Relationship between Phonemes and Tactile-emotional Evaluations in Japanese Sound Symbolic Words

Junji Watanabe (watanabe.junji@lab.ntt.co.jp)
NTT Communication Science Laboratories, Nippon Telegraph and Telephone Corporation
3-1, Morinosato-Wakamiya, Atsugi, Kanagawa, 243-0198 Japan

Yuuka Utsunomiya (u0816007@edu.hc.uec.ac.jp)
Department of Informatics and Engineering, The University of Electro-Communications
1-5-1, Chofugaoka, Chofushi, Tokyo 182-8585, Japan

Hiroya Tsukurimichi (h.tukurimichi@edu.hc.uec.ac.jp)
Department of Informatics and Engineering, The University of Electro-Communications
1-5-1, Chofugaoka, Chofushi, Tokyo 182-8585, Japan

Maki Sakamoto (sakamoto@inf.uec.ac.jp)
Department of Informatics and Engineering, The University of Electro-Communications
1-5-1, Chofugaoka, Chofushi, Tokyo 182-8585, Japan

Abstract

Many languages have a word class whose speech sounds are linked to sensory experiences (sound symbolism). Here we investigated sound symbolism in touch. Specifically, we performed psychophysical experiments to study the relationship between phonemes of Japanese sound symbolic words and emotional evaluations of objects in contact. Participants expressed the sensation obtained from touched materials using Japanese sound symbolic words and evaluated the comfort of tactile sensation. Our results show the existence of unique associations between the phonemes of the words for expressing the sensation and the evaluations of comfort in touch. Next, we compared the results with those for a condition in which the evaluations of comfort on tactile materials were made without expressing the sensations. We found that when certain phonemes are used for expressing the sensation, the evaluations can be biased.

Keywords: Sound symbolism; Tactile sensation; Emotional judgment; Onomatopoeia

Introduction

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 (e.g., Fox, 1935; Jespersen, 1922; Köhler, 1929, 1947; Newman, 1933; Sapir, 1929; Taylor, 1963; Werner & Wapner, 1952; Wertheimer, 1958, for early studies) and, more or less, in the languages of the world (e.g., Brown, Black, & Horowitz, 1955; Davis, 1961; Emeneau, 1969; Enfield, 2005; Hinton, Nichols, & Ohala, 1994; Klank, Huang, & Johnson, 1971; Kovic, Plunkett, & Westermann, 2010; Nuckrolls, 1999; Voeltz & Kilian-Hatz, 2001). The characteristics and universality of such sensory-sound correspondence have been studied to provide a clue for understanding the development of language abilities (Imai, Kita, Nagumo, & Okada, 2008; Kantartzis, Imai, & Kita, 2011; Maurer, Pathman, & Mondloch, 2006; Westbury, 2004) and language evolution (Ohala, 1997; Ramachandran & Hubbard, 2001, 2003).

It is also 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, 1929 and Ramachandran & Hubbard, 2001, respectively), but also in those referring to tactile, smell, and taste sensations. However, the majority of studies in the area of sound symbolism have been limited to visual-sound correspondence. Consequently, we are investigating the sound symbolic associations in touch, specifically the association between the phonemes of Japanese sound symbolic words (onomatopoeia) for expressing tactile sensations and subjective evaluations of comfort/discomfort for touched objects.

We focus on tactile-emotional evaluations, because compared with other languages, Japanese is known to have a large number of onomatopoeic words for tactile sensations, and because associations between the phonemes of Japanese onomatopoeic words and typical categories of tactile *sensations* (not *emotion*) can be observed. For example, onomatopoeic words expressing a sense of smoothness often use the consonant /s/ in the first syllable as in "sara-sara" [(a) in Table 1], while those expressing roughness often use /z/ in the first syllable as in "zara-zara" [(b) in Table 1]. Similarly, characteristic first consonants are observed in each of the tactile categories, such as /p/ for softness as in "puru-puru" [(c) in Table 1] and /k/ for hardness as in "kachi-kachi" [(d) in Table 1]. More importantly, tactile sensations are strongly connected to changes in the states of comfort and discomfort (Gallace, & Spence, 2010), and although it has been reported that touching objects can evoke distinct emotional states according to the textures of touched objects (Ramachandran,

& Brang, 2008), the associations between speech sound for expressing tactile sensations and touch-induced emotional states are unclear.

Table 1: Typical Japanese onomatopoeic words for expressing tactile sensations.

Sounds	Meanings
(a) Sara-sara	Smoothness
(b) Zara-zara	Roughness
(c) Puru-puru	Softness
(d) Kachi-kachi	Hardness

In the current study, we performed two psychophysical experiments. In the first experiment, when participants touched an object, they were asked to express the tactile sensation using Japanese onomatopoeic words [sound symbolic words (SSWs)] and then rate the comfort of the touched object with the semantic differential (SD) method (referred as the SSW+SD condition). This condition was aimed at specifying the systematic association between phonemes of Japanese onomatopoeic words and tactile-emotional evaluations. Our results demonstrate for the first time the existence of unique associations between them.

Next, we compared the results for the SSW+SD condition with those for a condition in which participants made only the tactile-emotional evaluations (SD-only condition). Since recent brain-imaging studies suggests that processing of SSWs could activate corresponding sensory areas (Arata, Imai, Okuda, Okada, & Matsuda, 2010; Hashimoto, Usui, Taira, Nose, Haji, & Kojima, 2006; Osaka, Osaka, Morishita, Kondo, & Fukuyama, 2004), it is expected that speaking them might affect speaker's subjective evaluation of the touched objects. The results demonstrate that when certain phonemes are used for expressing the sensation, the evaluation can be biased.

Materials and Methods

Participants

Thirty naïve participants, aged between 19 and 26 years old, took part in the experiments. Fifteen of the 30 (ten males and five females) performed the experiment in the SSW+SD condition; the other fifteen (ten males and five females) performed the experiment in the SD-only condition. They were unaware of the purpose of the experiments, and they had no known abnormalities of their verbal or tactile sensory systems or any particular skills with respect to touch. They visited a laboratory at the University of Electro-Communications for one day to conduct trials. Informed consent was obtained from the participants before the experiment started. Recruitment of the participants and experimental procedures were approved by the University of Electro-Communication Research Ethics Committee and were conducted in accordance with the Declaration of Helsinki.

Apparatus and Materials

We selected 120 types of tactile materials for the experiments, including fabrics, papers, metals, leathers, rubbers, woods, sand, rocks, and plastics. Preliminarily, we confirmed that onomatopoeic words for expressing the 120 materials would cover the major phonemes of Japanese onomatopoeic words in touch. When feasible, samples were cut to a size of 6 cm x 6 cm and stacked in layers to 2-mm thickness. The rocks and sand were loose in a container. As illustrated in Fig. 1, participants sat in front of a box with an 8 cm x 10 cm hole in it (the materials box) and placed the index finger of the dominant hand into the box through the hole to touch a material; they could not see a material while they were touching it.

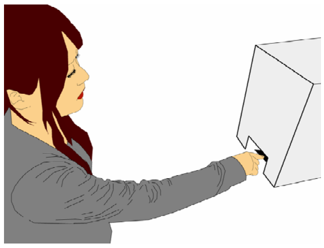

Figure 1: Participant touching a material.

Procedure

A trial in the SSW+SD condition comprised a describing period, in which participants reported an onomatopoeic word to express the tactile feeling while touching one of the 120 materials, and a rating period, in which they evaluated the comfort/discomfort of the touched material on a seven-point scale (Very comfortable +3, Comfortable +2, Slightly comfortable +1, Neither 0, and three levels, -1 to -3, for uncomfortable feeling) while touching it. In the describing and rating periods, they could freely run their fingers and push on the surface of the material, and the time for answering was not limited. A trial in the SD-only condition comprised only the rating period. In the experiments, the experimenter placed one material in the material box, and the participant touch it and respond, and then replaced it with another after the participant's response. Tactile materials were presented in a random order.

Results for SSW+SD condition

The results for the SSW+SD condition produced 1800 sets of onomatopoeic words and subjective evaluations of comfort level (120 materials x 15 participants). In 87.1% of all trials (1569 cases), the onomatopoeic word had a two-mora repetition form (e.g. "sara-sara"). We therefore analyzed the relationship between the phonemes of onomatopoeic words in two-mora repetitions form and evaluations of comfort/discomfort using the 1569 instances. The average of the ratings obtained across the 1569 cases was 0.08. This value suggests that half of trials yielded a rating in a comfortable level, and the other half a rating in an uncomfortable level (nonbiased for participant's response opportunities).

We took particular note of the vowels and consonants of the first syllable, which show strong sound symbolic associations (Hamano, 1998). The averages of ratings across trials in which the same phonemes were used in the first syllable were statistically compared with the average of the 1569 cases (0.08) (t-test comparing the average with constant value). Of the vowels, as shown in Table 2, only /u/ had a statistically significant relationship to comfort. Vowels /i/ and /e/ were not used often, but they were deeply related to discomfort (/i/ was marginally significant, and /e/ was significant). Among the consonants, /m/, /h/, and /s/ were related to comfort, while /g/, /z/, /j/, /b/, and /n/ were significantly related to discomfort.

Next, we combined the vowels and consonants of the first syllables and did a similar statistical analysis for the values (e.g, an analysis based on the value of /sa/ rather than the values of /s/ and /a/ separately). Table 3 shows the results of combinations between the vowels and consonants, which are listed in Table 2. The vowel /u/ was significantly related to comfort with many consonants (e.g., /h/ as in "huwa-huwa", /s/ as in "sube-sube", /t/ as in "tsuru-tsuru", and /p/ as in "puru-puru"). Conversely, /e/ was related to discomfort with any consonant (e.g., /p/ as in "pecha-pecha", /n/ as in "neba-neba", and /b/ as in "beta-beta"). Consonants /m/, /h/, and /s/ were related to comfort regardless of the vowel, while /g/, /z/, /j/, /b/, and /n/ were related to discomfort regardless of the vowel. Vowels /o/, /a/ and /i/ and consonants /p/ and /t/ were related to different levels of comfort depending on the consonant or vowel they were combined with, suggesting that as phonemes, they have only a weak relation to comfort level.

Table 2: Numbers (Num.) and average of ratings (Ave.) of the first vowel and consonant. Only phonemes whose numbers were more than 16 (1 % of 1569 cases) are listed. P-values of statistical analysis to the overall average (0.08) are also shown (+: $p < 0.1$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$). Red and blue shading indicate that the phoneme is significantly different in positive and negative values, respectively.

First vowel				First consonant			
	Num.	Ave.	*p* value		Num.	Ave.	*p* value
/u/	528	0.63	0.00 (***)	/m/	38	1.32	0.00 (***)
/o/	215	0.10	0.88	/h/	132	1.11	0.00 (***)
/a/	504	0.02	0.32	/s/	243	0.65	0.00 (***)
/i/	102	-0.21	0.05 (+)	/t/	189	0.54	0.14
/e/	220	-0.95	0.00 (***)	/k/	74	0.18	0.47
				/p/	209	0.07	0.87
				/g/	148	-0.18	0.02 (*)
				/z/	218	-0.33	0.00 (***)
				/j/	35	-0.47	0.03 (*)
				/b/	204	-0.96	0.00 (***)
				/n/	38	-1.37	0.00 (***)

Table 3: Averages of ratings for combinations of first consonants and vowels, which are listed in Table 2. Significant differences from the overall average (0.08) are also shown (+: $p < 0.1$, *: $p < 0.05$, **: $p < 0.01$, ***: $p < 0.001$). Red and blue shading indicate that the combination is significantly different in positive and negative values, respectively.

	/u/	/o/	/a/	/i/	/e/
/m/		1.31 (***)			
/h/	1.24 (***)				
/s/	0.63 (***)		0.66 (***)	0.61 (+)	
/t/	0.83 (***)			-0.65 (*)	
/k/			0.04		
/p/	0.42 (+)	0.75 (**)	-0.13	0.14	-0.41 (***)
/g/	-0.09	-0.02	-0.32 (*)		
/z/			-0.31 (***)		
/j/			-0.24		
/b/	-0.15	-0.58 (***)			-1.46 (***)
/n/					-1.15 (***)

Results for SD-only condition

We compared the results for the SSW+SD condition with those for the SD-only condition to examine the influence of expressing the sensations with sound symbolic words on the emotional evaluation (comfort level). First, we calculated averages of ratings for each tactile material (120 materials) in the SSW+SD (using 1569 cases) and SD-only (using 1800 cases) conditions. The analyses using 240 averaged values (120 materials x 2 conditions) were performed in two domains, in which the averaged values in the SD-only condition were positive (comfort materials) or negative (discomfort materials). For comfort materials (62 materials), the means of ratings across 62 materials were 0.70 in SSW+SD and 0.73 in SD-only. They were not significantly different (paired t-test, $t(61) = 0.39$, $p = 0.70$). On the other hand, for discomfort materials (58 materials), the means across 58 materials were -0.48 in SSW+SD and -0.73 in the SD-only. There were significant differences between the values ($t(57) = 3.41$, $p < .001$). These statistical analyses indicate that expressing tactile sensations with sound symbolic words while touching materials does not affect the emotional evaluation if the material is originally comfortable. However, when a touched material elicits discomfort, the emotional evaluation can be attenuated by expressing the sensation with sound symbolic words.

To clarify the systematic association between phonemes of onomatopoeic words and their influence on the evaluation, we made distribution maps of 120 materials as shown in Figs. 2 and 3, respectively. The phonemes represent each material in the maps. The representing phonemes were determined from the first syllables used for expressing the sensations most in the trials in the SSW+SD condition. Ones in the right-side area in the maps are comfortable materials and vice versa. In addition, ones in the upper side in the maps indicate materials whose comfort levels are improved (Left side: attenuated discomfort. Right side: enhanced comfort) and vice versa. Numbers of phonemes in the upper and lower right side areas are almost identical in the maps. On the other hand, more phonemes are located in the upper left area (attenuated discomfort) than in the lower left area (enhanced discomfort). This means that the comfort levels were systematically biased toward comfort for the discomfort materials, which agrees with the previous statistical analyses.

The differences in the effect of attenuation or enhancement according to the phonemes were statistically examined. We collected phonemes whose numbers in the comfort or discomfort area were more than six (5% of 120 materials) and calculated the means of differences of rating values in the SSW+SD condition from those in the SD-only condition across their corresponding materials. Figure 4 shows the trends for the comfort materials. For vowels, /u/ slightly enhances the comfort (marginally significant effect), but /a/ attenuates the comfort. For consonants, none of the phonemes affected comfort levels for the comfort materials. Figure 5 shows the trends for the discomfort materials. When the phonemes, /u/ in vowels, /z/ and /p/ in consonants, were used for expressing the tactile sensation, the level of discomfort can be attenuated. Some negative values in comfort level (discomfort materials) became positive (perceived as comfort).

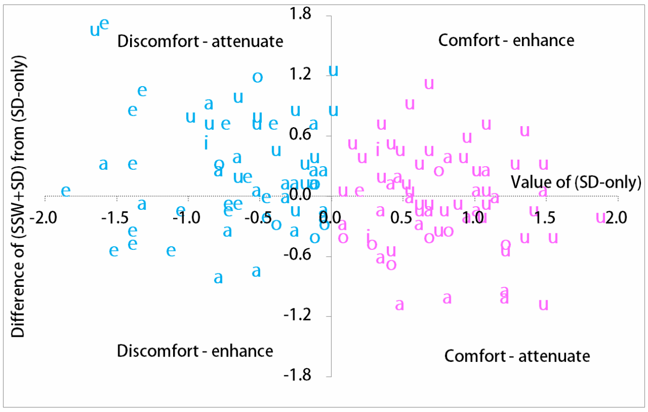

Figure 2: Distributions of vowels according to the values in the SD-only condition (horizontal axis) and difference of SSW+SD from SD-only (vertical axis).

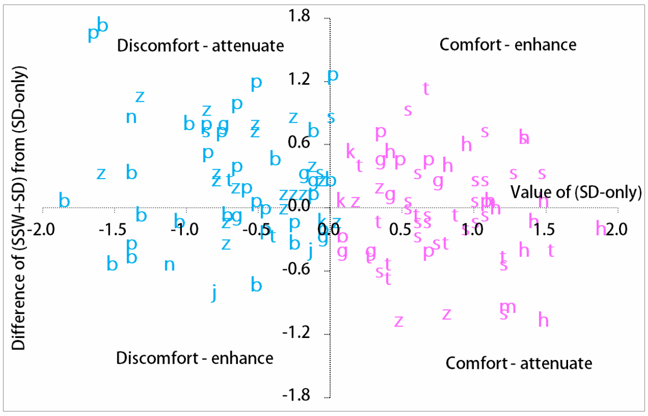

Figure 3: Distributions of consonants according to values in the SD-only condition (horizontal axis) and difference of SSW+SD from SD-only (vertical axis).

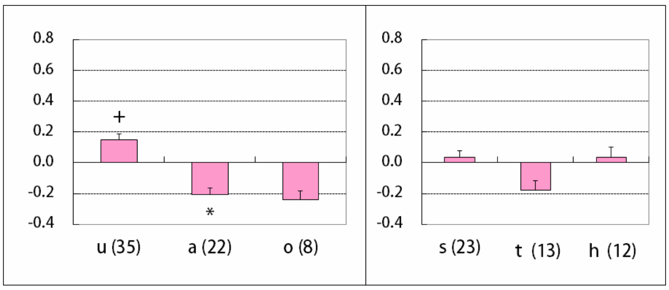

Figure 4: Difference of ratings in the SSW+SD condition from those in the SD-only condition for the phonemes in the comfort area. The data for vowels (left) and consonants (right) are shown with the number and statistical differences from zero. +: $p < 0.1$, *: $p < 0.05$.

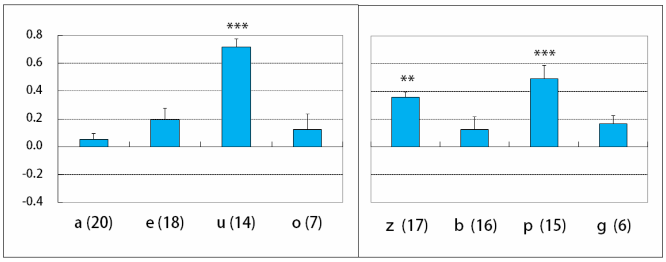

Figure 5: Difference of ratings in the SSW+SD condition from those in the SD-only condition for the phonemes in the discomfort area. The data for vowels (left) and consonants (right) are shown with the number and statistical differences from zero. **: $p < 0.01$, ***: $p < 0.001$.

Discussion

Sensory Category and Sound Symbolism

Humans categorize sensory inputs using words, and words are important indexes in investigating such sensory categories. Previous touch studies identified major factors in object recognition through touch and established standards of classification based on physical properties of materials or in terms of sets of adjectives (Hollins, Bensmaïa, Karlof, & Young 2000; Hollins, Faldowski, Rao, & Young, 1993; Picard, Dacremont, Valentin, & Giboreau, 2003; Tiest, & Kappers, 2006). However, the studies did not discuss sensibilities, such as like and dislike or comfort and discomfort, and to our knowledge, there has been no research regarding the association between touch-induced emotional states and sound symbolic words.

In the experiment in the SWS+SD condition, we found a strong association between comfort and the vowel /u/ and consonants /m/, /h/, and /s/ in the first syllables. If similar sensory categories are expressed using onomatopoeic words with similar phonemes, it will be possible to clarify the categories of comfort/discomfort, which is difficult to study directly. Since the tactile sensations described with the phonemes /m/, /h/, and /s/ seem different, as with "moko-moko" and "huka-huka" for squashiness and "sara-sara" for smoothness, these phonemes might be originated from different categories of comfort. Similarly, for discomfort, the vowel /i/ as in "chiku-chiku" for pointiness and /e/ and consonants /n/ and /b/ as in "neba-neba" and "beta-beta" for stickiness, and consonants /j/, /z/, and /g/ as in "jori-jori," "zara-zara," and "gori-gori" for roughness may represent different uncomfortable categories.

Uniqueness of Tactile Sound Symbolism

Phonemes related to tactile comfort or discomfort, together with the meanings of general sound symbolism in Japanese onomatopoeic words, are summarized in Table 4 (see Hamano, 1998). The association between the vowel /u/ and comfort has not been identified in the general sound symbolism. For vowel /i/, tactile sensations can be seen as analogous to general sound symbolism, but the association with discomfort seems to be particular to tactile sensation. The association of /e/ with discomfort can be seen as analogous to general sound symbolism. For consonants, no association between comfort and consonants /m/, /h/ and /s/ has been suggested. For discomfort, the tactile perception and comfort level agree with general sound symbolism for /n/. But it is difficult to analogize the comfort level for /b/ from general sound symbolism, and the association of /z/, /j/, and /g/ with discomfort also appears to be specific to the tactile sense.

As for consistency between modalities, there seems to be similar trends in the sound symbolic relationships between phonemes and perceptual experiences regarding touch and tastes. According to Sakamoto and Chiba (2005), vowel /u/ and consonants /s/ and /h/ are associated with positive evaluations of tastes, while vowels /i/ and /e/ and consonants /n/, /z/, /j/, /g/, and /b/ are associated with negative evaluations. In addition, as for the generality of our results, although the sound symbolism is observed in the languages of the world, whether the trends obtained in our experiments are universal or not is an issue awaiting further investigation.

Table 4: Phonemes related to tactile comfort or discomfort, together with the meanings of general sound symbolism in Japanese onomatopoeic words.

	Comfort	General sound symbolism	
/u/	+	Small round holes/ projections	Specific
/i/	-	Lines, straight elongations	Specific
/e/	-	Coarse, vulgar, unsuitable	Analogous
/m/	+	Indistinct, unclear	Specific
/h/	+	Softness	Specific
/s/	+	Smoothness	Specific
/n/	-	Sticky, uncomfortable	Agree
/b/	-	Taut	Specific
/j/	-	Abrasive	Specific
/z/	-	Abrasive	Specific
/g/	-	Touching a hard surface	Specific

Affection of Sound Symbolic Words on Evaluation

We found that when certain phonemes are used for expressing sensations for the touched material, the evaluations of comfort levels can be biased. Specifically, when /u/ was used, the bias was always toward comfort, which agrees with the association between phonemes and emotional evaluations in Table 2. But neutral phonemes /a/ and /p/ affect the evaluation. In addition, consonant /z/, which is associated with discomfort, attenuated the discomfort. Considering that emotional states can be evoked by the sensations automatically (Ramachandran, & Brang, 2008) and how words are articulated can be a possible mechanism relevant to sound symbolism (Ohala, 1983), the sound symbolism of comfort and discomfort for the tactile sense may be affected by phonetic (acoustic) comfort or discomfort, as observed in our experiment. But explaining the association is a problem for future research.

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References

Arata, M., Imai, M., Okuda, J., Okada, H. & Matsuda, T. (2010). Gesture in language: How sound symbolic words are processed in the brain. *Proceedings of the 32nd Annual Meeting of the Cognitive Science Society* (pp.1374-1379).

Brown, R. W., Black, A. H., & Horowitz, A. E. (1955). Phonetic symbolism in natural languages. *The Journal of Abnormal and Social Psychology*, 50, 388-393.

Davis, R. (1961). The fitness of names to drawings: A cross-cultural study in Tanganyika. *British Journal of Psychology*, 52, 259-268.

Emeneau, M. B. (1969). Onomatopoetics in the Indian linguistic area. *Language*, 45, 274-299.

Enfield, N. J. (2005). Areal linguistics and mainland southeast Asia. *Annual Review of Anthropology*, 34, 181-206.

Fox, C. W. (1935). An experimental study of naming. *The American Journal of Psychology*, 47, 545-579.

Gallace, A., & Spence, C. (2010). The science of interpersonal touch: An overview; *Neuroscience and Biobehavioral Reviews*, 34, 246-59.

Hamano, S. (1998). *The sound symbolic system of Japanese*. Stanford, CA: CSLI Publications; Tokyo: Kuroshio.

Hashimoto, T., Usui, N., Taira, M., Nose, I., Haji, T., & Kojima, S. (2006). The neural mechanism associated with the processing of onomatopoetic sounds. *Neuroimage*, 31, 1762-1770.

Hinton, L., Nichols, J., & Ohala, J. (Eds.). (1994). *Sound symbolism.* Cambridge, UK: Cambridge University Press.

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

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

Imai, M., Kita, S., Nagumo, M., & Okada, H. (2008). Sound symbolism between a word and an action facilitates early verb learning. *Cognition*, 109, 54-65.

Jespersen, O. (1922). The symbolic value of the vowel i. *Philologica*, 1, 1-19.

Kantartzis, K., Imai, M., & Kita, S. (2011). Japanese Sound-Symbolism Facilitates Word Learning in English-Speaking Children. *Cognitive Science*, 35, 575-586.

Klank, L. J. K., Huang, Y. H., & Johnson, R. C. (1971). Determinants of success in matching word pairs in tests of phonetic symbolism. *Journal of Verbal Learning and Verbal Behavior*, 10, 140–148.

Köhler, W. (1929) *Gestalt Psychology*. NewYork: Liveright Publishing Corporation.

Köhler, W. (1947) *Gestalt Psychology (2nd Ed.): An Introduction to New Concepts in Modern Psychology*. NewYork: Liveright Publishing Corporation.

Kovic, V., Plunkett, K., & Westermann, G. (2010). The shape of words in the brain. *Cognition*, 114, 19-28.

Maurer, D., Pathman, T., & Mondloch, C. J. (2006). The shape of boubas: Sound-shape correspondences in toddlers and adults. *Developmental Science*, 9, 316-322.

Newman, S. S. (1933). Further experiments in phonetic symbolism. *The American Journal of Psychology*, 45, 53-75.

Nuckrolls, J. (1999). The case for sound symbolism. *Annual Review of Anthropology*, 28, 225-252.

Ohala J. J. (1983) The origin of sound patterns in vocal tract constraints. In: MacNeilage (ed.) *The production of speech*. Berlin:Springer-Verlag.

Ohala, J. J. (1997). Sound Symbolism. *Proceedings of 4th Seoul International Conference on Linguistics* (pp. 98-103).

Osaka, N., Osaka, M., Morishita, M., Kondo, H., & Fukuyama, H. (2004). A word expressing affective pain activates the anterior cingulate cortex in the human brain: an fMRI study, Behavioral Brain Research, 153, 123-7.

Picard, D., Dacremont, C., Valentin, D., & Giboreau, A. (2003). Perceptual dimensions of tactile Textures. *Acta Psychologica*, 114, 165-184.

Ramachandran, V. S., & Brang, D. (2008). Tactile-emotion synesthesia. *Neurocase*, 14, 390-399.

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

Ramachandran, V. S., & Hubbard, E. M. (2003). Hearing colors, tasting shapes. *Scientific American*, 288, 43-49.

Sakamoto, M. & Chiba, A. (2005). Sound symbolic analyses of onomatopoetic words expressing tastes. *Proceedings of 130th Annual Meeting of Linguistic Society of Japan*, 306-311 (in Japanese) .

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

Taylor, I. K. (1963). Phonetic symbolism re-examined. *Psychological Bulletin*, 60, 200-209.

Tiest, W. M. B., & Kappers, A. M. L. (2006). Analysis of haptic perception of materials by multidimensional scaling and physical measurements of roughness and compressibility. *Acta Psychologica*, 121, 1-20.

Voeltz, F. K. E., & Kilian-Hatz, C. (Eds.). (2001). *Ideophones*. Amsterdam: John Benjamins.

Werner, H., & Wapner, S. (1952). Toward a general theory of perception. *Psychological Review*, 59, 324-38.

Wertheimer, M. (1958). The relation between the sound of a word and its meaning. *The American Journal of Psychology*, 71, 412-415.

Westbury, C. (2004). Implicit sound symbolism in lexical access: Evidence from an interference task. *Brain and Language*, 93, 10-19.