Development of Tactile Materials Representing Human Basic Tactile Sensations

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Abstract: Tactile sensation is known as one of important factors in the design of various products. The most characteristic feature of tactile sensation is a diversity of perceptual contents. This study proposes standardized materials, jointly developed with a company, which comprehend human basic tactile sensations. In previous studies subjective evaluations of tactile sensations were quantified using several pairs of adjective words regarding material properties. However, it is debatable whether the pairs of adjectives are capable of richly expressing variations of tactile sensations. To solve this problem, this study focuses on Japanese onomatopoeic words such as "sara-sara" meaning "soft and smooth sensation in touch as a new index of tactile sensation category. Japanese is known to have a large number of onomatopoeic words for touch and systematic associations between the phonemes of the onomatopoeia and typical categories of tactile sensations have been observed. In this study, professionals in Linguistics and Psychology selected tactile materials associated with a variety of onomatopoeic words frequently used for expressing tactile sensations. We succeeded in developing 50 standardized tactile materials which cover major tactile sensation categories.

Key words: Tactile Sensation, Material Developing, Tactile Onomatopoeia, Linguistics, Psychology

1. Introduction

Human perceives the physical properties of materials or textures by touching their surfaces (Jones & Lederman [5], Lederman & Klatzky [6]). Tactile sensation of materials is known as an important factor in the design of various products. The most characteristic feature of tactile sensation is a diversity of perceptual contents. There are many researches on identifying major factors in human tactile perception. However, the basic tactile factors reported by previous studies have varied depending on the method of psychological experiments and the stimuli used in the experiments.

Okamoto et al. [9] summarizes previous researches on psychophysical dimensions of tactile perception as follows. Yohida [21] used 25 materials in the experiment and described a mixture of hard/soft, cold/warm, and rough/smooth dimensions, a mixture of moist/dry and rough/smooth dimensions, and hard/soft dimension. Lyne et al. [7] used 8 tissues and paper towels in the experiment and extracted three dimensions such as surface softness, rigidity, and embossed properties. Hollins et al. [3][4] used 17 materials including paper, plastic, and velvet and extracted perceptual dimensions such as rough/smooth, warm/cold, sticky/slippery, and hard/soft. Picard et al. [11] used 24 car seats and Picard et al. [12] used 40 fabrics and extracted hard/soft and rough/smooth. Soufflet et al.

[17] used 26 fabrics and extracted three dimensions such as rough/smooth, hard/soft, and warm/cold. Shirado & Maeno [16] used 20 materials and extracted extracted 4 factors such as rough/smooth, cold/warm, moist/wet and hard/soft. Bergman-Tiest & Kappers [1] used 124 materials and extracted 4 dimensions such as hard/soft, rough/smooth and the other unspecified factors. Summers et al. [18] used 10 papers and described rough/smooth factor. Guest et al. [2] used 15 fluids and extracted three factors such as slippery/sticky, rough/smooth, and oily, while in the other experiment using 5 fabrics they extracted three factors such as rough/smooth, most/dry, and hard/soft. The overview of previous studies shows that basic tactile factors have varied depending on the stimuli used in the experiments. We believe that the reason why the number and the kinds of materials used in experiments have varied is that appropriate comprehensive kind and number of materials to be used in experiments is unknown. However, findings through experiments using arbitrarily selected materials and hard to replay may be incomplete. Therefore, our study proposes standardized materials jointly developed with a company, which represent human basic tactile sensations. Experiments using the materials proposed in this study can be replayed anytime and anywhere in the world.

Our method to develop the materials is unique in using Japanese onomatopoeia such as “sara-sara” expressing soft and smooth sensation in touch. In the most of previous studies, overviewed above, subjective evaluations of tactile sensations have been quantified using several pairs of adjective words regarding material properties such as rough or smooth. This method is called the semantic differential (SD) method. SD method was originally established by Osgood et al. [10]. According to Okamoto et al. [9], the method was first applied to the study of the dimensionality of tactile perception by Yoshida [21]. Since then, a number of researchers employed this method. In an SD method, participants rate materials one by one using scales whose ends represent the two adjectives in an opposing pair such as “rough” and “smooth”. Five or seven grades are used in many cases. While SD methods allow us to interpret fundamental tactile factors, they have limitations. Fundamental factors that would be extracted through SD methods are limited by the adjective pairs used in experiments. If adjective labels that represent a certain perceptual dimension are not involved, the perceptual dimension would never be extracted. Therefore, given that the number of adjectives for tactile sensations is limited, it is debatable whether the pairs of adjectives are capable of richly expressing variations of tactile sensations.

To solve this problem, this study focuses on onomatopoeic words as a new index of tactile sensation category. It is known that the sensory-sound correspondence can be found not only in words referring to visual shapes, which were demonstrated in the landmark studies (e.g., mal/mil and buba/kiki for round and sharp shapes in Sapir [15] and Ramachandran & Hubbard [13] respectively), but also in those referring to tactile, smell, and taste sensations. In addition, Japanese is known to have a large number of onomatopoeic words for tactile sensations. However, the majority of studies in the area of sound symbolism have been limited to visual-sound correspondence. In contrast, we are investigating the sound symbolic associations in touch. We found associations between the phonemes of Japanese onomatopoeic words and typical categories of tactile sensations. For example, onomatopoeic words expressing a sense of smoothness often use the consonant /s/ in the first syllable as in “sara-sara,” while those expressing roughness often use /z/ in the first syllable as in “zara-zara.” Similarly, characteristic first consonants are observed in each of the tactile categories, such as /h/ for softness as in “huwa-huwa” and /k/ for hardness as in “kori-kori.” Furthermore Watanabe et al. [19] proposes a novel method for classifying sensations derived from touching objects using onomatopoeic words in Japanese. The method generates a distribution diagram of the onomatopoeic words on the basis of subjective impressions of the words, and it enables users to arrange and

compare the tactile textures on the diagram. In this study, assuming that onomatopoeic words cover whole range of human tactile sensations, we develop tactile materials associated with a variety of onomatopoeic words frequently used for expressing tactile sensations.

2. Method

2.1 Selection of Onomatopoeia Covering Japanese Phonemes

Our method focuses on the sound symbolic association between phonemes of Japanese onomatopoeia and tactile sensations in order to develop tactile materials covering human basic tactile sensations. Therefore, it is better that onomatopoeias to be used include all kinds of phonemes. Fast of all, we combined all sounds in Japanese syllabary from the first sound /a/ to the last sound /n/, and created two-mora expressions (/aa/, /ai/, …, /wan/, /nn/). This is because 87.1% of onomatopoeic words participants answered as those associated with tactile sensations in our previous experiments (Watanabe et al. [20]) was two-more expressions (e.g. “sara-sara”). We obtained 11,075 words as those made by repeating two-mora onomatopoeic expressions (e.g., /aa-aa/, /ai-ai/). Moeover we added 3,509 words with all types of special phonemes such as /huwari/ and /peQtari/. Second, among those 14,584 words we selected 307 words, which were judged by 3 experts as tactile onomatopoeic expressions. We confirmed that the selected 307 words covered all kinds of phonemes.

2.2 Extraction of Basic Tactile Onomatopoeias

307 onomatopoeic words were tested by using Google search queries. Google search was conducted on 6th July 2012 using Windows 7 Internet Explorer. Top 43 search results were selected as indexes to develop tactile materials to cover major tactile sensation categories. 43 tactile onomatopoeic expressions are listed in Table 1 with English translations and examples. Translations are authors’. Onomatopoeia as shown in Table 1 is very short and simple, but associated with very rich information to be expressed by a combination of two or more adjectives. Onomatopoeia differentiates various tactile sensations which are similar to each other. For example, “huwa-huwa” and “mohu-mohu” both express soft and fluffy touch, but “huwa-huwa” is more associated with lightness, while “mohu-mohu” is more associated with warmness.

Table 1. 43 Tactile Onomatopoeic Expressions

Onomatopoeias	Explanations (examples)	Onomatopoeias	Explanations(examples)
sara-sara	dry and smooth	pasa-pasa	dry and powdery
tsuru-tsuru	slippery and smooth	huni-huni	soft and limp
sube-sube	smooth, silky, velvet hand	puri-puri	springy and soft
huwa-huwa	soft, light, and fluffy	kishi-kishi	creak ex. hair creaks.
zara-zara	texture of coarse paper	husa-husa	bushy and rich ex. feather
gowa-gowa	coarse and stiff sheets	chiku-chiku	ex. the undershirt scratches
gotsu-gotsu	rugged and scraggy rock	mohu-mohu	fluffy, warm ex. blanket
mochi-mochi	skin like a rich cake	howa-howa	fluff of clouds
poko-poko	texture like bubbling water	puru-puru	soft and elastic

beta-beta	grisly and sticky	shari-shari	crunch crunch
moko-moko	lumpy and fluffy surface	peta-peta	pasty
huka-huka	soft and fluffy	gishi-gishi	strongly creaking
gasa-gasa	dry and rough skin	beto-beto	sticky and greasy
nuru-nuru	slimy	jori-jori	ex. mustache
suru-suru	smooth	nume-nume	smooth, slimy and shining
kasa-kasa	desiccated skin	tsubu-tsubu	dots on the surface
shaka-shaka	mixture of smooth and rough textures	zaku-zaku	crunch through the snow
gunya-gunya	limp and soft	shori-shori	crispy and light
puni-puni	squishy, but comfortable	sawa-sawa	rustling
kori-kori	crunchy	mosa-mosa	sluggish
butsu-butsu	pimples on the surface	hunya-hunya	soft, flaccid and weak
boko-boko	uneven and nubby		

2.3 Developing Tactile Materials Based on 43 Onomatopoeias

5 professionals (including authors) in linguistics and psychology with many experiences in tactile psychophysical experiments matched 43 selected onomatopoeias with 120 candidates of tactile materials. Those 120 candidates have been used in psychophysical experiments of previous studies (Watanabe & Sakamoto [14], Ohkura et al. [8]) and their effectiveness has been verified. Jointly with a company (Takei scientific instruments Co., Ltd) we developed standardized materials uniquely associated with 43 onomatopoeic expressions.

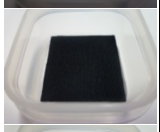
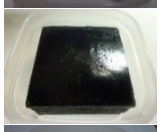
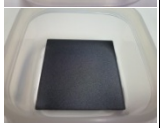
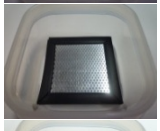
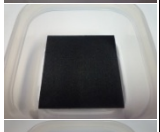
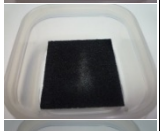
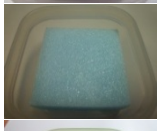
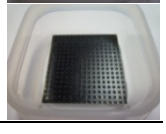
3. Results

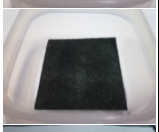
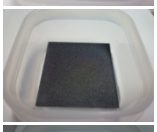
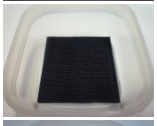
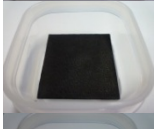
Through 3 times of modifications of prototypes we succeeded in developing 50 standardized tactile materials representing 43 onomatopoeia that are associated with major tactile sensation categories. Table 2 shows the developed materials with specifications of materials and corresponding onomatopoeias.

4. Conclusions

This study focused on Japanese onomatopoeic words as a new index of tactile sensation category, and proposes 50 standardized tactile materials jointly developed with a company, which represent human basic tactile sensations. 50 materials developed in this study are expected to be used in studies on haptics and designs related to human tactile perceptions. Furthermore, our method using the association between tactile materials and onomatopoeic expressions can be used to differentiate each sample among specific materials such as papers, clothes, and glasses. There are, for example, papers with various textures, but if you use onomatopoeias, you can easily categorize the papers into those associated with “sara-sara” texture, those with “tsuru-tsuru” texture, those with “sube-sube” texture, those with “zara-zara” texture, those “shori-shori” texture, and so on. We hope that the materials proposed in this study and our method using onomatopoeia will contribute to a wide range of design researches.

Table 2. 50 tactile materials with specifications of materials and corresponding onomatopoeias

No	Onomatopoeia	Material	Image	No	Onomatopoeia	Material	Image
1	sara-sara	Paper		15	poko-poko	Iron plate with holes φ6mm	
2		Cotton hemp fabric		16	beta-beta	Adhesive tape	
3		Black alumite sheet		17	moko-moko	Low-elasticity urethane foam	
4	tsuru-tsuru	Acrylic sheet		18	fuka-fuka	Wool fabric	
5		Glass sheet		19	gasa-gasa	Scourer	
6		Black nickel sheet		20	nuru-nuru	Vaseline	
7	sube-sube	Aluminum sheet		21	suru-suru	Iron plate with holes φ1mm	
8		Silk fabric		22		Snake leather	
9	fuwa-fuwa	Mouton fabric		23	kasa-kasa	Heat insulator	
10	zara-zara	Sand paper #80		24	syaka-syaka	Polystyrene foam	
11		Stone		25	gunya-gunya	Slime	
12	gowa-gowa	Artificial turf		26	puni-puni	Gel gems	
13	gotsu-gotsu	Pebble		27	kori-kori	Gel and ball	
14	mochi-mochi	Low-elasticity soft sheet		28	butsu-butsu	Dot sheet	

No	Onomatopoeia	Material	Image	No	Onomatopoeia	Material	Image
29	book-boko	Vibration-proof rubber		40	peta-peta	Gel sheet	
30	pasa-pasa	Dry leather		41	gishi-gishi	Sandpaper #240	
31	funi-funi	Skin-like gel		42	beto-beto	Soft gel sheet	
32	puri-puri	Hard slime		43	jyori-jyori	Magic tape	
33	kishi-kishi	Sandpaper #600		44	nume-nume	Paste	
34	fusa-fusa	Fake fur		45	tsubu-tsubu	Beads	
35	chiku-chiku	Wire-brush		46	zaku-zaku	Unit turf	
36	mofu-mofu	Cotton		47	syori-syori	Japanese paper	
37	howa-howa	Mouton leather		48	sawa-sawa	Suede (Reverse)	
38	puru-puru	Soft slime		49	mosa-mosa	Carpet	
39	syari-syari	Gourd scrubbing brush		50	funya-funya	Flexible rubber	

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6. References

[1] Bergman -Tiest, W. M. and Kappers, A. M. L. (2010) *Analysis of haptic perception of materials by multidimensional scaling and physical measurements of roughness and compressibility*, Acta Psychologica, vol. 121, no. 1, pp. 1-20.

[2] Guest, S., Dessirier, J. M., Mehrabyan, A., McGlone, F., Essick, G., Gescheider, G. Fontane, A., Xiong, R., Ackerley, R. and Blot, K. (2011) *The development and validation of sensory and emotional scales of touch perception*, Attention, Perception & Psychophysics, vol. 73, pp. 531-550.

[3] Hollins, M., Bensmaïa, S., Karlof, K. and Young, F. (2000) *Individual differences in perceptual space for tactile textures: Evidence from multidimensional scaling*, Perception and Psychophysics, 62, pp. 1534-1544.

[4] Hollins,M., Faldowski, R., Rao, S., and Young, F. (1993) *Perceptual dimensions of tactile surface texture: A multidimensional scaling analysis*, Perception and Psychophysics, 54, pp. 697-705.

[5] Jones, L. A. and Lederman, S. J. (2006) Human hand function, Oxford University Press.

[6] Lederman, S. J. and Klatzky, R. L. (2009) *Haptic perception: a tutorial*, Attention, Perception & Psychophysics, vol. 71, no. 7, pp. 1439-1459.

[7] Lyne, M. B., Whiteman, A. and Donderi, D. C. (1984) *Multidimentional scaling of tissue quality*, Pulp and Paper Canada, vol. 85, no. 10, pp. 43-50.

[8] Ohkura, N., Komatsu, T., Osaka, S. and Sakamoto, M. (2012) Systematic Study on Kapaii Products (The Fourteenth Report) – Basic Study of "Kawaii Tactile Sensation" using Tactile Materials -, Human Communication Group Symposium 2012 HCG2012-III-7-5, pp. 414-419. (In Japanese)

[9] Okamoto, S., Nagano, H. and Yamada, Y. (2013) *Psychophysical Dimensions of Tactile Perception of Textures*, IEEE Transaction on Haptics, vol. 6, issue, 1.

[10] Osgood, C. E., Suci, G. J. and Tannenbaum, P. H. (1957) The measurement of meaning, University of Illinois Press.

[11] Picard, D., Dacremont, C., Valentin, D. and Giboreau, A. (2003) *Perceptual dimensions of tactile Texture,*. Acta Psychologica, 114, pp. 165-184.

[12] Picard, D., Dacremont, G., Valentin, D. and Giboreau, A. (2004) *About the salient perceptual dimensions of tactile textures space*, In S. Ballesteros and M. A. Heller, eds. Touch, Blindness, and Neuroscience, pp.

[13] Ramachandran, V. S. and Hubbard, E. M. (2001) *Synaesthesia -A window into perception, thought, and language,* Journal of Consciousness Studies, 8, pp. 3-34.

[14] Sakamoto, M. and Watanabe, J. (2012) Tactile Onomatopoeia Affects Tactile-Emotional Evaluations, In Proceedings of the 29th Annual Meeting of the Japanese Cognitive Science Society, pp. 627-629. (In Japanese)

[15] Sapir, E. (1929). *A study of phonetic symbolism*, Journal of Experimental Psychology, 12, pp. 225-239.

[16] Shirado, H. and Maeno, T. (2005) *Modeling of human texture perception for tactile displays and sensors*, In Proceedings of the 2005 World Haptics Conference, pp. 629-630.

[17] Soufflet, I., Calonnier, M. and Dacremont, C. (2004) *A comparison between industrial experts and novices haptic perceptual organization: a tool to identify descriptors of the handle of fabrics*, Food Quality and Preference, vol. 15, pp. 689-699.

[18] Summers, I. R., Irwin, R. J., Brady, A. C. and Grunwald, M. (2008) *Haptic discrimination of paper*, Human Haptic Perceptions: Basics and Applications 1st Edition, pp. 525-535.

[19] Watanabe, J., Hayakawa, T., Matsui, S., Kano, A., Shimizu, Y. and Maki Sakamoto(2012) *Visualization of Tactile Material Relationships Using Sound Symbolic Words*, In P. Isokoski and J. Springare eds. EuroHaptics 2012, Part II, LNCS 7283, pp. 175-180. Springer, Heidelberg.

[20] Watanabe, J., Utsunomiya, Y., Tsukurimichi, H. and Sakamoto, M. (2012) *Relationship between Phonemes and Tactile-emotional Evaluations in Japanese Sound Symbolic Words*, In Proceedings of the 34th Annual Meeting of the Cognitive Science Society (CogSci2012), pp. 2517-2522.

[21] Yohida, M. (1968) Dimension of tactual impressions (2), Japanese Psychological Research, vol. 10, vo. 4, pp. 157-173.