1. INTRODUCTION

Recently, kansei value has become crucial in the field of manufacturing in Japan. The Japanese Ministry of Economy, Trade and Industry (METI) has determined that it is the fourth most important characteristic of industrial products after function, reliability, and cost. METI believes that it is important to not only offer new functions and competitive prices but also create a new value to strengthen Japan’s industrial competitiveness.

Several years ago, we began new research to apply our previous research results to the systematic creation of kansei values of artificial products. In particular, there are large export surpluses of Japanese games, cartoons, and animations, the so-called digital content [1]. One of the main reasons for the success of digital content is considered to be the existence of “kawaii” characters, together with their highly sensitive techniques [2]. Therefore, we decided to select “kawaii” as a crucial kansei value of artificial products.

“Kawaii” is an adjective in the Japanese language. In some recent works [2-7], the following are recognized as common attributes of “kawaii”:

• It is an emotional value of Japanese origin.

• It has positive meanings, such as cute, lovable, and small.

Because the Japanese word “kawaii” is not the same as “cute” or “lovable,” and its use has become international [7], we will use this Japanese word directly. In addition, we will use it as both an adjective and a noun (to represent its nominal).

Even though Japanese kawaii characters such as Hello Kitty and Pokemon have become popular worldwide, few studies have focused on kawaii attributes; therefore, we systematically began to analyze the kawaii interfaces themselves: kawaii feelings caused by attributes such as shapes, colors, and materials. Our objective is to describe a method for constructing a kawaii interface from the research results.

Previously, we performed experiments and obtained valuable knowledge on kawaii attributes [8-11]. For example, curved shapes such as tori and spheres are generally evaluated as more kawaii than straight-lined shapes [8, 10]. However, a discrepancy exists in kawaii colors among the experimental results [8]. Warmer colors were chosen as the most kawaii by both male and female participants in one experiment, but in another, most male participants chose blue objects as the most kawaii, while no such particular tendency was found for female participants [8, 10]. Thus, to resolve this discrepancy, we performed a new experiment that employed the Munsell Color System, in which a color has three elements: hue, saturation, and brightness [11]. We obtained the following results:

• Brightness of a color is effective in inducing kawaii feelings.

• Saturation of a color is also effective in inducing kawaii feelings.

• Although all hues can be chosen as the most kawaii, purple and yellow tend to be chosen most frequently.

• The comparison results between pure color and the brightest and most saturated candidates for each hue in the experiment depend on the hues.

These results suggest that the discrepancy between the results of our previous experiments may have been caused...
because in some experiments only red, blue, and green were selected as the hue candidates.

Another potential cause is that only questionnaires were employed to evaluate kawaii colors in all of the above experiments. Although questionnaires are the most common method of kansei evaluation, they suffer from the following demerits:

- Linguistic ambiguity.
- Possibility of mixing the experimenter’s and/or participants’ intentions with the results.
- Interruption in the system’s input/output stream of information.

Thus, to compensate for these questionnaire shortcomings, we examined biological signals that offer the following merits:

- Can be measured as physical quantities.
- Resistant to the influence of experimenters’ and participants’ intentions.
- Can be measured continuously without interruption.

Some studies have focused on emotions by using biological signals. However, most studies dealt with mental stress or simulator sickness, which are considered negative sensations (e.g., [12-16]). Moreover, some studies on nonnegative sensations dealt with relaxation or comfort (e.g., [17-20]), which are considered static compared with dynamic feelings such as excitement. Thus, since little previous research exists on dynamic and positive feelings such as excitement, we performed experiments for dynamic and positive kansei evaluation using biological signals [21-26], and utilized the signals based on these experiments to evaluate kawaii feeling.

This study clarifies the relationship between kawaii colors and biological signals and that between kawaii sizes and biological signals.

2. KAWAII COLORS AND BIOLOGICAL SIGNALS

2.1 Experimental Method

Our first experiment addressed kawaii colors. For the preliminary selection of color candidates, the participants, four male and two female students in their twenties, selected the most kawaii color and the least kawaii color one by one, by viewing 381 colors in the color table [27]. The selection results indicated that pink and colors basically similar to pink were selected as “kawaii” colors, while dark brown and dark green were selected as “non-kawaii” colors. Thus, we selected pink (5R 7/10 from the Munsell Color System [28]), blue (10B 7/6), brown (5R 4/6), and green (between 2G 4/4 and 3G 4/4) for the following evaluation experiment, where blue represented a middle color between “kawaii” and “non-kawaii” colors.

Figure 1 shows the experimental setup. Participants watched at a large, 100-inch screen on which one of the above four colors was projected and evaluated its kawaii score on a 7-scale evaluation, where –3 indicated extremely “non-kawaii,” +3 indicated extremely “kawaii,” and 0 indicated neither.

The experimental procedures were as follows:
1. Participants sat on chairs.
2. The experimenter explained the experiment.
3. Participants wore electrodes.
4. They kept quiet for 30 seconds.
5. They watched a color projected on the screen for 30 seconds.
6. They answered questionnaires.

Steps 5 and 6 were repeated four times for the four colors that were displayed randomly. Biological signals such as electrocardiogram (ECG), galvanic skin reflex (GSR), breathing rate, and electroencephalogram (EEG) were measured both before and while watching, by using the BIOPAC Student Lab (BIOPAC Systems, Inc.) [29], except for the EEG, which was measured by the Brain Builder Unit (Brain Function Research Center) [30].

2.2 Experimental Results

Experiments were performed with eight female and eight male student volunteers in their twenties. On the basis of our previous experiments [21-26], we selected the following physiological indexes for analysis:

- Average heart rate
- Variance of heart rate
- Average R-R interval
- Variance of R-R interval
- Average GSR
- Variance of GSR
- Number of breaths
- Variance of number of breaths
- Average breath magnitude
- Variance of breath magnitude

Figure 1: Experimental setup
• Ratios of power spectra of theta, slow alpha, mid alpha, fast alpha, and beta waves
• Superiority rates of theta, slow alpha, mid alpha, fast alpha, and beta waves

The R-R interval is defined as the time interval between the two R waves of the ECG. In this experiment, the R-R interval was computed from an ECG measured at a sampling rate of 100Hz. The heart rate, which is defined as the number of heart beats per minute, was computed as the inverse of the R-R interval. The superiority rate is defined as the dominant duration of each category of EEG divided by the duration of measurement. All indexes described above were normalized by the values in the quiet state for each participant.

Figure 2 exhibits the questionnaire results, where the horizontal axis shows the participants (males: a–h, females: i–p) and the vertical axis shows the kawaii scores of each color.

Table 1 shows the results of a two-factor analysis of variance. The main effect of color is significant at the 1% level, the main effect of gender is significant at the 5% level, and a significant cross effect exists between color and gender at the 5% level. Thus, we analyzed the biological signals by dividing the data into two groups according to kawaii scores.

The data of the physiological indexes were divided into the following two groups: the “kawaii” group with kawaii scores above 0 and the “non-kawaii” group with kawaii scores below 0. The data with 0 score were omitted from analysis. From the unpaired t-test results of the difference between the mean values of the two groups, the heart rates, which are normalized by the subtraction of the average value of 30-second quiet state of each participant, showed a significant difference (Table 2). The heart rates of the “kawaii” group were significantly faster than those of the “non-kawaii” group. This result suggests that watching a “kawaii” color is more exciting than watching a “non-kawaii” color, from the results of our previous research related to biological signals [25, 26].

Moreover, from the unpaired t-test results of the difference between the mean values of the two groups by gender, the superiority rate of the mid alpha wave showed a significant difference. The superiority rate of the mid alpha wave of the “kawaii” group was significantly larger than those of the “non-kawaii” group. This result suggests that watching a “kawaii” color is more exciting than watching a “non-kawaii” color, because a decrease in the superiority rate of the mid alpha wave is considered as an index of relaxation.

3. KAWAI SIZES AND BIOLOGICAL SIGNALS

The second experiment addressed the kawaii sizes of objects. The experimental setup resembled that shown in Figure 1, except that the display used two projectors with polarized filters, and that the participants wore polarized glasses to stereoscopically watch the objects on the screen. Participants watched an object on the large screen and evaluated its kawaii degree. Each object’s shape and color were set as torus and yellow, 5Y8/14 in the Munsell Color System (Figure 3), on the basis of the results of our previous experiments described above. The size, which implies the visual angle, of each object was set as one of the four sizes shown in Table 3, based on our preliminary experiment.

Experiments were performed with 12 female and 12 male student volunteers in their twenties. Figure 4 exhibits the questionnaire results, where the horizontal axis shows the participants (males: m1–m12, females: f1–f12) and the vertical axis shows the kawaii score for each object size. The results of a two-factor analysis of variance show that the main effect of size is significant at the 1% level, but the main effect of gender is not significant (Table 4). The data of physiological indexes were divided into two groups, as in the first experiment. From the unpaired t-test results of the difference between the mean values of the two groups, the heart rates, which are normalized by the subtraction of the average value of 30-second quiet state of each participant, showed a significant difference (Table 2). The heart rates of the “kawaii” group were significantly faster than those of the “non-kawaii” group. This result suggests that watching a “kawaii” color is more exciting than watching a “non-kawaii” color, from the results of our previous research related to biological signals [25, 26].

Moreover, from the unpaired t-test results of the difference between the mean values of the two groups by gender, the superiority rate of the mid alpha wave showed a significant difference. The superiority rate of the mid alpha wave of the “kawaii” group was significantly larger than those of the “non-kawaii” group. This result suggests that watching a “kawaii” color is more exciting than watching a “non-kawaii” color, because a decrease in the superiority rate of the mid alpha wave is considered as an index of relaxation.

Table 1: ANOVA of kawaii score

<table>
<thead>
<tr>
<th>Factor</th>
<th>Sum of Squared Deviation</th>
<th>DOF</th>
<th>Mean Square</th>
<th>F-value</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Color</td>
<td>60.31</td>
<td>3</td>
<td>20.01</td>
<td>13.94</td>
<td>0.000**</td>
</tr>
<tr>
<td>Gender</td>
<td>6.25</td>
<td>1</td>
<td>6.25</td>
<td>4.33</td>
<td>0.042*</td>
</tr>
<tr>
<td>C x G</td>
<td>17.13</td>
<td>3</td>
<td>6.71</td>
<td>3.96</td>
<td>0.013</td>
</tr>
<tr>
<td>Error</td>
<td>80.75</td>
<td>56</td>
<td>1.44</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>164.44</td>
<td>63</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Unpaired t-test of mean value differences of heart rate

<table>
<thead>
<tr>
<th>Factor</th>
<th>Kawaii</th>
<th>Non-kawaii</th>
<th>Difference</th>
<th>Equality of Variance</th>
<th>t-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>32</td>
<td>26</td>
<td>6</td>
<td>DOF1: 25</td>
<td>T: 1.75</td>
</tr>
<tr>
<td>Average</td>
<td>3.14</td>
<td>0.88</td>
<td>2.26</td>
<td>DOF2: 31</td>
<td>0.08</td>
</tr>
<tr>
<td>Unbiased variance</td>
<td>17.92</td>
<td>31.11</td>
<td>14.19</td>
<td>DOF2: 31</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Unbiased variance | 4.23 | 5.58 | 1.34 | P: 0.15 | 0.04* |
results of the difference of the mean values of the two groups, the heart rates showed a significant difference (Table 5). Because a higher heart rate shows the unrelaxed state, the mental state while feeling kawaii is considered to be more excited than while not feeling kawaii. In addition, the results of a similar difference test of the heart rate for objects C and D showed a significant difference at the 5% level (Table 6) and at the 1% level (Table 7) respectively. These results show that the mental state while feeling kawaii is probably more excited than while not feeling kawaii, even if the size of the object being watched is the same.

4. DISCUSSION

We obtained the following from the analysis results of the first experiment on kawaii colors:

- The heart rates of the feeling-kawaii group were significantly faster than those of the not-feeling-kawaii group in both experiments of kawaii colors and sizes.
- For female participants, the superiority rates of the mid alpha wave of the feeling-kawaii group were significantly larger than those of the not-feeling-kawaii group in the first experiment of kawaii colors.

From the analysis results of the second experiment of kawaii sizes, the heart rates of the feeling-kawaii group were observed to be significantly faster than those of the not-feeling-kawaii group, which was confirmed independently by the objects’ varying sizes.

These results confirmed that ECG shows the mental state, and feeling kawaii is probably more exciting than not-feeling kawaii.

In these experiments, significant results were obtained for the analysis of heart rate. However, the analysis of the R-R interval did not show any significant results. As already described, the heart rates of each participant were normalized by the subtraction of their average value of 30-second quiet state. On the other hand, the R-R intervals of each participant were normalized by dividing their averaged R-R interval of the 30-second quiet state. The difference of power between the test of difference of
means and the test of difference of mean rates may lead to these different results between the heart rate and the R-R interval.

In addition, all of the participants of the experiments were students affiliated with us; this may affect the experimental results.

5. CONCLUSIONS

In the 21st century, the kansei values of industrial products will probably be considered crucial. In this study, we focused on “kawaii” as an important kansei value for future industrial products and concentrated on the relationship between kawaii attributes and biological signals. We performed two experiments to clarify the relationship between kawaii colors and biological signals and between kawaii sizes and biological signals.

From the analysis of the experimental results, the heart rates of the “kawaii” group were observed to be significantly faster than those of the “non-kawaii” group. These results suggest that the human mental state is more active while watching “kawaii” objects than while watching “non-kawaii” objects.

We intend to continue this research in future based on more precise considerations.

Acknowledgments

This research was partly supported by the Grant-in-Aid for Scientific Research (C) (No. 09017360), the Japan Society for the Promotion of Science, and by the SIT Research Promotion Funds. We thank the students of Shibaura Institute of Technology, who contributed to this research and served as volunteers.

REFERENCES

[18] P. Poesssel, S. Ahrens, and M. Hautzinger; Influence


Michiko OHKURA
Michiko Ohkura is a professor of College of Engineering at Shibaura Institute of Technology (SIT). She received her B.S.(1976) M.S.(1978) in Mathematical Engineering and Ph.D (1995) in Advanced Interdisciplinary Studies from the University of Tokyo, respectively. She worked for Central Research Laboratory, Hitachi, Ltd. and other companies, and joined SIT in 1999. Her research interests include safety of medical usage, interactive systems and Kansei information processing. She is now a director of Human Interface Society, Japan Society of Kansei Engineering, and Virtual Reality Society of Japan.

Sayaka GOTO
Sayaka Goto is a system engineer of NEC Saitama, Ltd. from 2009. She received her B.S.in Information Science and Engineering from Shibaura Institute of Technology (SIT) in 2009. Her research field was the evaluation of kawaii attributes of objects in virtual space while she was a student of SIT.

Asami HIGO
Asami Higo is a system engineer of NTT Comware Corporation from 2010. She received her B.S.in Information Science and Engineering from Shibaura Institute of Technology (SIT) in 2010. Her research field was the evaluation of kawaii attributes of objects in virtual space while she was a student of SIT.

Tetsuro AOTO