A System to Visualize Tactile Perceptual Space of Young and Old People

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Abstract

Sound symbolic words are known to exhibit synesthetic associations between sounds and sensory experience. We constructed a system that visualizes the relationship between sound symbolic words and standardized tactile materials on the tactile perceptual space map. The system enables us to compare the affective tactile evaluations of young people with old people.

Introduction

Humans can perceive surface textures and material properties through the sense of touch, and the tactile modality is considered to play an important role in evaluations in daily experience. In the psychophysical domain, a large body of literature deals with tactile perceptual dimensions (Hollins et al. 1993; Hollins et al. 2000; Picard et al. 2003; Gescheider et al. 2005; Bergmann Tiest et al. 2006; Chen et al. 2009; Okamoto, Nagano, and Yamada 2013). However, very few stud-ies have paid attention to the perceptual space in touch of old people. In the current study, we propose a method to compare tactile perceptual space of young people with old people and pay more attention to affective tactile perception of old people. Analyzing how tactile materials are mapped into words could be an effective way to investigate human perceptual space. Sound symbolic words (hereafter, SSWs) are known to exhibit synesthetic associations between sounds and sensory experiences. Against a classical notion in linguistics that speech sounds and meanings of words are independent, the existence of synesthetic associations between sounds and sensory experiences (sound symbolism) has been demonstrated over the decades (Sapir 1929; Ramachandran and Hubbard 2001). It is known that Japanese SSWs evoke strong and systematic sensory-sound associations, and the phonemes of Japanese SSWs may characterize categories of tactile sensations. For example, “basa-basa” and “pasa-pasa” are different only in one sound /b/ or /p/. The difference in only one sound can convey a critical difference in affective evaluations of textures. Therefore, we use Japanese SSWs to compare the affective tactile evaluations of young people with old people.

System Construction

A System for Evaluating Tactile Feelings Expressed by Sound Symbolic Words

The tactile rating scales include 26 pairs of adjectives appropriate for evaluating the texture perceptions of objects, such as “warm - cool”, “thick - thin”, “smooth - rough”, and “wet - dry”. The 26 pairs of adjectives given in Table 1 were extracted from previous studies related to tactile sensation (Doizaki, Watanabe, and Sakamoto 2014). These scales were used in our psychological experiment described below and then applied in the system.

Our method calculates subjective impressions of onomatopoeia on the basis of the impressions evoked by each phoneme. Therefore, the experimental stimuli are required to include all varieties of Japanese phonemes, that is, basic phonemes (consonants /C/ and vowels /V/) as well as special phonemes (syllabic nasals /N/, choked sounds /Q/, long vowels /R/, and adverbs ending in /ri/). We created various combinations of sounds to consider the effects of sound order, that is, to investigate whether first-syllable and second-syllable phonemes could evoke different subjective impressions (e.g., between “kasa” and “saka”). First, we combined all sounds in the Japanese syllabary (from /a/ to /n/) and then created two-syllable expressions (i.e., /aa/,

/ai/, . . . , /wan/, /nn/). We obtained a total of 11,075 words, including those made by repeating two-syllable onomatopoeic expressions (e.g., /aa-aa/, /ai-ai/). Moreover, we added 3,509 words with all types of special phonemes, such as /fuwari/ and /peQtari/. Second, from these 14,584 words, we selected 312 words that were judged by three participants as onomatopoeic expressions for describing texture sensations. The selected 312 words used as stimuli covered every possible kind of phoneme.

Table 1. 26 Tactile rating scales

warm - cool	wet - dry
thick - thin	heavy - light
easy - uneasy	firm - fragile
good - bad	slippery - sticky
impressive - unimpressive	sharp - dull
comfortable - uncomfortable	elastic - nonelastic
hard - soft	strong - weak
regular - irregular	bumpy - flat
clean - dirty	smooth - rough
individual - typical	stretch - nonstretch
cheerful - gloomy	intense - calm
natural - artificial	luxury - cheap
friendly - unfriendly	repulsive- nonrepulsive

Using the experimental stimuli, we conducted an impression-rating experiment (using the SD method) in which we measured the actual value of the relationship between phonological features and impression ratings to create a quantitative rating database. The participants consisted of 78 native Japanese speakers aged 20 to 24 (51 males and 27 females) who were presented with onomatopoeic expressions that conveyed tactile feelings as well as tactile rating scales for evaluation. Using a seven-point SD scale (Very comfortable +3, Comfortable +2, Slightly comfortable +1, Neither 0, and three levels, -1 to -3, for uncomfortable feeling), the subjects responded in regard to what extent they felt each word related to each scale. The questionnaire form used in the experiment presented the stimuli at random. Since the participants were divided into six groups of 13, the calculations included 13 people per an onomatopoeic expression. Thus, each participant gave their impressions of about 52 onomatopoeic expressions chosen from 312 expressions. They were unaware of the purpose of the experiments, and they had no knowledge about linguistics. They were not trained to answer this type of questionnaire so that they simply answered intuitively their impressions.

The experiment produced 105,456 items of data (26 rating scales × 312 expressions × 13 participants). Then, we calculated the average rating value for each scale multiplied by each expression. On the basis of the hypothesis that tactile feelings associated with onomatopoeic expressions can be determined by the sound symbolism of each expression, we created an impression-rating predictive model according to the format below. The following equation can express the degree of impact, the type of consonants, and the presence or absence of voiced or semi-voiced sounds, especially in regards to the impression created by the expression as a quantity. Furthermore, it will provide a predictive value as a linear sum of the constituents.

$$\hat{Y} = \frac{X_1 + X_2 + X_3 + \cdots + X_{11} + X_{12} + X_{13}}{the\ number\ of\ morae} \quad (1)$$

Where $\hat{Y}$ represents a predictive rating value of onomatopoeia on a certain rating scale. $X_1 - X_{13}$ represent the category quantity (the degree of the impact each phoneme has on the predictive rating value) for each phoneme. $X_1 - X_6$ respectively represent the consonant category, voiced/semi-voiced, palatalized, lower case vowel, vowel and medial indicator for the first mora, and $X_7 - X_{12}$ respectively represent the consonant category, voiced/semi-voiced, palatalized, lower case vowel, vowel, and end of a word indicator for the second mora ("mora" means a minimum size of a sound unit in Japanese). X_{13} represents the presence or absence of repetitions. The detailed correspondences between variables and phonemes are shown in Table 2.

Table 2. Correspondences between Variables and Phonemes

First mora	**Second mora**	**Phonological characteristics**	**Phonemes**
X_1	X_7	consonants	/k/, /s/, /t/, /n/, /h/, /m/, /y/, /r/, /w/ or absence
X_2	X_8	voiced sounds / p-sounds	presence or absence
X_3	X_9	contracted sounds	presence or absence
X_4	X_{10}	vowels	/a/, /i/, /u/, /e/, /o/
X_5	X_{11}	semi-vowels	/a/, /i/, /u/, /e/, /o/ or absence
X_6	X_{12}	special sounds	/N/, /Q/, /R/, /Li/ or absence
X_{13}		repetition	presence or absence

Table 3. Examples of Category Quantities for Rating Scales

Rating scales	**First mora**				
	Consonants			**Voiced / p-sounds**	
	/k/	/t/	/h/	voiced	p -
warm - cool	0.16	0.21	-0.28	0.18	-0.13
hard - soft	-0.82	-0.07	0.29	-0.39	0.48
wet - dry	0.62	-0.74	0.49	-0.46	-0.68
slippery - sticky	-0.19	0.04	-0.18	0.62	-0.15
bumpy - flat	-0.06	0.31	0.13	-0.68	-0.22

As shown in Table 3, the results of the quantification theory I analysis include the average predictive rating value given to the category quantity for each scale. In addition, the rating value for each onomatopoetic expression could be determined by totaling the category values for each phoneme in the expression. The multiple correlation coefficients R between the predicted values and average rating values (actual values) were used as an indicator of prediction accuracy. As a result, for 20 scales, the R values were in the range of 0.8 to 0.9, while for the other 6 scales, the R values were 0.9 or higher. Therefore, we considered our model to be sufficient for estimating onomatopoeia impressions to be evaluated by humans.

Using the above results, we constructed a system that estimates users' tactile feelings expressed by input onomatopoeic words and quantitatively presents the estimated tactile feelings on the 26 tactile rating scales. Our system comprises a user interface module, an onomatopoeia parsing module, and a database. Figures 1 and 2 show examples of the results output by our system. These examples confirm that our system can evaluate the subtle difference in characteristics of tactile feelings expressed by onomatopoeic words which are different in one phoneme "s" vs "z". Figure 1 shows that onomatopoeia "sara-sara" is strongly associated with "thin", "clean", "dry", "light", "slippery" and "nonelastic" feelings. On the other hand, Figure 2 shows that onomatopoeia "zara-zara" is strongly associated with "impressive", "hard", "dry", "nonelastic", "rough", "nonstretch" and "intense" feelings.

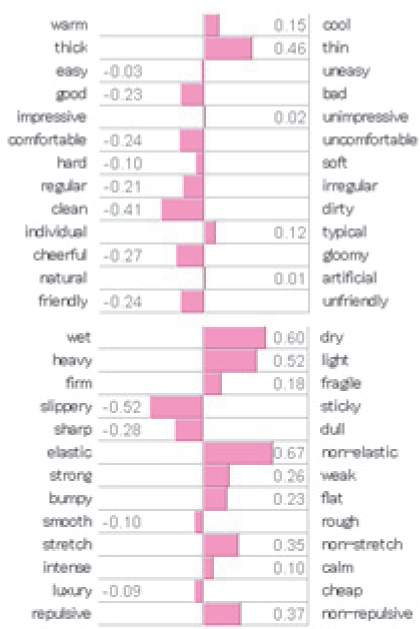

Fig. 1. *An evaluation result of onomatopoeia "sara-sara"*

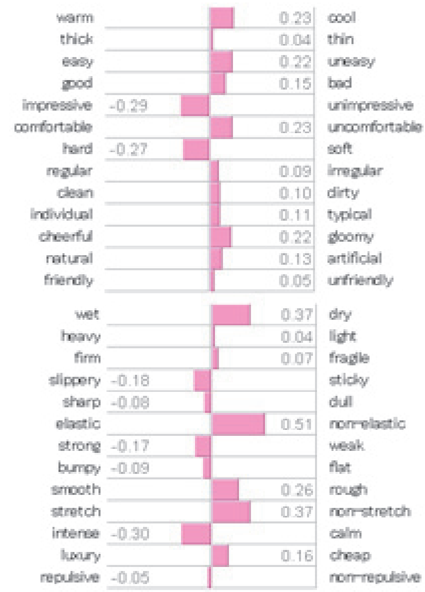

Fig. 2. *An evaluation result of onomatopoeia "zara-zara"*

A System to Visualize Tactile Perceptual Space

First, we decided to use 43 SSWs shown in Table 4 to visualize tactile perceptual space (Sakamoto, Yoshino, and Watanabe 2013). Sakamoto, Yoshino and Watanabe (2013) selected 307 words that were judged by 3 experts as tactile SSWs and confirmed that the selected 307 words covered all kinds of Japanese phonemes. 307 SSWs were tested by using Google search queries. Google search was conducted on 6th July 2012 using Windows 8 Internet Explorer. Top 43 research results were selected as indexes to develop tactile materials to cover major tactile sensation categories.

Table 4. 43 sound symbolic words

sara-sara	kasa-kasa	puru-puru
tsuru-tsuru	syaka-syaka	syari-syari
sube-sube	gunya-gunya	peta-peta
fuwa-fuwa	puni-puni	gishi-gishi
zara-zara	kori-kori	beto-beto
gowa-gowa	butsu-butsu	jyori-jyori
gotsu-gotsu	boko-boko	nume-nume
mochi-mochi	pasa-pasa	tsubutsubu
poko-poko	funi-funi	zaku-zaku
beta-beta	puri-puri	syori-syori
moko-moko	kishi-kishi	sawa-sawa
fuka-fuka	fusa-fusa	mosa-mosa
gasa-gasa	chiku-chiku	funya-funya
nuru-nuru	mofu-mofu	
suru-suru	howa-howa	

Then, we have analyzed 43 SSWs by the system above. Fig.3, Fig.4 and Fig.5 show the examples of evaluation results of SSWs.

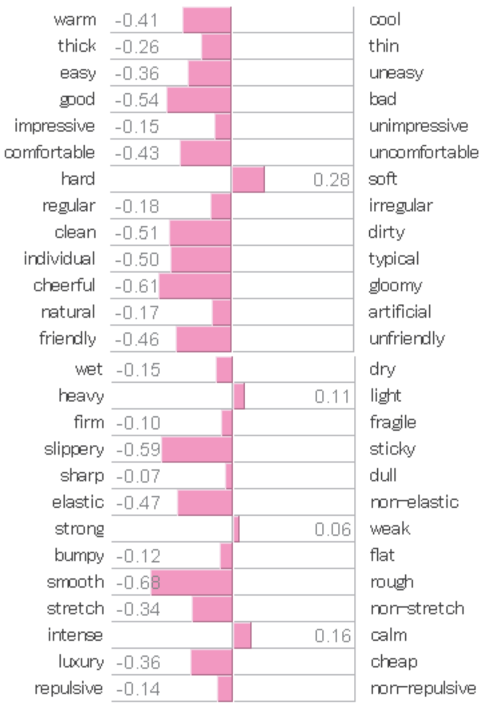

Fig.3 An evaluation result of onomatopoeia "kasa-kasa"

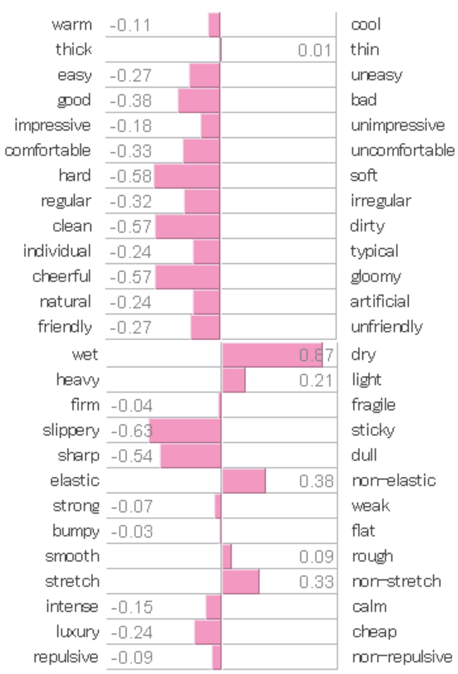

Fig.4 An evaluation result of onomatopoeia "gowa-gowa"

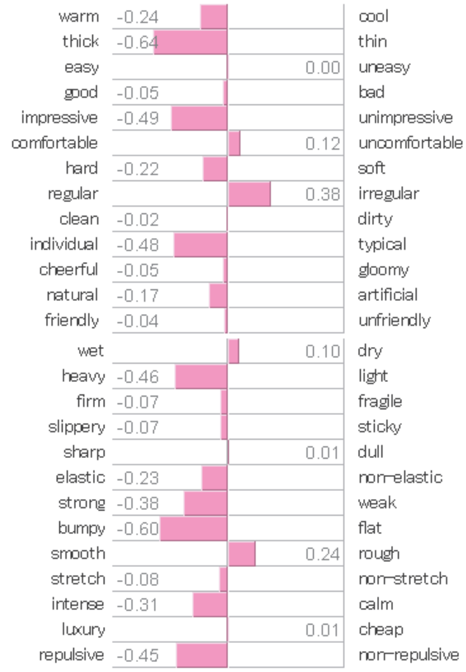

Fig.5 An evaluation result of onomatopoeia "puru-puru"

In our system, when a word expressing a tactile sensation intuitively is input into the text field, information equivalent to evaluations against the sounds of the word. Then we performed a principal component analysis using the output of our system in the fundamental six tactile dimensions "hard - soft," "rough - smooth," "bumpy - flat," "sticky - slippery," "wet - dry," and "warm - cold" and generated a distribution diagram of the SSWs using the first and second principle components as the horizontal axis and the vertical axis, respectively. In this diagram, SSWs that express closely related sensations are also located close to each other on the map. Mapping the SSWs spatially enables us to visualize the categories of tactile sensations.

In order to visualize the standard relationship between 43 sound symbolic words and tactile materials, we have decided to use the 50 standardized tactile materials developed by Sakamoto, Yoshino and Watanabe (2013), which are materials uniquely associated with 43 SSWs. Finally, we succeeded in visualizing the relationship between 43 SSWs and 50 tactile materials on a kind of tactile perceptual space map. The distribution map shows how tactile sensations are categorized by young people. Although mapping the SSWs spatially enables us to visualize the categories of tactile sensations, the categories of tactile sensations might be different among individuals, for example between young and old people, males and females, different cultural backgrounds. Therefore, we constructed a system that enables us to move SSWs to appropriate locations on the distribution map. When users move only a few

SSWs towards materials to be expressed by the SSWs, the system automatically visualizes their tactile perceptual space. The following is the algorithm to control movement of SSWs.

When word A is moved, word B is influenced by word A and moved. The following equation is used to calculate the influence.

$$\text{The influence of word A} = \exp\left[\frac{-(\text{the distance between word A and word B})^2}{2(\text{gravitation})^2}\right] \quad (2)$$

This equation is based on Gaussian function, and an elementary function of Gaussian function is used as "gravitation" in this equation.

In our system, a moved SSW can be fixed when its location fits user's affective tactile evaluation. When word C has been fixed and word A is moved, word B is influenced by word A and word C. The following equation is used to calculate the influence of word C.

$$\text{The influence of word C} = \exp\left[\frac{-2(\text{the distance between word B and word C})^2}{(\text{gravitation})^2}\right] \quad (3)$$

As the same as (2), this equation is based on Gaussian function, and an elementary function of Gaussian function is used as "gravitation" in this equation.

Our system comprises a user interface module, analyzing module and a database. When a user moves a SSW on the map, the analyzing module calculates the influence of the word according to (2), (3) and the database. Then, the other sound symbolic words on the map are moved according to the influences.

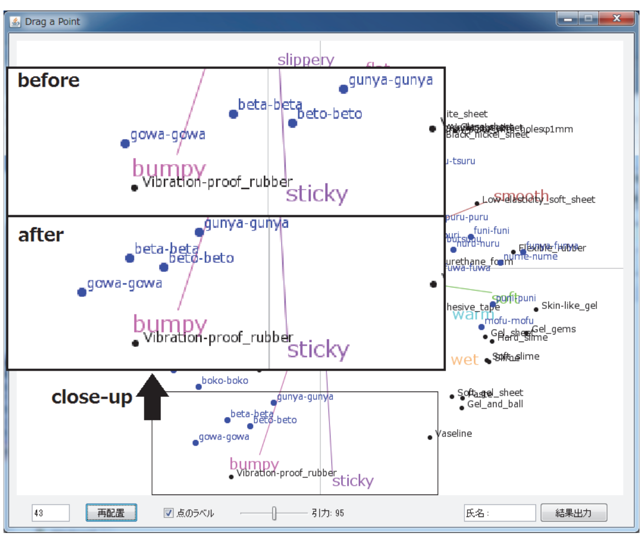

Fig. 6 State of a change of the distribution map.

Fig. 6 shows a state of a change of the distribution map. In Fig. 6, the sound symbolic words are moved to the left. As shown in Fig. 3, this system can make a different distribution map appropriate for individual tactile perceptual space. We can compare tactile sensations among individuals by comparing the maps. Therefore, we propose this system to compare the affective tactile evaluations of young people with old people.

Conclusion

In this paper, we proposed a method to compare tactile perceptual space of young people with old people and contributed to pay more attention to affective tactile perception of old people. In our future work, we aim to use this system to recommend tactile product materials appropriate for each consumer's perceptual tendency.

Acknowledgements

This work was supported by a Grant-in-Aid for Scientific Research on Innovative Areas "Tagenshitukanchi" (No. 15H05922) and Grant-in-Aid for Scientific Research(A) and (B) (No. 15H01720 and 15H02766) from MEXT, Japan.

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