Study of Haptics and Tactile Sense of the Direction of Movement

Sakae Yamamoto[1(✉)], Yukiko Yokomizo[2], and Daiji Kobayashi[3]

[1] Tokyo University of Science, Tokyo, Japan
sakae@ms.kagu.tus.ac.jp
[2] Tokyo Metropolitan University, Tokyo, Japan
mogeta3159@gmail.com
[3] Citose Institute of Technology, Chitose, Hokkaido, Japan
daiji.kobayashi@dream.com

Abstract. The operating tool is not mentioned for the case of a location cannot be directly confirmed visually. In above cases, by that people touch the operation tools at our fingertips, its direction can be confirmed. This paper was focused onto the touch, in other words, tactile and haptic. When the operator touches the operation device, for example, button, switch, etc. It is possible to understand of the direction of its movement of machine (equipment) from texture information of device obtained from the operation of the tactile device. From this, when performing multiple operations at the same time, and also the working conditions it is difficult to be confirmed an operation device in the eye, it is to aim to reduce operation errors. The experimental study was done. Tow impression are found as follows; the raise-get down and positive rotation – negative rotation. It has been proven that there is an association between directionality and textural sense of materials.

Keywords: Haptics · Tactile · Direction of operation · Direction of movement

1 Introduction

In recent years, users have been required to perform multiple tasks simultaneously when operating a machine or system. For example, some drivers may be required to shift gears using a button located on the back side of the steering wheel to operate a car navigation system while driving. In such situations, it is difficult or impossible to confirm every single operating device visually.

Hence, for the purpose of such confirmation, touch sense support may be incorporated into the machine. In this case, it is necessary to work on the design of buttons and device surfaces. In other words, touch support is a means of providing a different type of information. In the operation of a machine or system, the functions that this information represents, and, in particular, to which direction of movement such functions lead is important. However, it is often dangerous when driving a car to confirm the functions of various operational devices by checking what results they cause.

S. Yamamoto (Ed.): HIMI 2015, Part I, LNCS 9172, pp. 477–487, 2015.
DOI: 10.1007/978-3-319-20612-7_46

For direction of movement, an international standard is provided by ISO1503: Spatial orientation and direction of movement-Ergonomic requirements. Therefore, industrial operating tool products have to be manufactured in compliance with this standard in relation to the direction of movement. Operating tools that do not comply with the standard are difficult to operate and even can lead to dangerous situations in some cases.

The objective of this study is to clarify how the texture of a button may convey the resulting direction of movement of a machine or system just by touching it. It is desirable to convey such information to the operator. In particular, touching an operating tool with a finger may be contribute an important interface.

It may result in activating touch sense among the five human senses. Studies on touch sense have been performed for centuries but many of them have been physiological such as those by Katz (1925) and Iwamura (2001). Furthermore, there have been applicative studies relating to braille and tactual mapping as well. It is believed that even sighted people may be able to enhance their certainty while simplifying operation through use of the tactile sense. In this study, we performed basic research toward the development of operational interfaces based on touch. Specifically, we examined whether operational or movement direction of a machine or system may be properly extracted from the textural information conveyed by touching operating tools with a finger.

Therefore, we considered sense of direction according to pairs of antonymic directional adjectives to indicate directionality as shown in ISO1503. In addition, we examined how kinetic sensation is felt by the tactile sense.

As a preliminary experiment, we prepared buttons whose surfaces were coated with plain rubber (n = 10), felt (n = 5), silicon rubber (n = 22 ± 0.4), stockings (n = 5), polyurethane (n = 24.6 ± 4.72). Test subjects were made to operate each button, and their tactile sensation was examined. As a result, six types of subjective reactions regarding directionality were extracted:

Clockwise/Counterclockwise
Upward/Downward
Forward/Backward
Forward/Backward tilting
Straight line/Diagonal
Advance/Retreat (Progress/Regress)

In addition, nine pairs of words were obtained regarding the feeling of pressing on the button:

Detectable by pressing once/Detectable by pressing repeatedly.

Fast/Slow
Warm/Cold
Strong /Weak
Low/High
Automated/ Manual
Frozen /Chilled
Soft/Hard
Clear/Confused

We believe that on the basis of our results, it may be possible to provide information to enhance operational support and safety by examining the association between the textural sense of the button and directionality.

2 Purpose

In this study, we clarify the association between the functions of a button and the sensations evoked by difference in textures of button material. In particular, we would like to clarify the association between directionality and impressions from haptic sense.

3 Experiments

The touch senses are divided into Tactile and Haptics at the described above.

In Experiment 1, we examined whether touching way of both tactile and haptic is good. In Experiment 2, using a good touch way, to examine the relationship between the movement direction and material.

3.1 Experiment 1: Experimental Test of Detectability of Differences in Texture Using Different Ways of Tactile and Haptics

In general, the touching motion is roughly divided into two actions: pressing (tactile) and rubbing (haptic) by a finger. In the experiment 1, we determine whether "pressing" or "rubbing" allows greater detectability of differences in texture in the case where the evaluation target is a button.

3.2 Experiment Methods

The test subjects were 21 students (male 16 and female 5) with a mean age of 21.7 and a standard deviation of 0.82. They were asked to press or rub reference button and stimulus buttons on which different materials coated without looking at them. The reference button was placed on the left and the stimulus buttons were placed on the right. Subjects were instructed to touch the buttons with the index finger of their dominant hand, allowing repeated touch during the experiment. After touching the reference button and each of the stimulus buttons once, they were asked to respond which way of touching –pressing or rubbing– was more effective for detecting the differences of materials on a 5-point scale, as shown in Fig. 1. The case where pressing was more detectable was defined as "+ and that where rubbing was more detectable was defined as –". Every experiment was performed with two buttons made of polyurethane, felt, and plain rubber; so six patterns of experiment were performed in total. The combinations of the materials in these experiments are listed in Table 1.

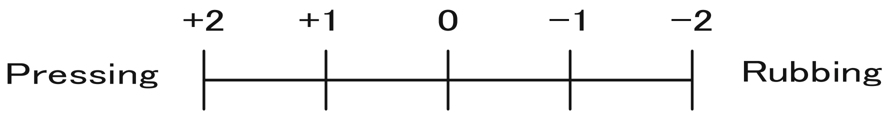

Fig. 1. Example of questionnaire

Table 1. Combinations of materials

Combination No.	Reference switch	Stimulus switch
1	Polyurethane	Felt
2	Polyurethane	Plain rubber
3	Felt	Polyurethane
4	Felt	Plain rubber
5	Plain rubber	Polyurethane
6	Plain rubber	Felt

3.3 Materials Used in the Experiments

Three types of materials – polyurethane (Exseal, Pit Cushion PC-16), felt (Ambic, Feltace, K-7 301) and plain rubber (Matech, 123-41) – were affixed to push buttons (Miyama Electric, DS660R-C(R)). Buttons with polyurethane, felt, and plain rubber applied are shown in Figs. 2, 3, 4. applied.

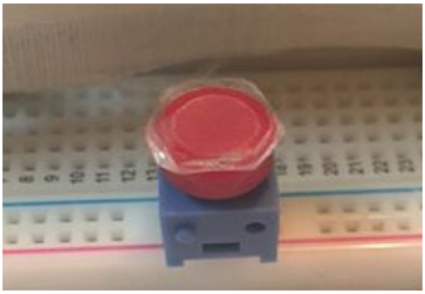

Fig. 2. Button with polyurethane

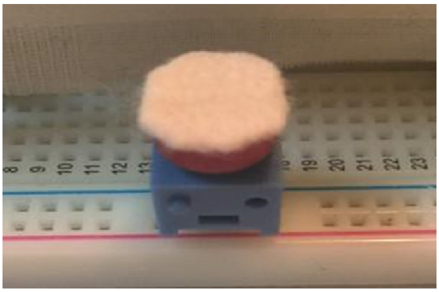

Fig. 3. Button with felt applied

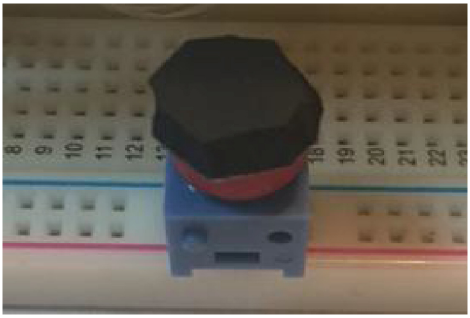

Fig. 4. Button with plain rubber applied

3.4 Experimental Device

An experimental device that incorporated the buttons was prepared using polystyrene boards (85 × 90 × 70) as the outer frame, and the inside of the device was hidden with a cloth curtain (Fig. 5). Furthermore, by combining breadboard (CIXI WANJIE ELECTRONICS, 0BB-801), jumper cord (CIXI WANJIE ELECTRONICS, BBJ-20), cord with a compact chip (AVVICON ELECTRONIC CORPORATION, MC-761), a AAAA×3 battery holder with lead wire (TAKACHI, MP- 4-3), and 5 mm red LED for 5 V with a built-in resistor (OptoSupply, OSR6LU5B64A-5 V), the LED was set to flash with the pressing of a button. Figure 6 shows inside of the experimental device.

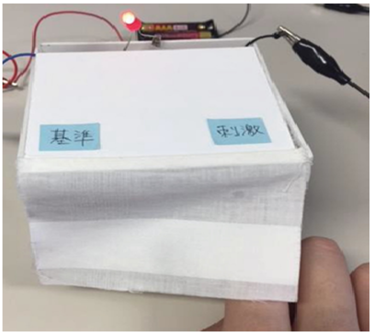

Fig. 5. Experimental device

3.5 Results

The sum of the evaluation points for all subjects is shown in Table 2.

3.6 Discussion

As Table 2 shows, the values of subjective reaction are negative under all combinations, suggesting that difference in materials is more detectable by rubbing rather than

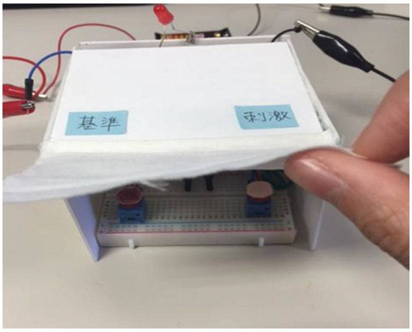

Fig. 6. Inside of the experimental device

Table 2. Evaluation by all subjects

Combination No.	Evaluation points
1	-33
2	-3
3	-35
4	-16
5	-8
6	-27
Sum	-122

pressing. We also observed the LED during the experiments, and it did not flash, even though the object of the experiments was the button. In other words, the results were obtained simply by touching, rather than by pressing.

Combinations 2 and 5 include plain rubber and polyurethane. In a comparison between softness (plain rubber) and a hard and slippery surface (polyurethane), it was proved that the sensory difference is smaller when touching than it is when rubbing. It is understood that the difference in textural sense at the time of touching the surface before pressing is more difficult to detect than in other cases.

On the basis of this result, we decided to make subjects identify differences in button surface through a haptics motion.

4 Experiment 2: Experimental Test of the Association Between Different Textures and Impressions of Directionality and Function

In response to the result of experiment 1 (described in Sect. 3), another experiment was performed to clarify what impressions the different textures conveyed regarding function and directionality of motion.

4.1 Experimental Method

Subjects were 30 students (male 25 and female 5) with a mean age of 22.4 and a standard deviation of 2.33. Using buttons covered with three types of materials as described above, the experiment was performed using pair comparison method (revised Scheffe's method). Methods of switch layout and the like were the same as those in the experiment 1, described in Sect. 3.

Subjects, for the same items as in Experiment 1, have been asked to answer their impression by the comparing with two buttons. In this experiment, subjects were touched button by using a repeatedly haptics to compare. A major factor estimation was obtained by analysis of the variance of resulted the questionnaire.

4.2 Pairs of Question Items

In the questionnaire, subjects were asked to rate stimulus switches on scales pertaining to six directional impressions.:

Clockwise /Counterclockwise, Upward/Downward, Forward/Backward,
Forward/Backward tilting, Straight line/Diagonal,
Advance/Retreat (Progress/Regress)

In addition, pair words regarding material characteristics were also provided, including the following nine items of paired questions:

Detectable by pressing once/Detectable by pressing repeatedly,
Fast/Slow, Warm/Cold, Strong/ Weak, High/Low, Automated/Manual
Frozen/Chilled, Soft/Hard, Clear/Confused

4.3 Results

From analysis of variance on the reaction results, significant differences were observed in major effects, and the number of question items that could be ignored was 11 in total. Of those 11 items, two were about directionality, seven were about the impression of the function, and two were about the switch itself. The results of the variance analysis are shown in Tables 3, 4, 5.

Table 3. The table of analysis of variance for Positive rotation-Negative rotation

Factor	Sum of Squares	Degree of freedom	Mean Squares	F0	Test result
α	16.411	2	8.206	9.95	***
α (k)	103.589	58	1.786	2.166	***
β	0.272	1	0.272	0.33	ns
σ	0.05	1	0.05	0.061	ns
o (k)	28.283	29	0.975	1.183	ns
ε	73.394	89	0.825		
τ	222	180		*** : p < 0.01	

Table 4. Directional property estimated value of each item

Combination of directionality/motion	Plain rubber	Felt	Poly-urethane	Test result
Clockwise/ Counterclockwise	–0.094	–0.150	0.244	***
Upward/Downward	–0.033	–0.172	0.206	**
Forward/Backward	0.033	–0.172	0.206	**
Forward/Backward tilting	–0.028	–0.122	0.150	Interaction
Diagonal/Straight line	0.078	0.424	–0.267	***
Advance/Return (Progress/Reverse)	–0.078	–0.167	0.222	*** (Interaction)

***: $p < 0.01$, **: $p < 0.05$

Table 5. Estimated value of textural sense

Combination of directionality/motion	Plain rubber	Felt	Poly-urethane	Test result
Press repeatedly/ Press once	0.36	–0.16	–0.19	***
Fast/Slow	–0.16	–0.16	0.32	***
Warm/Cold	0.08	0.40	–0.48	***
Strong/Weak	–0.01	–0.24	0.24	***
High/Low	–0.01	–0.19	0.21	***
Automated/Manual	–0.01	–0.25	0.26	***
Frozen/Chilled	–0.17	–0.07	0.23	***
Soft/Hard	0.47	0.24	-0.71	***
Clear/Confused	–0.12	–0.32	0.44	***

***: $p < 0.01$

4.4 Discussion

As these results were obtained by performing separate pair comparisons, we attempted to obtain their correlation by combining directionality and textural sense. The results are shown as follows: (Tables 6, 7, 8, 9, 10).

Here, directionality was examined for just five items, excluding the "forward/backward tilting" pair because this pair resulted in a strong interaction between the major effects and the individual. Those items with higher negative correlation were also omitted because we considered distinguishability as well as operability. Therefore, the examination was limited to the same directionality of the impression, leaving negative correlations as a problem to be considered in the future.

Since materials are considered to be suitable if they provide a sense of fast or slow for rotation and a sense of clear or confused from these results, we determined that the combination of polyurethane and plain rubber is excellent from the perspectives of directionality and textural sense. We concluded that polyurethane is suitable for use in a positive direction (in this case clockwise) and plain rubber is suitable for use in moving in a negative direction (in this case counterclockwise).

Table 6. Major factors, test results and coefficient of rotation and textural sense of each material.

Major factor estimate value of each material					
Directionality/Motion type	Plain rubber	Felt	Polyurethane	Test result	
Rotation (Clockwise/ Counterclockwise)	-0.09	-0.15	0.24	***	
Major factor estimate value of each material					
Pair of quality	Plain rubber	Felt	Polyurethane	Test result	Correlation coefficient
Fast/Slow	-0.16	-0.16	0.32	***	0.991
Clear/Confused	-0.12	-0.32	0.44	***	0.993

***: $p<0.01$

Table 7. Major Factors, test results, and correlation coefficient of upward/downward and textural sense of each material.

Major factor estimate value of each material					
Directionality/Motion type	Plain rubber	Felt	Poly-urethane	Test result	
Upward/ Downward	-0.03	-0.17	0.21	**	
Major factor estimate value of each material					
Pair of quality	Plain rubber	Felt	Polyurethan	Test result	Correlation coefficient
Strong/Weak	-0.006	-0.239	0.244	***	0.991
High/Low	-0.011	-0.194	0.206	***	0.995
Automated/ Manual	-0.006	-0.25	0.256	***	0.991
Clear/Confused	-0.122	-0.317	0.439	***	0.993

**: p<0/05, ***: $p<0.01$

Table 8. Major factors, test results, and correlation coefficient of forward/backward and textural sense of each material.

Major factor estimate value of each material					
Directionality/ Motion type	Plain rubber	Felt	Poly-urethane	Test result	
Forward/ Backward	0.03	-0.17	0.21	**	
Major factor estimate value of each material					
Pair of quality	Plain rubber	Felt	Poly-urethane	Test result	Correlation coefficient
Strong/Weak	-0.01	-0.24	0.24	***	0.998
High/Low	-0.01	-0.19	0.21	***	0.995
Automated/ Manual	-0.01	-0.25	0.26	***	0.998

In case of other directions, the result was the same as that for rotation. However, in the case of diagonal or straight lines, we showed that it is effective to assign felt to the positive direction (in this case clockwise) and polyurethane to the negative direction (in this case counterclockwise) to provide a sense of warmth or coldness.

Table 9. Major factors, test results and correlation coefficients of diagonal/straight line and textural sense of each material.

Major factor estimate value of each material					
Directionality/ Motion type	Plain rubber	Felt	Poly-urethane	Test result	
Diagonal/ Straight line	0.078	0.424	-0.267	***	
Major factor estimate value of each material					
Pair of quality	Plain rubber	Felt	Poly-urethane	Test result	Correlation coefficient
Warm/Cold	0.078	0.400	-0.478	***	0.988

Table 10. Major factors, test results, and correlation coefficients of advancing/retreating direction and textural sense of each material.

Major factor estimate value of each material					
Directionality/ Motion type	Plain rubber	Felt	Poly-urethane	Test result	
Advance/ Return (Progress/ Reverse)	-0.078	-0.167	0.222	*** (Interaction)	
Major factor estimate value of each material					
Directionality/ Motion type	Plain rubber	Felt	Poly-urethane	Test result	
Fast/Slow	-0.161	-0.161	0.322	* * *	0.976
Clear/ Confused	-0.122	-0.317	0.439	* * *	1.000

This result may be considered reliable because the material is easy for humans to accept. It is necessary to incorporate such considerations into designs.

Furthermore, in the context of virtual reality (VR), it is necessary to consider what types of sensations should be given to humans to suggest directions of movement. Some may be of the opinion that just considering the asperity of a surface is enough; however, humans must accept certain stimulation to perform operations. Therefore, the textural sense of a material becomes a crucial factor. In ISO 1503, directionality in human motion management is standardized for use in product design. Nevertheless, some products do not comply with this standard. Since certain directions tend to be accepted by humans on the basis of certain textures, operating tools that that imply such directions are demanded. However, it is important to select materials carefully in such cases.

From 30 types (30 pairs) of textural sense of materials selected at an early phase depending on personal experiences, we narrowed to six types (six pairs) by directionality. Moreover, textural senses were also narrowed down to nine items (nine pairs). In consideration of diverse reactions in humans, we do not believe that what we have done is sufficient. It is necessary to undertake further examination by increasing the number of items. However, whether these same reactions are also observed in people other than the Japanese has not been examined, and will be considered later. In addition, even though quantification of stimulation is necessary, we believe it is necessary to perform basic research to determine whether there is any association between directional sense and textural sense.

5 Summary

It has been proven that there is an association between directionality and textural sense of materials. From these findings, it is believed that such an association may be applied to directionality in the design of new switches and the VR world.

References

Katz, D.: Der Aufbau der Tastwelt. Verlag von Johann Ambrosius Barth, Leipzig (1925). translated Japanese by Higashiyama, A., Iwakiri, K., Shinyousha, Tokyo, Japan (2003)
Iwamura, Y.: Touch (Japanese). Igakushoin, Tokyo, Japan (2001)