Transmissibility of information through tactile perception

– The combination of material and shape to transmit the information

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Abstract: The purpose of present study was to clarify the relationship between the transmissibility of the information through tactile perception and the combination of materials and shape of a product. In order to make clear the transmissibility by the finger and the foot, two experiments were carried out. In the first experiment, the transmissibility of operation information using push button was discussed. The operation information was “on - off”, “low - middle - high” and “up - down”. There were nine kinds of button’s shape and four kinds of the materials; alloy of aluminum, poly methyl methacrylate, woof of *hoonoki* and foam polystyrene. The suitable samples to transmit the information were selected by the sighted and the visually impaired. In the second experiment, the transmissibility of information using tactile tiles was discussed. The information was as follows; “goal”, “for men”, “for women”, “up”, “down” and “danger”. Tactile tiles with eight kinds of raised parts were used as samples. Those were made of five kinds of materials; concrete, unsaturated polyester, silicon rubber, the alloy of aluminum and hardwood. The subjects were selected the most suitable sample for the information. Obtained data were analyzed using dual scaling method and Hayashi’s quantification theory I and II analysis. The results were summarized as follows:

(1) The shape of the buttons for “on - off” and “low - middle - high” greatly affected the transmissibility of the information, but the difference of material does not affect it.

(2) As for the button for “up - down”, the difference of material affected the transmissibility of the information.

(3) The combination of material and shape of raised part in tactile tile could transmit the information such as “danger”, “goal”, “for men” and “for women”.

***Key words*:** *Tactile perception, Information, Visually impaired*

1. Introduction

The sighted operate a product using visual information such as descriptions, illustrations and icons. For the visually impaired, there are many difficulties in daily life and their independence is restricted. It was reported that the most difficult products to operate for them were home electric appliances such as a microwave oven, a washing machine, an audio center, and so on [1]. Because of the flat and similar shape buttons, the visually impaired can not use them without beforehand instruction. Even the sighted operate a switch without visual information. Under such situation, it may cause operational errors or accidents. Although a large number of studies have been made on usability of the interface, little attention has been given to the transmissibility of

operational information without visual information. Almost all the studies about usability have been focused on shape of switches, and little attention has been given about the relationship between texture or material and operational information.

Furthermore, the visually impaired have more difficulty when they are traveling around. There are some assistive devices such as canes, tactile tiles and audible traffic signals. Especially, the tactile tile is effective for them. It has been discussed the relation of the probability and the easiness of cognition and the dimensions and patterns of raised parts of tactile tiles [2-4]. Although tactile tile is efficient, those do not indicate enough information for the visually impaired. It is the reason why tactile tiles indicate only two kinds of information: guidance and warning. Guidance tiles are used to indicate the direction of travel to be taken, and warning tiles are used to indicate a potential hazard or a junction. The visually impaired require tactile tiles to indicate more information [1]. Requirements from the visual impaired suggested that the necessity to transmit more information for operation or guiding intuitively.

In this study, we focus on tactile cognition for transmitting the information to prevent operational errors and accident. Therefore we aimed to clarify the effect of difference of shapes or materials on transmissibility of information. We carried out two kinds of subjective experiments. One was an experiment to clarify the possibility to transmit operational information using push buttons. The other was that to clarify the possibility to transmit guidance information using the tactile tiles. Finally, we discussed the transmissibility of information by the combination of the shape and materials of products.

2. Investigation of information to transmit

2.1. Required information to operate the home electric appliance

The indications used for eight kinds of home electric appliances were investigated to confirm indications of high priority of operational information. The home electric appliances were microwave oven (50 models), air conditioner (75 models), washing machine (43 models), rice cooker (90 models), electric fan (21 models), videotape recorder (16 models), vacuum cleaner (34 models) and facsimile (18 models). As the result, it was clarified that the highest frequency indications were “on – off” and “cancel”. Other high frequency indications were “start and stop”, “upper or lower temperature”, “menu” and so on.

2.2. Information transmissibility using tactile cognition by finger

In order to clarify the possibility of operational information transmissibility using tactile cognition of finger, subjective evaluation was carried out. Fourteen subjects aged from 19 to 25 participated in the experiment. Subjects evaluated the image of 33 kinds of materials using 30 paired of items without visual information (Fig.1). The materials used in this experiment were classified into seven groups; metals, plastics, leathers, rubbers, woods, foams and sandpapers. The obtained results were analyzed using factor analysis. As the result, six factors were extracted and the cumulative ratio was 85.1% [5]. The main three factors were identified “opposite operation”, “selective operation with adjusted level” and “continuous operation”.

2.3. Required information by the tactile tiles

Although wide range of information was required for tactile tiles from the visually impaired, we considered that the number of information to indicate using tiles should be limited. That was the reason why it would be easier and suitable to transmit information. The required information for tactile tiles was investigated using questionnaire. Forty two visually impaired persons replied the questionnaire. As the result, the required information for tactile

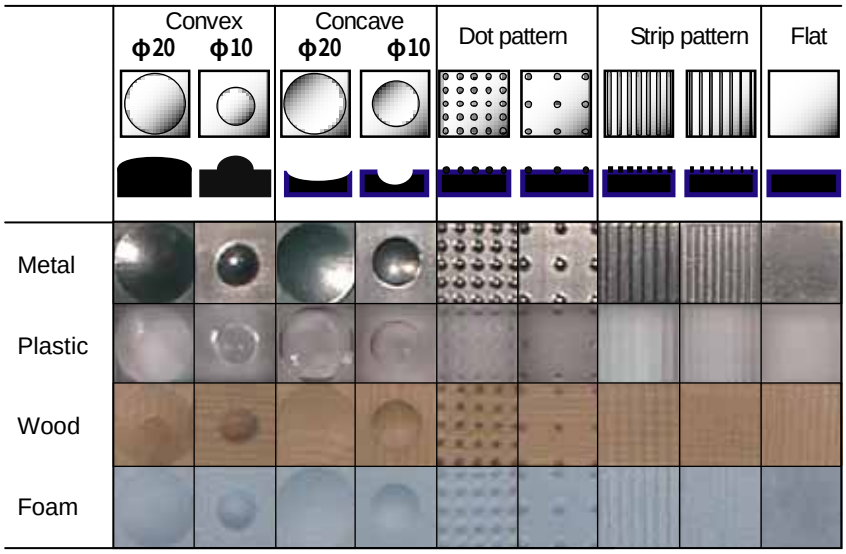


Fig.1 Shapes and materials of experimental samples

tiles can be classified into four: “goal”, “gender”, “direction” and “forbidden” [6]. “Goal” is the information to indicate one’s destination such as a bus stop and a railway station. “Gender” is information to indicate a divided room for men or for women such as a lavatory, a locker room and a dressing room. “Direction” is information to indicate where the front of upstairs or downstairs is. “Forbidden” is information to indicate a danger place such as an edge of platform or in front of a construction site.

3. Method

3.1. Selection of suitable combination of shape and material for push button to transmit the operational information (Experiment 1)

As shown in Fig. 1, nine types of shape were used as samples in this experiment. The samples were made of four kinds of material; alloy of aluminum (metal), Poly methyl methacrylate (plastic), Wood *of Hoonoki*: *Magnolia obovata* Thunb (wood), and foam polystyrene (foam). The size of the button was 20×20 mm. Ten sighted persons and 12 visual impaired persons participated in this experiment. The average age of the visually impaired and the sighted were from 24.4 yr and 23.3yr, respectively. The sighted used eye mask blindfold when they evaluated the samples to avoid the effect of visual information. The operational information to transmit was four kinds of information: “on – off”, “low – middle – high”, “up the volume – down the volume” and “up the temperature – down the temperature”. The subjects selected the suitable samples for the operational information without visual information. Obtained results were summarized into frequency table, and then analyzed using the dual scaling method. The effect of the shape and the material of the button on transmissibility of the operational information was analyzed using Hayashi’s quantification theory II.

3.2 Selection of suitable shape, material and the combination of those for tactile tile to indicate information

(1) Effect of material (Experiment 2):

The purpose of this experiment was to clarify the effect of differences of materials on easiness of cognition and suitableness for guidance information. Tactile tiles for guidance and warning were made of alloy of aluminum, unsaturated polyester, hard wood, and silicon rubber. Nine sighted persons and 11 visual impaired persons participated in the experiment. All the subjects used the same blind cane and same kinds of shoes. Subjects

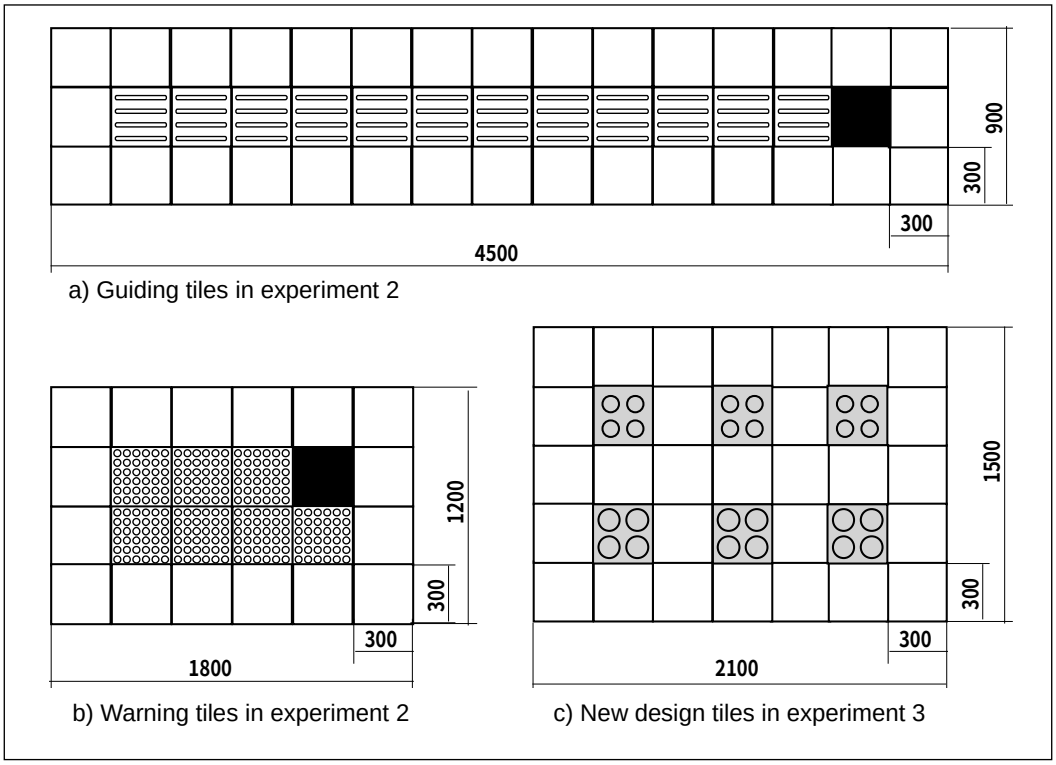


Fig.2 Layout pattern of experimental tiles (unit in mm)

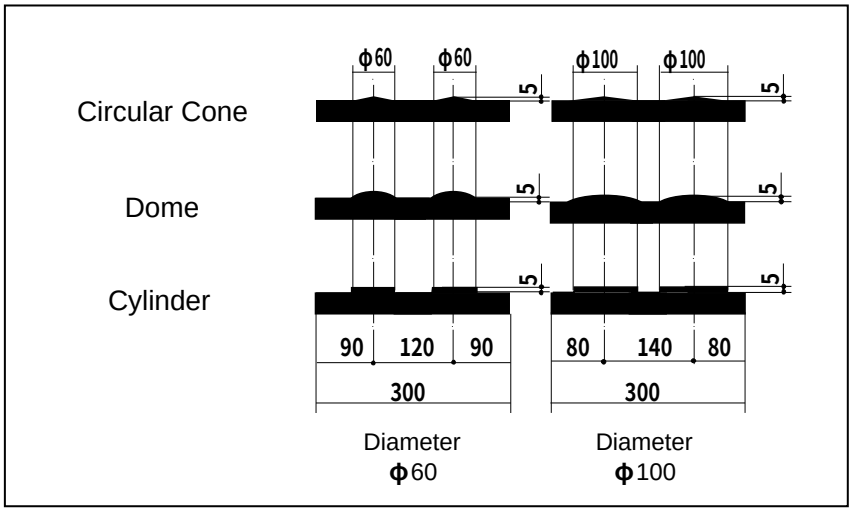


Fig.3 Shapes of raised part and patterns of experimental tiles (unit in mm)

compared the easiness of cognition of the tiles with existing concrete tile. Subsequently, subjects evaluated the suitableness of tiles to indicate guiding and warning. The layout patterns of experimental tiles are shown in Fig.2-a) and b).

(2) Effect of shape of the raised parts (Experiment 3):

The purpose of the experiment was to clarify the relationship between shape of raised parts and the suitableness for the guiding information. The subjects selected the most suitable tile to indicate the following six kinds of information: “goal”, “for men”, “for women”, “up”, “down” and “danger”. As samples, six types of raised part were prepared as shown in Fig. 3. There were three types of raised parts; circular conic shape, dome shape and cylinder shape. The size of tile was 300×300 mm and the height of raised parts was 5 mm [2]. We used

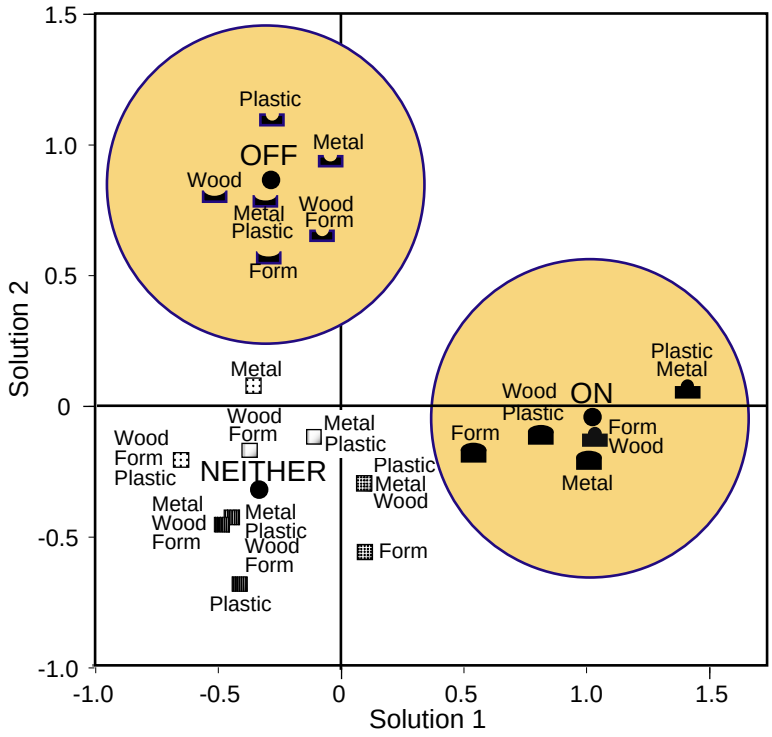


Fig.4 Scatter diagram of optimal weighted vectors between solution 1 and 2

concrete as material and did not paint tiles for the purpose of removing the effects of elasticity [3]. Figure 2-c) indicates the layout pattern of experimental tiles.

(3) Effect of combination of material and shape of raised parts (Experiment 4):

From the result of experiment 3, the most suitable shapes of the raised parts for the information were used in this experiment. The tiles were made of four kinds of materials as we mentioned in experiment 2. The subjects selected the most suitable combination of them to transmit the information. Obtained results were analyzed by dual scaling method. The relationship between both the shape and the material of the tile and transmissibility of the information was investigated using Hayashi's quantification theory I.

4. Results and discussion

4.1. Suitableness of the combination shape and material to operational information

Figure 4 indicates the suitableness of samples for the information: "on - off". These plots are the optimal weighted vectors obtained by dual scaling method. The samples placed near "on" are suitable to transmit the information "on". All of the samples near "on" have convex shape button, but all of samples near "off" have concave shape. The diagram shows the result of evaluation by the sighted, however, that by the visually impaired was quite similar.

4.2. Contribution of shape and material to the transmissibility of operational information

In order to clarify the effect of the shape and the material on transmissibility of the information using Hayashi's quantification theory II analysis, the optimal weighted vectors should be converted into categorical data. It was regarded as the suitable samples for "on" and "off" were within each hatched circle as shown in Fig.4. The radius of the circle was defined 40% of the distance between furthest distance operations by trial and error.

Table 1 shows the range of category scores obtained by Hayashi's quantification theory II analysis. The range of category scores shows how each factor contributes to the information transmissibility. In the case of the

Table 1 Range of category scores by Hayashi's quantification theory II

Operation	The sighted		The visally impaired	
	Shape	Material	Shape	Material
On	0.464	0.098	0.939	0.335
Off	1.000	0.036	0.487	0.192
High	1.000	0.141	0.682	0.034
Middle - low	0.622	0.353	1.000	0.473
Up/ Down Volume	0.945	0.572	0.901	0.470
Up/ Down Temperature	0.790	0.815	0.799	0.357

information: "on – off", the ranges of shape were much larger than those of material. This result indicates that the shape is dominant over material for transmissibility of the information: "on – off". On the other hand, in the case of the information: "up the temperature – down the temperature", the range of "shape" was 1.97, and that of 'material' was 1.95. This result shows both of shape and material affected the transmissibility of the information.

4.3. Suitable combination of the shape and the material to transmit the operational information

Table 2 shows partial correlation coefficients, range of category scores, and category scores in the case of the information: "up the temperature – down the temperature" for the sighted. The most suitable combination of the shape and the material is predicted by the values of the category scores. The largest value of "shape" is 0.48 for "convex" and "dense dot pattern", and that of "material" is 0.56 for foam. It means that the most suitable button to indicate the information: "higher temperature" should be made of form with convex shape or dense dot pattern. On the other hand, the smallest value of "shape" is -1.48 for "sparse dot pattern", and that of "material" is -1.39 for metal. It means the most suitable button to indicate the information: "down the temperature" should be made of metal with concave shape. Figure 5 shows the most suitable combination of shape and material to the information by the category scores. Obtained results can be summarized as follows;

(1) In the case of the opposite operation: "on – off", both the sighted and the visually impaired judged the

Table 2 Suitable combination of shape and material by category scores of design factor by Hayashi's quantification theory II

	Category	Partial correlation coefficient	Range	Category score
Shape	convex	0.790	1.966	0.484
				0.311
	concave			0.067
				-1.147
	Dot pattern			0.484
				-1.482
	Stripe pattern			0.327
				0.374
	plane			-0.276
Material	Metal	0.815	1.949	-1.389
	Plastic			-0.006
	Wood			0.372
	Form			0.560

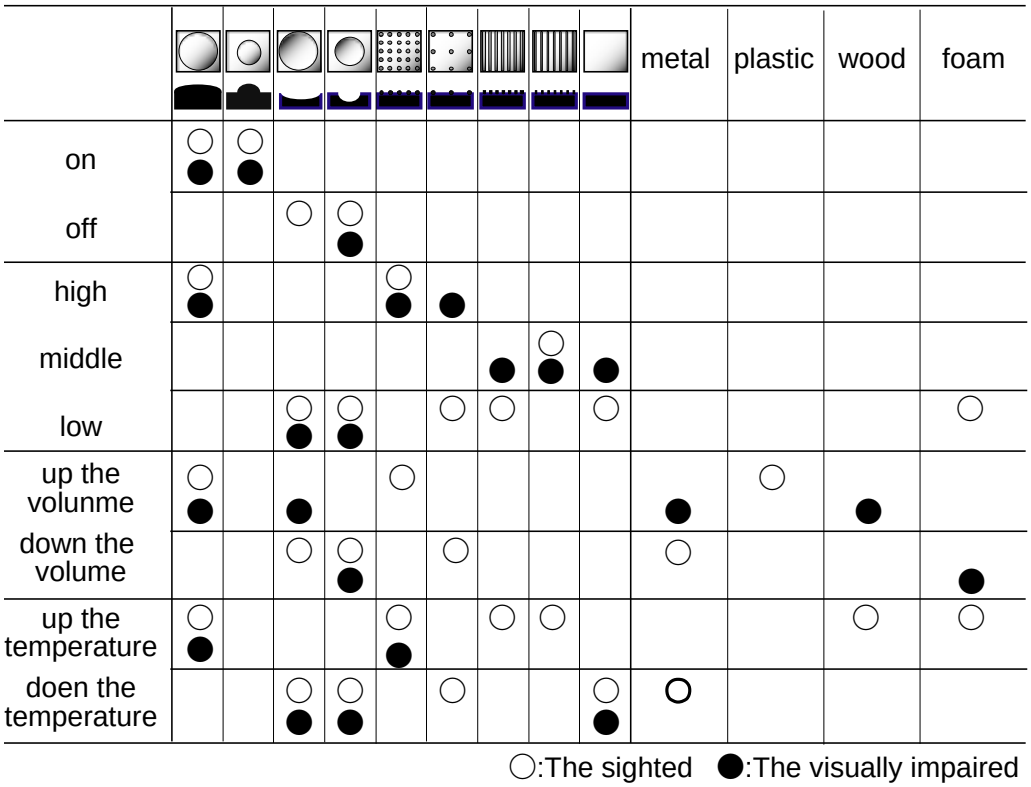


Fig. 5 Suitable combination of shape and material based on category scores

operation corresponding to concavo-convex shape.

(2) In the case of the selective operation: "low – middle – high", concavo-convex shape was selected as most suitable shape to indicate the information by both of the sighted and the visually impaired. However, it was suggested that the difference of dot pattern density may be effective to indicate the selective operation for the sighted.

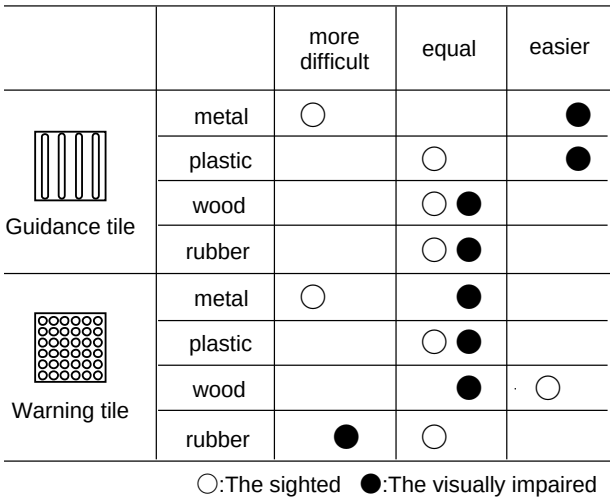


Fig. 6 Difference of easiness of cognition with the difference of materials

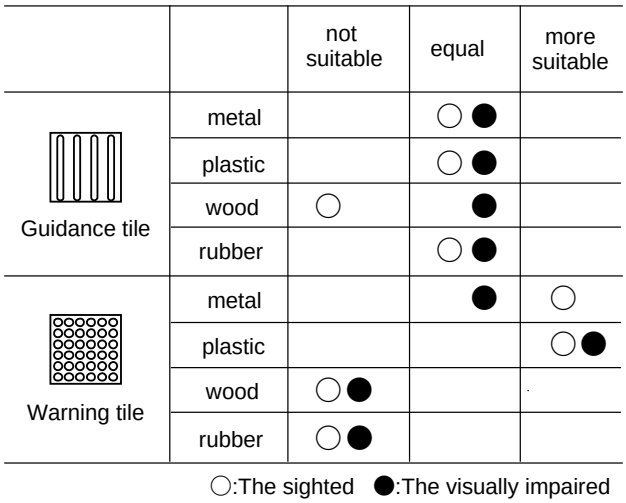


Fig. 7 Difference of Suitableness for information with the difference of material

(3) In the case of the continuous operation: “up the temperature – down the temperature”, the sighted judged the information correspondent to the concavo-convex shape and the density of dot, but the visually impaired did not judged it correspondent to density of dot.

(4) In the case of the continuous operation: ‘up the volume – down the volume’, both the sighted and the visually impaired judged the information correspondent to concavo-convex shape. However, only the sighted judged it correspondent to warm- cool sense of material.

4.4. Effect of the difference of tile materials on easiness of cognition

As the result of experimental 2, it was clear that the easiness of cognition by difference of tile materials (Fig. 6). The visually impaired judged that the guidance tiles made of metal and plastic were easier to recognize than that made of concrete. In addition, they judged warning tile made of rubber was more difficult to recognize than that made of concrete. This result means that the visually impaired judge the harder tiles are easier to recognize. On the other hand, the sighted judged that the warning tile made of wood was easier to recognize, but that made of metal was more difficult. These results indicate the difference of the easiness of cognition between the sighted and the visually impaired.

4.5. Effect of the difference of tile materials on suitableness for the information

Figure 7 shows the relationship between the suitableness to indicate guidance or warning and the difference of materials. Both of the sighted and the visually impaired judged the warning tile made of plastic to be most suitable for warning. Furthermore, the warning tiles made of wood and rubber were judged to be not suitable. These results indicate that the suitableness of the tile for information is not correspondent to the easiness of cognition. It was suggested that not only tactile cognition with feet but also cognition of the sound with blind cane relate to the information transmissibility using tactile tiles.

4.6. The suitable shape of raised parts to indicate information

In experiment 3, the subjects selected the most suitable tiles to indicate the following information: “goal”, “for men”, “for women”, “up”, “down” and “danger”. Except for the information to indicate “for men”, the circular conic shape was selected as the most suitable. The reason is that circular cone was the easiest shape to recognize by feet. In other words, this result suggested that the tactile tiles should be easy to recognize. While it was obtained that the dome shape was the most suitable to indicate “for men” and “goal”. This result also suggested

Table 3 Suitable combination of shape and material to indicate "danger" (for the visually impaired)

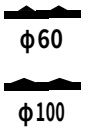
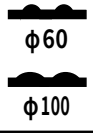
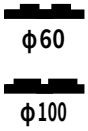
The visually impaired	Category		Partial correlation coefficient	Range	Category score
Shape	circular cone		0.824	1.556	-0.407 1.148
	dome				-0.407 0.370
	cylinder				-0.407 -0.296
Material	metal plastic wood rubber		0.802	2.500	1.375 0.000 -0.250 -1.125

Table 4 Suitable combination of shape and material to indicate "goal" (for the visually impaired)

The visually impaired	Category		Partial correlation coefficient	Range	Category score
Shape	circular cone		0.351	0.667	-0.037 0.296
	dome				-0.148 0.296
	cylinder				-0.370 -0.037
Material	metal plastic wood rubber		0.870	2.625	-1.125 -0.500 0.125 1.500

that the criterion of judgment could be produced in the case of opposite information: "for men – for women". In addition, some of subjects told us, "Tile indicating "for male" should be felt larger than that female". It agreed with the result.

4.7. The suitable material to indicate information

In experiment 4, tactile tiles with the most suitable shape to indicate the information were made of four kinds of materials: “metal, plastic, wood and rubber”. The tile made of metal was judged as the most suitable material to indicate the information: “danger” and “for men”. While the tile made of rubber was judged to indicate the information: “goal” and “for women”. In the case of information: “up – down”, the sighted selected metal tiles as the most suitable, however, the visual impaired selected rubber tiles. This result suggested that the reminded image from the hardness of material is different between the sighted and the visually impaired.

4.8. The suitable combination of shape and material to indicate information

Table 3 shows the most suitable combination of the shape and the material for the sighted to indicate the information: “danger”. In this case, the range of category scores of the shape and the material are 1.56 and 2.50, respectively. It means that the difference of material affect on the transmissibility of the information. Similar result was obtained in the case of the sighted. From the category scores, it was clarified the most suitable tile to indicate each information. The most suitable tiles to indicate “danger” are metal tiles with circular cone of 100mm diameter (Table 3), also that to indicate “goal” is a tile made of rubber with circular cone or dome of 100mm diameter (Table 4).

5. Conclusions

The purpose of this paper was to clarify the effect of shape and material on transmissibility of information. As the results of two kinds of experiments, the effect of shape and material on information transmissibility was clarified quantitatively. Obtained results indicate that the difference of material is effective for transmissibility of information, and suggested the possibility to transmit information intuitively by changing the texture of a product.

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