Recognition Mechanism of the “Sara-sara Feel” of Cosmetic Powders

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Abstract: The Sara-sara feel, which means “a state in which things are not damp or sticky and feel dry,” is a preferred tactile sensation when people touch human skin, hair, clothing, and cosmetics. In this study, the Sara-sara feel was evaluated for silicone powder, cellulose powder, hydrophobized sericite powder, and various mixes of these powders. It was found that the highest Sara-sara feel score was achieved by the silicone powder. A multiple regression analysis showed that the Sara-sara feel was strongly correlated with a slippery feel. The relationship between certain physical properties, e.g., particle size distribution, and the slippery feel was analyzed to demonstrate how the subjects felt the slippery feel. It was observed that as the friction coefficient μk was reduced, most subjects strongly felt the slippery feel. This coefficient slightly decreased when the composition of spherical silicone powder increased, because the contact area between spherical particles is smaller than that between plate and amorphous particles.

Key words: friction, tactile feel, cosmetic powder

1 Introduction

Sara-sara is a Japanese onomatopoeia originally meant to represent the sound that occurs when light objects touch each other or when water flows shallowly⁷. However, a new meaning, i.e., “a state in which things are not damp or sticky and feel dry,” has been added to this definition. At present, the Sara-sara feel is a preferred tactile sensation when people touch human skin, hair, clothing, and cosmetics.

Sara-sara is important when touching powder, because the sensation is related to the tactile and lubrication properties of cosmetics and other daily products. Yamamoto et al. have found that this sensation occurs when touching powder with a grain size greater than 10 μm⁵. Oheda et al. have reported that Sara-sara is a comforting tactile feel for powder cosmetics⁶, and Sambe et al. have shown that this sensation is desired for antiperspirant powder, which refreshes sweaty or greasy skin⁵.

Although Sara-sara is a common and important sensation in several industrial fields, there are few reports on its physical origin. Kamikawa et al. have evaluated the tactile texture of cosmetic powders and oils and found that both boundary lubrication and fluid lubrication properties are essential to evoke this feel⁶. Kuri has defined the degree of the Sara-sara feel based on the outflow velocity of powder particles from a container⁷. In addition, there are several reports about the phonological impressions of the term itself. Watanabe et al. have reported that the sound /s/ in the first syllable of Sara-sara is associated with the emotion of pleasure⁷. Hayakawa et al. have created a distribution map of Japanese onomatopoeias in which Sara-sara is close to the words “tsuru-tsuru” and “sube-sube”⁸.

We have recently shown that various tactile sensations can be comprehensively analyzed via in situ friction evaluation on the skin surface or model analysis using a biomimetic tactile sensing system, i.e., a friction evaluation system using a finger model as the contact probe in which the smooth finger movement of human tactile motion is reproduced by sinusoidal motion with an ever-changing velocity⁹. The finger model mimics the mechanical properties of a finger and the morphology of a fingerprint. Using this evaluation system, Kikegawa et al. have proposed the physical origin of the Shittori feel, a tactile sensation of moderate moisture¹⁰. Tsuchiya et al. have found that Shit-
tori is a complex combination of moist and smooth feels induced by a frictional phenomenon on the skin, i.e., when the finger starts to move and when the finger rubs a powder, respectively\(^{13,14}\).

In this study, we conduct a multifaceted analysis to clarify the mechanism behind how humans experience the Sara-sara feel when touching powder. First, we analyze the phonological impression of the term itself using a phonological impression evaluation system expressed by 43 adjective pairs\(^{13,14}\). Next, we perform a sensory evaluation using silicone powder, cellulose powder, hydrophobized sericite powder, and various mixes of these powders. Then, we evaluate physical properties, such as friction characteristics, particle size distribution, angle of repose, bulk specific gravity, water content, thermal conductivity, and surface energy. Specifically, the friction characteristics are evaluated using a biomimetic tactile sensing system. Finally, the relationship between the sensory evaluations, tactile impressions, and physical properties is analyzed to demonstrate the mechanism of the Sara-sara feel.

2 Experimental

2.1 Materials

Table S1 lists the chemical composition, particle shape, and scanning electron microscopic (SEM) image of the powders: A: [silicone, vinyl dimethicone/methicone silsesquioxane crosspolymer, spherical particle, \(\phi5.3 \mu m\) (Shim-Etsu Chemical Co., Ltd., Tokyo, Japan)], B: [cellulose, amorphous particle, \(\phi14.7 \mu m\) (Daito Kasei Kogyo Co., Ltd., Osaka, Japan)], and C: [hydrophobized sericite, plate particle, \(\phi17.3 \mu m\), alkyl silane-treated sericite (Daito Kasei Kogyo Co., Ltd., Osaka, Japan)]. The compositions of powders C] are listed in Table S2.

After being pre-mixed via hand shaking, the powders were mixed by a high-speed blender (Wonder Crusher WC-3, Osaka Chemical Co., Ltd., Osaka, Japan). The rotation speed and mixing time were 14,000 rpm and 1 min, respectively. Powders A-J were filtrated by a sieve with 0.5-mm openings and dried for 6 h.

2.2 Phonological impression evaluation

The phonological impression of the term Sara-sara was evaluated by the system developed by Sakamoto et al.\(^{13,14}\), in which a sound-symbolic word in Japanese is converted into quantitative ratios of 43 pairs of adjectives containing tactile dimensions.

2.3 Sensory evaluation

The tactile evaluations were performed by 20 female students (ranging in age from 20 to 25 years) in a quiet room at 25 ± 0.5°C and 50 ± 5% relative humidity after they washed both hands with a commercial liquid hand soap and acclimatized for 20 min. The subjects picked the powder (approximately 0.01 cm\(^3\)) up with the thumb and forefinger of their dominant hand and rubbed their fingers together for 25 s (Fig. 1). The tactile textures of powders were evaluated in a random order to eliminate order effects when the subjects touched the materials through a blackout curtain. The test’s purpose was revealed to the subjects before the evaluations, and the subjects decided by themselves whether to participate or not. All evaluations were conducted according to the principles expressed in the Declaration of Helsinki. The responsible party at Yamagata University confirmed that the ethics and safety of the present test were acceptable (approval number R01-8). Informed consent was obtained from all subjects.

After the evaluation, the subjects answered five questions. Q1 and Q2 were as follows: "When you touched the powder, did you feel the Sara-sara feel?" and "Why did you feel that?" Q3 asked when the Sara-sara feel was felt: 1. "The moment when you touched the material"; 2. "While touching"; or 3. "Other." Next, in Q4, the subjects evaluated ten tactile sensations regarding the following tactile dimensions: warm, cold, soft, hard, moist, dry, smooth, sticky, rough, slippery, and creak feels\(^{15}\). Finally, in Q5, the subjects freely described the powders’ tactile feel. In Q1 and Q4, the tactile sensations were evaluated based on the visual analog scale method\(^{16}\).

2.4 Physical evaluations

The friction force was evaluated using a sinusoidal motion friction evaluation system, in which the contact probe slide on objects under sinusoidal motion, at 25 ± 0.5°C and 50 ± 5% relative humidity\(^{9,11,12}\). Figure 2 shows a photograph and overview of the device. The sinusoidal motion was achieved by a scotch yoke mechanism that rotated an eccentric disk and made the yoke reciprocate. The friction force applied to the contact probe, \(F_x\), and the forces applied to the material, \(F_y\) and \(F_z\), were detected by strain gage-type load cells. The measurement ranges of
the friction forces were as follows: $F_x = F_0 = 0.04 - 9.2 \text{ N}$ and $F_z = 0.04 - 9.7 \text{ N}$. In this study, the $F_x$ and $F_z$ data obtained from the load cells in the sample stage were analyzed, because an inertial force was applied to the contact probe.

The contact probe was a finger model composed of urethane resin (Fig. 2 (b)). On the probe’s surface, 0.15-mm-deep grooves were carved at 0.5-mm intervals to mimic fingerprints. The friction evaluations were performed when 20 mg of dried powder was applied to the artificial skin (Beaulax, Saitama, Japan). The velocity $V$ during sinusoidal motion is described by the following equation:

$$V = |A| \omega \cos \omega T$$  \hspace{1cm} (1)

where $A$, $\omega$, and $T$ are the moving width, angular velocity, and time, respectively. The experimental conditions were as follows: $\omega = 2.1 \text{ rad s}^{-1}$ (maximum velocity $= 30 \text{ mm s}^{-1}$), vertical load $= 0.98 \text{ N}$, $A = \pm 14.5 \text{ mm}$, and number of cycles $= 11$.

The contact probe was in contact with the artificial skin for approximately 60 s prior to sliding. The coefficient of static friction depended on the friction conditions. In particular, the contact time between the contact probe and the artificial skin before sliding could have a significant effect on the static friction. To confirm their repeatability, the evaluations were conducted three times. The friction data were analyzed based on the following parameters: (i) the static friction coefficient ($\mu_s$), (ii) the kinetic friction coefficient ($\mu_k$), and (iii) the normalized delay time $\delta$, given as $\delta = \Delta t / T_0$, where $\Delta t$ is the time lag between the velocity and friction force and $T_0$ is the time for a cycle (Fig. 3).

Although $\delta$ is uncommon, we added this parameter for analysis, because it was found to reflect some characteristic friction phenomena on soft matter surfaces in several previous studies\(^9\,17\,20\).

The particle size distribution, angle of repose, bulk specific gravity, and water content were measured for powders $A$–$J$. The particle size distribution was determined via a laser diffraction/scattering particle size distribution apparatus (Microtrac MT3300EX II; Nikkiso Co., Ltd., Tokyo, Japan). The angle of repose measurements was performed as Japanese Industrial Standards JIS R 9301-2-2: A funnel (discharge nozzle diameter, 20 mm) was fixed 40 mm above a petri dish (diameter, 50 mm), and the powder was dropped at 30 g min$^{-1}$ to form a conical pile using a quantitative feeder (constant feeder type F3, Toyo Seiki Seisakusho, Ltd., Tokyo, Japan). The bulk specific gravity measurements were performed with measuring instrument TPM-1P/TPM-3P (Tsutsui Scientific Instruments Co., Ltd., Tokyo, Japan) in accordance with JIS K 7370 (ISO 1068). The water content was measured using an MKC-510 Karl Fischer moisture meter (Kyoto Electronics Manufacturing Co., Ltd., Kyoto, Japan). The thermal conductivity and surface tension of each powder were cited from the literature\(^21\,25\). The physical parameters of powder $L$ were speculated from the mass fraction of powders $A$–$C$. The physical parameters of powder $C$ were cited from the literature on mica, while the morphological and physical parameters of powders $D$–$L$ were speculated from the mass fraction of powders $A$–$C$. 

Fig. 2 Sinusoidal motion friction evaluation system. (a) Overall view, (b) finger model, (c) conceptual diagram.

Fig. 3 Typical friction profile and definition of parameters. The parameters $\mu_s$ and $\mu_k$ are the static and kinetic friction coefficients, respectively.
2.5 Statistical analysis

A regression analysis was conducted using the Sara-sara feel as a target variable. We analyzed the tactile sensations regarding tactile dimensions, with warm, cold, soft, hard, moist, dry, smooth, sticky, rough, slippery, and creak feels as explanatory variables. A Student’s t-test was conducted for each explanatory variable. The null hypothesis was rejected if the p-value was greater than 0.05. The statistical analyses were performed using the software Excel version 16 (Microsoft Corp, Washington, USA) and SPSS 25 Regression (IBM, New York, USA).

3 Results

3.1 Phonological impression

Figure 4 shows the output from the conversion system for the word Sara-sara. The scores for “nonelastic,” “dry,” “slippery,” and “light” were high: 0.67, 0.60, 0.52, and 0.52, respectively. The evaluation scores of the tactile dimensions were as follows: “dry,” 0.60; “slippery,” 0.52; “cold,” 0.15; “hard,” 0.10; and “smooth,” 0.10. These results suggested that Sara-sara could be a complex tactile sensation involving a dry or slippery feel.

3.2 Sensory evaluation

The Sara-sara feel scores are shown in Fig. 5. The original sensory evaluation data are shown in Tables S3–S5. The highest average scores were for powders A (8.8 ± 1.7, mean ± SD) and F (8.6 ± 1.3), whereas the lowest scores were for powders B (4.5 ± 2.8) and C (4.6 ± 2.1). Figure 6 shows the tactile score and appearance rate of the words in the comments for Q2, which asked why the subjects felt the Sara-sara feel based on the tactile dimensions for each powder. Powders A and F, with the highest Sara-sara feel scores, strongly evoked slippery and smooth feels. In the Q2 comments, words concerning the slippery and smooth feels appeared at a relatively high probability. The appearance rate concerning the slippery feel of powders A and F was 5.0 and 2.0, respectively, and that of the smooth feel was 2.5 and 1.0, respectively.

Figure 7 shows the dendrogram obtained via the cluster analysis of the tactile scores based on the tactile dimensions of each powder. Powders A–L were classified into two groups: Group 1 [powders A, D, E, F, G, and J (containing silicone powder)] and Group 2 [powders B, C, H, and I]. According to the sensory data shown in Fig. 5, the Sara-sara feel score of all powders in Group 1 was seven or higher, while that of the powders in Group 2 was six or

![Fig. 4](output from the conversion system for Sara-sara.png)

![Fig. 5](Sara-sara scores, which shows the strength of the Sara-sara feel is shown in blue (mean ± SD) with contour lines at 1-point intervals in ternary chart. Samples are A: silicone, B: cellulose, C: hydrophobized sericite, and D-J: mixed powders.)

![Fig. 6](dendrogram obtained via the cluster analysis of the tactile scores based on the tactile dimensions of each powder. Powders A–L were classified into two groups: Group 1 [powders A, D, E, F, G, and J (containing silicone powder)] and Group 2 [powders B, C, H, and I]. According to the sensory data shown in Fig. 5, the Sara-sara feel score of all powders in Group 1 was seven or higher, while that of the powders in Group 2 was six or)
The relationships between the Sara-sara feel score and other tactile scores were analyzed using a correlation analysis (Table S6). In particular, the Sara-sara feel was strongly correlated with the slippery feel (Fig. 8). The correlation coefficients associated with the slippery, smooth, creak, and sticky feels were 0.67, 0.61, −0.54, and −0.52, respectively. Next, the results of the regression analysis using the Sara-sara feel as a target variable and the slippery feel as an explanatory variable were as follows:

Fig. 6 The score of tactile dimension: for each powders A: silicone, B: cellulose, C: hydrophobized sericite and D–J: mixed powders. The blue solid line is the scores of tactile dimensions for powders and the red dash line is the appearance rate of the words on each tactile dimension in the subject’s comment of the reason why did you feel Sara-sara feel (Q2).

Fig. 8
3.3 Physical evaluations

Table S7 lists the frictional and physical properties of powders A–L. We observed a significant difference in frictional parameters $\mu_s$, $\mu_k$, and $\delta$ between powders $A$ and $F$ with a high slippery feel score and powders $B$ and $C$ with a low score. The $\mu_s$ of $B$ and $C$ was $0.71 \pm 0.02$ and $0.76 \pm 0.03$, respectively, whereas that of $A$ and $F$ were $0.43 \pm 0.06$ and $0.43 \pm 0.04$, respectively. Parameter $\mu_k$ was high for powders $C$ and $B$ at $0.85 \pm 0.04$ and $0.72 \pm 0.03$, respectively, and low for powders $A$ and $F$ at $0.43 \pm 0.06$ and $0.43 \pm 0.04$, respectively. Time lag $\delta$ was long for powders $B$ and $C$ at $0.033 \pm 0.001$ and $0.030 \pm 0.004$, respectively, and short for powders $A$ and $F$ at $0.026 \pm 0.002$ and $0.025 \pm 0.003$, respectively.

The relationship between the characteristics and frictional properties of each powder was assessed to determine why the frictional properties differed depending on the powder. We observed differences in the powder characteristics, ratio of spherical particles, particle size $D_{50}$, and bulk specific gravity between powders $C$ and $I$ with a high value of $\mu_s$ and powders $A$, $D$, and $F$ with a low value. The ratio of spherical particles was 1.00, 0.67, and 0.67 for $A$, $D$, and $F$, respectively. Powders $C$ and $I$ did not contain spherical particles. Particle size $D_{50}$ was 17.3, 13.7, 5.3, 6.0, and 6.5 µm for $C$, $I$, $A$, $D$, and $F$, respectively. The bulk specific gravity was 0.35, 0.64, 0.47, 0.36, and 0.65 g mL$^{-1}$ for $A$, $C$, $D$, $F$, and $I$, respectively.

4 Discussion

In this study, the phonological impression and sensory evaluations suggested that the slippery feel is one of the frictional dimensions composing the Sara-sara feel. In the sensory evaluation, the Sara-sara feel scores were strongly correlated with those of both the smooth and slippery feel. The correlation coefficient between the Sara-sara and slippery feel was 0.67, the highest among these three feels. In addition, words implied as slippery, such as “suberu” and “suberigayoi,” in Japanese were given. Moreover, the phonological impression of the word Sara-sara suggested that the slippery feel was most strongly recalled from the Sara-sara feel: the slippery feel score was 0.52 in the pho-

$$X^{Sara-sara} = 2.77 + 0.634X^{Slippery}$$

where $X^{Sara-sara}$ and $X^{Slippery}$ are the Sara-sara and slippery feel scores, respectively. The determination coefficient $R^2$ for equation (2) was 0.447. The Student’s $t$-test suggests that the $p$-values of the slope and intercept were less than 0.05.
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Object: the more slippery the object, the higher the grip force\(^{26}\). Allan \textit{et al.} found that the friction coefficient applied during finger movement is related to the smooth feel\(^{27}\). Liu \textit{et al.} also indicated that the friction force that arises when touching materials such as wood, leather, plastic, and metal is highly correlated to the slippery feel\(^{28}\).

To determine when \(\mu_k\) is small for a powder’s composition and properties, we focused on the relationship between the ratio of spherical particles and \(\mu_k\). As shown in Fig. 10, \(\mu_k\) slightly decreased when the composition of spherical particles increased. In general, Coulomb’s friction law shows that friction force \(F_f\), i.e., the force required to cut the junctions by shearing, is as follows:

\[ F_f = \tau_c \Delta A \]  

where \(\tau_c\) and \(\Delta A\) are the yield stress and the area of real contact, respectively\(^{29}\). Equation (3) suggests that \(F_f\) is directly proportional to \(\Delta A\). In addition, contact radius \(a\) between two spherical particles is described by equation (4) \(R_1, R_2 = \text{radius of spherical particles}, E_1, E_2 = \text{Young’s modulus}, \nu_1, \nu_2 = \text{Poisson’s ratio of two spherical particles}, \)\(F = \text{Normal force}\)\(^{30}\):

\[ a = \left( \frac{3R*}{4E*F} \right)^{\frac{1}{2}} \]  

Conversion radius \(R^*\) and converted Young’s modulus \(E^*\) are defined as follows:

\[ R^* = \frac{R_1R_2}{R_1 + R_2}, \quad \frac{1}{E^*} = \frac{1 - \nu_1^2}{E_1} + \frac{1 - \nu_2^2}{E_2} \]  

Therefore, contact area between two spherical particles \(A\) is given as follows:

\[ A = \pi \left( \frac{3R^*}{4E^*F} \right)^{\frac{2}{3}} \]  

In the case of plate particles, \(R^*\) and \(A\) are infinite, since \(R_1, R_2 = \infty\). The \(F_f\) of a plate particle is larger than that of a spherical particle.

5 Conclusions
In this study, we found that the Sara-sara feel is caused by one of the tactile dimensions, i.e., slippery feel, which relates to the friction characteristics of powdery material. Many subjects felt this sensation when they touched spherical silicone powder.

These findings are important for designing cosmetics and daily products containing powdery materials. The sensation is difficult to understand among people of different backgrounds, because it strongly depends on language and culture. However, there is no doubt that the Sara-sara feel is important in the Japanese market.

Acknowledgments
This work was supported by Grant-in-Aids for Scientific Research on Innovative Area (No. 16H01661) and for Scientific Research (B) (No. 18H01402) from the Ministry of Education, Culture, Sports, Science and Technology, Japan (MEXT).

Supporting Information
This material is available free of charge via the Internet at http://dx.doi.org/jos.69.10.5650/jos.ess20252

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