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Hardness Evaluation for Silicone Rubber Button on the Basis of Tactile and Visual Information

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Abstract: Information about the product value acquired through the five senses is important and if a new factor can be added to a product, it would lead to the differentiation of such a product from other similar products, as well as would improve the value of such a product. This research was aimed at investigating how the evaluation of objects is impacted by the hardness of an object as determined by the tactile sense. This investigation was carried out using silicone rubber and involved examining how the findings can be applied to the differentiation of product values. The investigation indicated that the results of sensitivity evaluation of a product depend on the hardness of silicone rubber and that the hardness values can be distinguished if they vary by at least five degrees. However, it was also found that once the hardness exceeds 60 degrees, it becomes harder to distinguish between the hardness values. Furthermore, when experiments on the application of silicone rubber to push switches were performed, sensitivity evaluation for the products was simultaneously performed, and the evaluation results indicated that the distinction between hardness values became more sensitive by the use of silicone rubber.

Keywords: Hardness Evaluation, Kansei Evaluation, Tactile Information, Visual Information, Paired Comparison Method.

1. INTRODUCTION

We use various products around us by using our five senses. Information concerning products and services broadcast by television advertisements and the like, for instance, is received by consumers as visual information or auditory information leading to the conception of images on the values of advertised products and services. This then leads the consumers to actually visit a store to look at and feel such products in order to determine their values to make a purchase. The various types of information acquired through the five senses, therefore, have an important role in

evaluating products and services.

The “tactile sense” can be considered the most important sense out of these five senses for evaluating the quality and structure of a product itself. And it has been reported that they have investigated discrimination and influence elements for tactile sensation [1], [2]. However, there is still a shortage of researches for investigating factors that can improve product values through the information acquired from the tactile sense.

This research was focused on information pertaining to the hardness of objects, acquired from the tactile sense, among the five senses. Silicone rubber was selected as our experimental material, since a wide range of hardness values can easily be achieved for this rubber and also because it is used in many products. We decided that the objective of the research shall be to investigate how the difference in hardness values as perceived by the tactile sense influences the evaluation of an object through experiments and to examine how the results obtained can be applied to differentiate product values.

2. Preliminary experiment 1

2.1. Outline

The possibility of the thickness of an object having an influence on the evaluation of hardness of the object can be considered. The potential influence of the thickness of objects has been reported in a prior research [3]. Re-examining the extent of this influence from the thickness of an object and selecting a suitable sample thickness for evaluation were set as the objectives of preliminary experiment 1. The standard for the measurement of rubber hardness JIS K 6253a was adopted as the standard for hardness and all hardness values were set to 20 degrees. Furthermore, the thickness was broken down into six levels of 4, 6, 8, 10, 12, and 14 mm. The diameter was set to 20 mm to ensure that the hardness can be determined using a finger and to make the sample size suitable for application to push buttons used in the main experiment. The paired comparison method was used to evaluate and analyze the hardness of six silicone rubber pieces prepared as described above. A total of 20 people, 14 males and 6 females of ages 21 to 22, were asked to assist as test subjects.

Figure 1: Experimental environment for evaluations based on tactile information only.

2.2. Method

The possibility of visual information on the thickness having an influence on the tactile information was considered, since the difference in thicknesses of silicone rubber pieces could be determined visually by the test subjects when they evaluate hardness. In order to investigate the relationship between visual and tactile information, experiments were conducted by setting up situations where test subjects could only acquire tactile information, only visual information only, and both visual and tactile information. First, a panel was set up to block visual information on silicone rubber to have our test subjects evaluate the hardness of silicone rubber pieces on the basis of tactile information alone (Figure 1). Next, the panel was removed to have our test subjects evaluate the hardness of silicone rubber pieces on the basis of visual information alone. Finally, our test subjects were asked to feel the silicone rubber pieces with their fingers to evaluate the hardness of the silicone rubber pieces on the basis of both tactile and visual information. Furthermore, in order to avoid any influence from differences in how the evaluations were performed, the manipulation of rubber silicone pieces by “grasping or lifting with fingers” was eliminated as a restriction on evaluations and the hardness evaluations were conducted by “pushing movements of fingers only.”

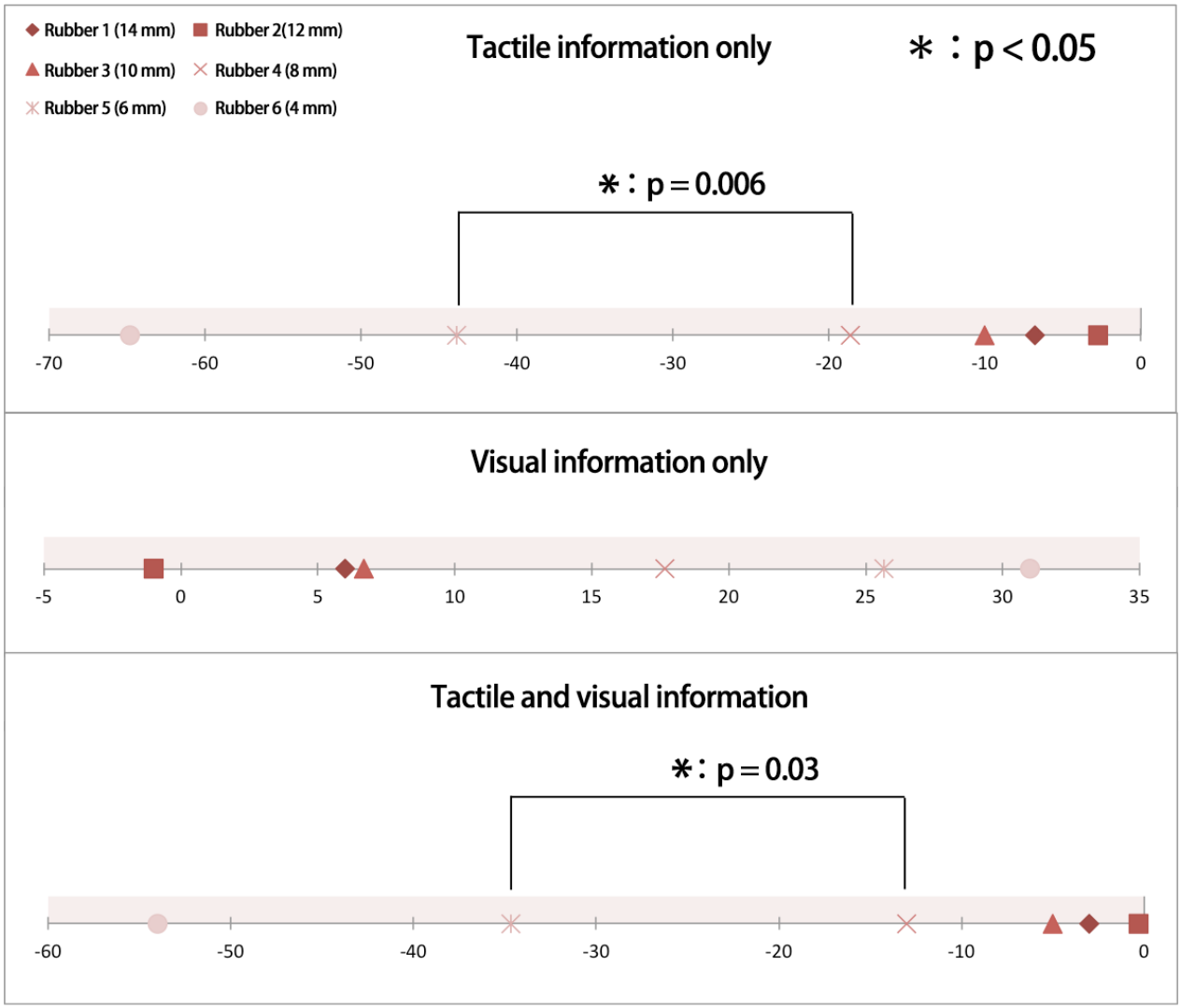

Figure 2: Results of preliminary experiment 1

2.3. Results and considerations

In terms of analysis, after conducting multiple regression analyses, a binomial test was performed to verify if there was any significant difference in the comparison evaluations on pairs of two silicone rubber pieces (Figure 2). Figure 2 depicts a plot of the results of evaluations on respective silicone rubber pieces, derived from the partial regression coefficient of the regression equation. Furthermore, in cases when any significant difference in thickness values was observed between neighboring pieces with six different thicknesses, for instance, in the case of 14 mm and 12 mm, such instance was marked with an asterisk (*). The experiment results revealed that when hardness evaluations were conducted on the basis of visual information alone, the thinner pieces were perceived as being softer. On the other hand, when hardness evaluations were conducted on the basis of tactile information alone or on the basis of both visual and tactile information, the thicker pieces were perceived as being softer. This led us to conclude that the thickness of an object is a factor that affect the evaluation of its hardness. Furthermore, our test subjects were considered to have placed more emphasis on the tactile information than on the visual information (thickness of silicone rubber pieces) when they were able to acquire tactile information to evaluate the hardness of an object.

3. Preliminary experiment 2

3.1. Outline

Silicone rubber pieces used in the experiments were prepared with color coding according to their hardness, in order to distinguish the differences in their hardness. In a previous report, it was mentioned that the evaluation of hardness was impacted by the difference in the color of objects [4]. Preliminary experiment 2 was conducted to re-examine whether the visual information provided by the difference in colors influenced the hardness evaluations. A total of 30 people, 22 males and 8 females of ages 21 to 22, were asked to assist as test subjects.

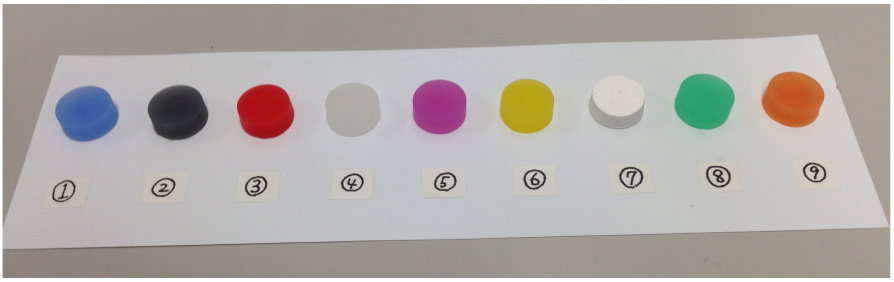

Figure 3: Nine silicone rubber pieces with varying colors

Figure 4: Evaluation sheet for entering ranking

3.2. Method

Nine pieces of silicone rubber with various colors were prepared. Test subjects were asked to

evaluate the hardness of these pieces without touching them and solely by looking at them; they were further asked to decide on the order of their hardness by using the Ranking method. Silicone rubber pieces with varying colors were randomly placed in a single horizontal row and were assigned numbers ① to ⑨ (Figure 3). The test subjects were asked to rank the pieces according to their hardness and to enter the number in the empty columns on the evaluation sheet (Figure 4). The silicone rubber pieces used for the experiment had a diameter of 20 mm and a thickness of 6 mm but had varying hardness (5, 10, 20, 30, 40, 50, 60, 70, and 80 degrees according to JIS K6253a). The order of their placement was in the sequence of 60, 40, 10, 70, 80, 30, 5, 50, and 20 (from left to right).

3.3. Results and considerations

The analysis was conducted by performing the Friedman test (Table 1). The calculation equation for the test is shown below.

$$\chi_F^2 = \frac{12}{nk(k+1)} \sum_{i=1}^{k} R_i^2 - 3n(k+1)$$

(k = 9, n = 30)

where k is the number of pieces subjected to testing, and n is the number of test subjects. It would be fair to say that there is a variance in the evaluation of hardness on the basis of color, since the sample statistic was indicated $p < 0.05$ in accordance with the chi-square distribution having eight degrees of freedom, on the basis of calculation results listed in Table 1. This implies that the difference in the color of samples used on this occasion had little influence on hardness evaluations. When considering the results for the hardness of 5 and 10 degrees, the evaluations were concentrated on the “hard” scale. Furthermore, many test subjects provided opinions, such as that “they felt that the feel of the material was different for silicone rubber pieces ③ and ⑦ (hardness of 5 and 10 degrees)”; “the degree of transparency appeared to be low”; and “they felt as if other materials were used.” This is considered to have been due to the fact that the colors of these two samples had lower transparency than other silicone rubber pieces and instead of color, factors such as material feel and material quality were believed to have influenced the evaluations.

Table 1: Analysis on the basis of Friedman test

N number	30		
Group number	9		
X ~ 2r (statistical quantity)	91.49		
Degrees of freedom	8	→	In accordance with the chi-square distribution having eight degrees of freedom

4. Main experiment

4.1. Outline

According to the results obtained in preliminary experiment 1, significant differences were present when the thickness according to the visual information was 6 mm or more and the hardness evaluation was impacted. The value of 6 mm was therefore set as the suitable thickness for hardness evaluation in the main experiment. On the basis of the results obtained in preliminary experiment 2, furthermore, the colors of silicone rubber pieces were not changed for the main experiment, as the difference in the colors of samples used in the experiment had little influence on hardness evaluation. Silicone rubber pieces of 20 mm diameter, 6 mm thickness, and nine varying hardness values (i.e., 5, 10, 20, 30, 40, 50, 60, 70, and 80 degrees according to JI K6253a adopted as the standard) were prepared and test subjects were asked to evaluate them according to the details provided on the evaluation sheet for the paired comparison method consisting of ranking in scales of five levels. A total of 30 people, comprising 22 males and 8 females of ages 21 to 22, were asked to assist as test subjects.

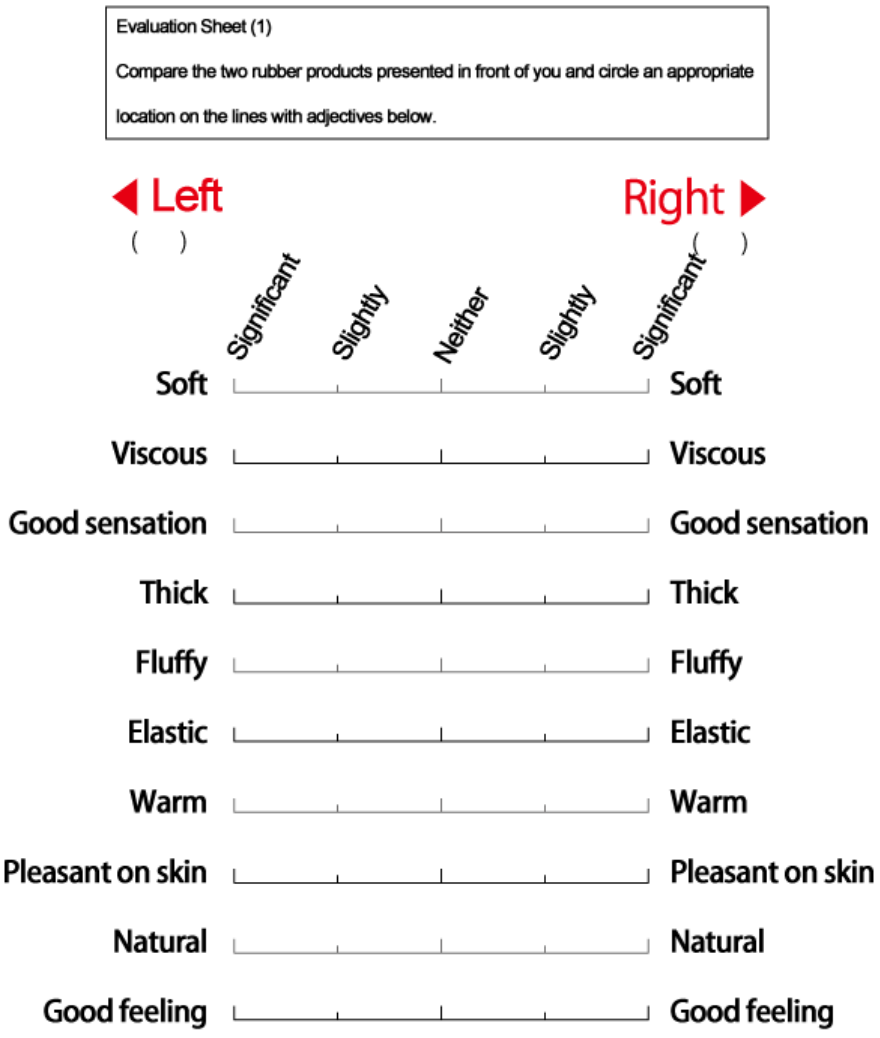

Figure 6: Evaluation sheet for the paired comparison method for experiment I (case with silicone rubber only)

4.2. Method

Since the application of silicone rubber in products can potentially manifest changes in hardness

evaluation, the experimental environment was split into two types, namely, the “case with silicone rubber only” and the “case with application on a push button switch,” to conduct the experiments. Furthermore, more test subjects used their index finger for evaluating the hardness than in preliminary experiment 1. In order to avoid the influence of how the hardness evaluation was performed, the test subjects were instructed to perform their evaluations on hardness by using the “index finger only,” as a restriction of the experiment. Furthermore, they were also asked to perform their evaluation of hardness with “push motion” only, as was the case with the preliminary experiments.

Experiment I (case with silicone rubber only): Test subjects were presented with pairs of silicone rubber pieces with varying hardness and were asked to touch the pieces, evaluate their hardness, and make their entries on the evaluation sheet for the paired comparison method, containing adjectives (Figure 6). Adjectives were considered to be associated with hardness evaluation based on tactile senses and ten adjectives, namely, “soft,” “viscous,” “good sensation,” “thick,” “fluffy,” “elastic,” “warm,” “pleasant on skin,” “natural,” and “good feeling,” were adopted. This process was conducted with all combinations of the nine possible hardness values of the silicone rubber pieces, or 9C2 = 36 patterns.

Experiment II: (case of application to push button switches): After experiment I was completed, a break of about 5 min was taken and then experiment II was started. Push button switches were presented to our test subjects two at a time in experiment II (Figure 5). These switch components were installed with silicone rubber, and as before, the test subjects were asked to touch them with their finger, evaluate the hardness, and make their entries in the evaluation sheet for the paired comparison method, containing adjectives. The adjectives comprised the ten types that were used in experiment I and that were associated with hardness evaluation. Further, two more adjectives, “good response” and “stable,” were added in consideration of the application of silicone rubber to products such as push button switches, thereby making the total number of adjectives to 12. Experiment II was also conducted with all combinations of the nine possible hardness values of the silicone rubber pieces, or 9C2 = 36 patterns.

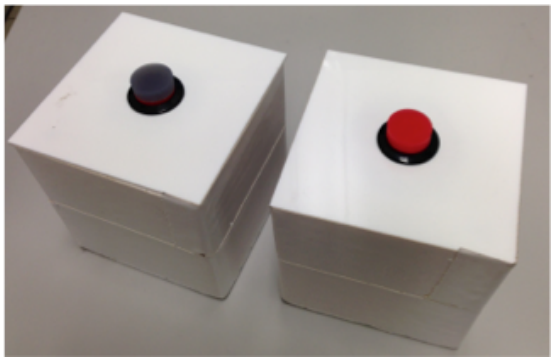

Figure 5: Push button switch

4.3. Results and considerations

In the case of experiment I with silicone rubber only, there was a declining trend in evaluations on the seven adjectives of “soft,” “viscous,” “good sensation,” “fluffy,” “elastic,” “warm,” and “good feeling” with increasing hardness. This implied that there was a trend for materials with lower hardness to be evaluated on the basis of these adjectives. On the other hand, the evaluation for the adjective of “thick” appeared to have an increasing trend with increasing hardness. These results

differed from those obtained in preliminary experiment 1, in which “those that were thicker were perceived as being softer.” This is believed to have been due to the influence of visual information, since the difference in thickness could be distinguished visually in the experimental environment for preliminary experiment 1. There was a decreasing trend with evaluations for the adjective of “natural” and “pleasant on skin” with increasing hardness to some extent, but this appeared to be contrary to this trend in some parts. This led us to conclude that when only information on hardness was available, these two adjectives did not show a concentrated evaluation trend. Furthermore, a binomial test was performed to verify significant differences in evaluations due to difference in hardness. The results revealed many significant differences in the cases of combinations involving silicone rubber pieces with a hardness of 50 degrees and lower. In cases of combinations where the hardness was 50 degrees or higher, however, a trend that no more significant differences appeared was observed. From these results, a hardness difference of at least 5 degrees was considered necessary for confirmation of any significant difference with evaluations owing to the difference in hardness. Furthermore, the difference in hardness was considered difficult when the hardness exceeded 60 degrees in the case of experiment I with silicone rubber pieces only.

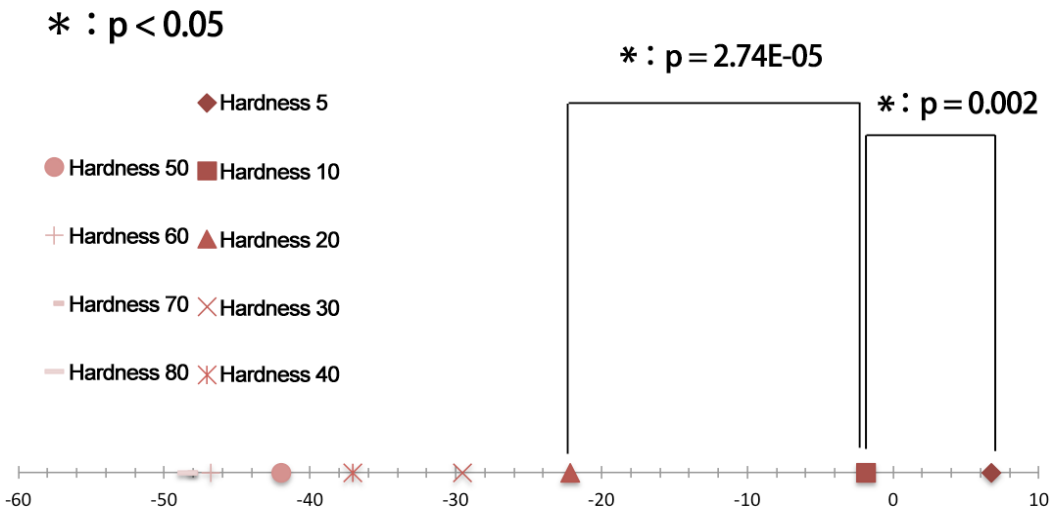

Figure 7: Analysis result example: plot of evaluation results for the adjective “soft”

Experiment II: A decreasing trend was observed in the evaluations with the eight adjectives of “soft,” “elastic,” “fluffy,” “viscous,” “warm,” “pleasant on skin,” “good feeling,” and “good sensation” with increasing hardness in the case with silicone rubber applied to switch buttons. This implied that there was a trend of evaluating materials with lower hardness on the basis of these adjectives. The evaluation for the three adjectives of “thick,” “good response,” and “stable,” on the other hand, appeared to have an increasing trend with increasing hardness. The results indicated that the evaluation of the adjective “thick” provided the same results as the trends of experiment I. The evaluations of the two adjectives “good response” and “stable” were considered to have resulted from the test subjects placing more weight on the evaluations of push button switches than evaluations of silicone rubber pieces. The evaluations of the adjective “natural” showed roughly the same trend as the results from experiment I. Furthermore, a binomial test was performed to verify significant differences in evaluations due to differences in hardness. The results revealed that many significant differences appeared in cases of combinations involving silicone rubber pieces with a

hardness of 60 degrees or lower, whereas the differences ceased to appear in cases of combinations involving silicone rubber pieces with a hardness of 60 degrees and higher. As a result, the difference in hardness was considered difficult to determine when the hardness exceeded 70 degrees in the case of experiment II with silicone rubber applied to switches. In comparison with the cases involving silicone rubber pieces only in experiment I, in the cases involving application of silicone rubber on switch buttons in experiment II, the boundary value for the emergence of a significant difference in evaluations was higher by 10 degrees. This led us to believe that the evaluations of the difference in hardness became more sensitive when silicone rubber was applied to products.

5. Conclusions and future issues

This research confirmed that the results of sensitivity evaluation varied according to differences in the hardness of silicone rubber pieces. The fact that visual information on the thickness of silicone rubber pieces influence the evaluations based on tactile sense was also confirmed.

When the hardness was 60 degrees or lower and if the difference was at least 5 degrees, the trend was that it was easy to distinguish the difference in hardness. The apparent trend was that the distinction of hardness became difficult when hardness was higher. When silicone rubber was applied to products such as push button switches, the sensitivity evaluation for products was performed in addition to the sensitivity evaluation for silicone rubber, increasing the number of items for the evaluation. Furthermore, the distinction of hardness was more sensitive in comparison with experiments involving silicone rubber pieces only. The fact that the difference in the hardness of flexible objects can become product values presents a potential for future applications with development of products using flexible objects such as silicone rubber.

In cases of comparison evaluations for silicone rubber pieces with identical hardness but different thickness, the pieces felt softer with a larger thickness during the experiments in this research. On the other hand, in cases of comparison evaluations for silicone rubber pieces with identical thickness but different hardness, the trend was that they felt thicker with more hardness. This was believed to have occurred owing to the mutual influence of visual information and tactile information and this needs to be examined further in the future [5], [6]. According to the results of these experiments, furthermore, some of the test subjects were conducting their evaluations with “stroking with finger” movements, in addition to “pushing with finger” movements during the evaluations for the adjective “pleasant to skin.” The evaluation for this adjective, therefore, was believed to have been conducted by evaluating the “quality of object” rather than “hardness of object,” and for that reason, it would be necessary to examine the differences in evaluation for materials other than silicone rubber as well in the future.

REFERENDES

[1]. Bergmann Tiest, W. M., & Kappers, A. (2009): Cues for haptic perception of compliance. Haptics, IEEE Transactions on, 2(4), 189–199.

[2]. Srinivasan, M. A., & LaMotte, R. H. (1995). Tactual discrimination of softness. Journal of Neurophysiology, 73(1), 88–101.

[3]. Takashi Irie, Hideo Nakanishi, Naofumi Fujita: Hardness Evaluation of Flexible Objects with Varying Thicknesses. the Journal of the Virtual Reality Society of Japan. Vol. 9. No. 1. pp. 27-34. 2004.

[4]. Satoko Yamakawa, Shinichi Matsuie: Influence of Color on Perception of Harness of Objects. the

Journal of the Virtual Reality Society of Japan. Vo. 16. No. 3. pp. 355-361. 2011.

[5]. Johnson, R. M., Burton, P. C., & Ro, T. (2006). Visually induced feelings of touch. Brain research, 1073, 398–406.

[6]. Kuschel, M., Buss, M., Freyberger, F., Farber, B., & Klatzky, R. L. (2008). Visual-haptic perception of compliance: fusion of visual and haptic information. In Haptic Interfaces for Virtual Environment and Teleoperator Systems, 2008. Haptics 2008. Symposium On (pp. 79–86).

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