 rd factor
Feeling of Detail clarity			
Clean – Dirty (Texture)	.976	.148	-.002
Clearly – Fade (Texture)	.957	.091	.006
Clean – Dirty (Color)	.938	.244	-.160
Transparent – Opaque (Color)	.933	.251	.016
Distinct – Light (Color)	.932	.268	-.151
Strong contrast – Weak contrast (Color)	.909	.083	-.333
Feeling of Naturalness			
Natural – Artificial (Texture)	.279	.907	-.017
Natural – Artificial (Shape)	.281	.906	-.151
Whitish – Blackish (Color)	.052	.850	.061
Feeling of Impact			
Strong – Light (Shape)	-.089	.012	.983
Strong – Light (Texture)	-.124	-.067	.978

Table 3: Factor loadings (Chinese only)

	1 st factor	2 nd factor	3 rd factor
Feeling of Detail clarity			
Clearly – Fade (Texture)	.971	.063	.110
Strong contrast – Weak contrast (Color)	.962	.129	-.003
Distinct – Light (Color)	.945	.230	.045
Transparent – Opaque (Color)	.940	.251	.163
Clean – Dirty (Color)	.930	.298	.091
Clean – Dirty (Texture)	.926	.231	.194
Feeling of Naturalness			
Natural – Artificial (Shape)	.239	.922	.157
Whitish – Blackish (Color)	.157	.897	-.060
Natural – Artificial (Texture)	.262	.881	.288
Feeling of Impact			
Strong – Light (Texture)	.096	.071	.933
Strong – Light (Shape)	.123	.158	.916

Table 4: Factor loadings (Japanese only)

	1 st factor	2 nd factor	3 rd factor
Feeling of Detail clarity			
Clean – Dirty (Texture)	.947	-.102	.055
Clean – Dirty (Color)	.927	-.266	.162
Distinct – Light (Color)	.913	-.223	.206
Transparent – Opaque (Color)	.885	.073	.228
Clearly – Fade (Texture)	.883	-.013	.091
Strong contrast – Weak contrast (Color)	.829	-.447	-.006
Feeling of Impact			
Strong – Light (Shape)	-.144	.960	-.094
Strong – Light (Texture)	-.198	.947	-.152
Feeling of Naturalness			
Natural – Artificial (Texture)	.142	-.305	.885
Natural – Artificial (Shape)	.133	-.413	.843
Whitish – Blackish (Color)	.139	.279	.737

Figure 5: Factor scores of all subjects (1st, 2nd factor)

image E, all images have a plus score of the first factor. Image E was a painting of sheep with a rather monotonous color pattern, which makes it different from the other images. The reason of a low point in the first factor is obvious: the object was not clear and the contrast was low. Images with a high score on the second factor were all reflecting real-life natural things. Therefore, the two CG images received a negative score. This is considering that image contents contribute a great impact on the impression.

To find the relationship between resolution and factors, we drew approximate straight lines from low to higher resolutions for each image (as shown in Figures 6 and 7). Figure 6 shows the approximate straight lines of the first and second factors, the horizontal axis represents the score of the first factor, and the vertical axis represents the score of the second factor. In Figure 7, the horizontal axis represents the score of the first factor, and the vertical axis represents the score of the third factor. We discovered that when the resolution used was higher, the first and third factors got a higher score, while the second factor did not change significantly. Furthermore, the change in the first factor was much more remarkable than in the third factor. In another word, if the resolution of images were increasing, people would feel the image has more details and the impact is heavier. Furthermore, the result of Friedman test, adjective-pairs belonged to factor “feeling of naturalness” and “feeling of impact” showed no significant different of Chinese subjects, and adjective pairs belonged to factor “feeling of naturalness” and “feeling of impact” showed no significant different of Japanese subjects. It means that only the “feeling of detail clarity” was influenced by resolution in all subjects.

These results can be summarized as the following: when observing an image, peoples’ impressions can

Figure 6: Approximate straight lines (1st, 2nd factor)

Figure 7: Approximate straight lines (1st, 3rd factor)

be classified by three factors: feeling of detail clarity, feeling of impact and feeling of naturalness. Image contents gave a great impact on the impression, while the feeling of detail clarity was strongly affected by resolution, and the “feeling of impact” and the “feeling of naturalness” was almost unaffected by resolution.

3.5 Comparison between Chinese and Japanese

In order to examine regional difference, we compared the results between Chinese and Japanese subjects. For both groups, the three factors have been extracted: the feeling of detail, feeling of naturalness and feeling of impact, with the same adjective pairs for each factor.

Figure 8 shows the factor scores for Chinese subjects (1st factor – 2nd factor). The horizontal axis represents the score of the first factor, while the vertical axis represents the score of the second factor. From Figure 8 we can easily see that all images, except image E, had a positive factor score. Furthermore, Image A (CG-museum), Image C (flower), Image D (spinning), Image G (doll) received the highest factor score of the first factor; these images are all colorful images. From the distribution of second-factor scores, we found that the factor scores of Image A, Image B and Image E were negative, while the others were positive. Image A and B are CG images and Image

E is a painting, all of them not being real-world representations. Thus, we can argue that colorful images made Chinese subjects focus more on details, compared with other images with simple or less color, and the contents influenced the feeling of naturalness.

Figure 9 shows the factor scores for Japanese subjects (1st factor – 3rd factor). The horizontal axis represents the score of the first factor and the vertical axis represents the score of the second factor. For Japanese subjects, all images, except image E, had a positive factor. First factor scores were concentrated, but the images of landscape had relatively high scores compared to the others. From the distribution of third-factor scores, we can deduce that, similar to Chinese subjects, Image A, Image B, and image E were negative. Image D (spinning) and Image G (doll) were also negative. Therefore, only the images of landscapes and flower got a positive score. We observed the difference where images with clean or pure color made Japanese subjects focus more on details, compared with Chinese subjects.

For having a further investigation on the influence of region on 1st factor “Feeling of Detail clarity”, we conducted Wilcoxon Signed-rank test on the subjective assessment scores of all adjective-pairs of 1st factor. The result showed that there were significant differences between Chinese and Japanese in adjective pairs: “Strong contrast – Weak contrast (Color)” and “Clearly – Fade (Texture)”. We believe that the difference on assessment score of these two adjective-pairs resulting in the difference of factor score between Chinese and Japanese.

Figure 10 shows the factor scores for Chinese subjects (1st factor – 3rd factor). The horizontal axis represents the score of the 1st factor and the vertical axis represents the score of the 3rd factor. We could see that pictures were clearly separated into two group, one group for the impression of impact: the images of landscape, CG-wonder world, doll for one group with positive third-factor scores, and one other for the impression of softness: CG-museum, spinning, flower for another with negative third factor scores, and the images in the same group have a close score. From these results, we can conclude that the feeling of impact is strongly dependent on contents.

Figure 11 shows the factor score of Japanese subjects (1st factor – 2nd factor). The horizontal axis represents the score of the first factor and the vertical axis represents the score of the second factor. As in the case of Chinese subjects, pictures were separated into two parts. Except for Image D (doll), the other images had very similar points from Chinese subjects. We can argue that for both Chinese and Japanese subjects the feeling of impact is strongly

dependent on contents. We also found a difference in a few images, where Chinese subjects’ impression of Image E (doll) was hard, but Japanese subjects’ was soft. As Image E was a picture of a Japanese cultural element, we supposed that cultural differences led to this result.

Figure 8: Factor scores of Chinese (1st, 2nd factor)

Figure 9: Factor scores of Japanese (1st, 3rd factor)

Figure 10: Factor scores of Chinese (1st, 3rd factor)

Figure 12, Figure 13 reflect the factor scores of Chinese (2nd, 3rd factor) and Japanese (2nd, 3rd factor) subjects. In Figure 12, the horizontal axis represents the score of the second factor, and the vertical axis represents the score of the third factor. Unifying the factors in Figure 13, the

Figure 11: Factor scores of Japanese (1st, 2nd factor)

Figure 12: Factor scores of Chinese (2nd, 3rd factor)

Figure 13: Factor scores of Japanese (2nd, 3rd factor)

horizontal axis is the score of the third factor and the vertical axis is the score of the second factor. Comparing Chinese and Japanese subjects' results, the doll and spinning images were very different in factor scores. In order to make sure whether there is a significant difference in "feeling of naturalness" between Chinese and Japanese, we conducted a Wilcoxon Signed-rank test by using the subjective assessment score of image D (doll) and image G (spinning), we found significant differences in adjective pairs: "Natural – Artificial (Texture)" and "Natural – Artificial (Shape)". Result showed that the differences in the second factor were perhaps caused by the different understanding of naturalness, where Japanese people may define things that exist in nature as natural, while Chinese people may have a wider definition. We also found that cultural differences may play a certain role in the difference in the third factor.

4. CONCLUSIONS

In this paper, we have examined the influence on the subjective impression by images in different resolutions and discussed the regional differences through a comparison between Japanese and Chinese subjects.

To examine the influence on the subjective impression of images at various resolutions, we showed subjects ten images at four resolutions (4K, FHD, HD and FWVGA). Images in FHD, HD and FWVGA resolutions have been enlarged to 4K size to adjust to the 4K display used.

For experiments, we first used the Semantic Differential (SD) method to acquire the impression of images, while the adjective pairs used in the SD method were selected previously by questionnaire and 11 main selected. We then calculated the average for each image, for all adjective pairs, and conducted a factor analysis (major factor method, varimax rotation) based on the mean value. As a result, the impressions observed when looking at images can be classified by three factors: feeling of detail clarity, feeling of impact and feeling of naturalness. We found that image contents gave a great impact on impression, while the feelings of detail clarity were strongly affected by resolution, and the feeling of naturalness was almost unaffected by resolution. Finally, we conducted a comparison between Chinese and Japanese subjects to analyze the regional difference. Results show that Chinese subjects felt that colorful images have more detail-clarity than images with simple color, while clean or pure colors made Japanese subjects focus more on details. Contents are strongly influenced by the sense of naturalness and impact, but we also found a difference in

making sense caused by cultural differences between Chinese and Japanese subjects.

In this research, we studied the factors that influence image impressions and found a difference between Chinese and Japanese subjects which can be effectively applied in the field of human-centric QoE assessment. In the future, we need further analysis with different groups of people, like various age groups, professions, nationalities etc., in order to establish the degree of influence on impression, to abstract contents that can meet the individual requirements of different people and ultimately improve Quality of Experience.

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