Differences in pleasant texture stimuli between fingertips and the palm

Sun Qingyu[1], Shogo Okamoto[1,2], Yasuhiro Akiyama[1] and Yoji Yamada[1]
1. Nagoya University, Aichi, Japan
2. Tokyo Metropolitan University, Tokyo, Japan

***Abstract*—Because of the differences in the mechanical and anatomical properties of body parts, including the density of mechanical receptors, humans' perception of pleasantness varies depending on which body part is affected. We tested this hypothesis on fingertips and palm centers using 18 types of 3D-printed dots scales. The participants pressed their finger or palm to these dots scales with no sliding motions, and reported the degree of pleasantness. For the fingertip, finer surfaces felt more comfortable than rougher ones; this finding agrees with the results of earlier studies. However, for the palm, pleasantness reached its peak when a moderately rough scale was touched. These findings will help design comfortable surfaces for different body parts.**

***Index Terms*—Dots scale, roughness, comfort**

I. Introduction

Thus far, several researchers have studied the perception of pleasantness when touching surface textures [1], [2], [3]. Existing studies agree that smoother surfaces, which present less mechanical stimuli to the skin, feel more comfortable. It is generally believed that this trend does not depend on which body part is in contact with the surface. However, the sensitivity to surface textures largely varies among body parts. The sensitivities are high at lips and fingers, whereas they are low at heels, back, and thighs [4]. These differences are in part caused by the mechanical and anatomical differences between body parts, including the varying densities of mechanical receptive units. Therefore, we reasonably hypothesize that the degree of pleasantness felt by touching surfaces also varies among different body parts. However, the relationship between pleasantness and surface roughness has yet to be thoroughly compared among different body parts. For example, researchers [1], [3] compared the pleasantness associated with active versus passive rubbing motions for different body parts using natural materials including cotton, denim, and sandpaper. However, the perception of roughness has not been considered. Therefore, we used surface specimens with different levels of coarseness in our experiment.

We investigated the pleasantness perceived when pressing roughness scales with the fingertip or central part of the palm, instead of active or passive rubbing motions [1], [2]. The two body parts included in our study have different mechanical receptors. Eighteen types of dots roughness scales were used, and the perception of pleasantness was then compared between the two body parts.

This study was in part supported by MEXT Kakenhi 21H05819 and 20H04263.

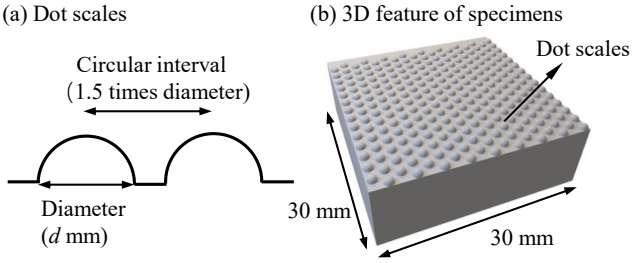

Fig. 1. Specimens used in the experiment. (a) Surface parameters of the dot scales. (b) Overall size of the specimens

II. Methods

A. Stimuli: Dots scale

We used 18 types of 3D-printed dots scales. The printer employed was Form 3 (Formlabs Inc., MA), with a nominal resolution of 25 μm. The surface area of the specimen was 30 $\times$ 30 mm, and the height was 10 mm. The diameter d of the dot scales varied from 0.75 to 16.72 mm by a geometric factor of 1.2. Accordingly, the interval between the centers of the consecutive dots varied from 1.125 to 24.96 mm, always 1.5 times the diameter, as shown in Fig. 1 Because the fingertip would fall into the circular intervals of rougher specimens, we only used the first 14 of the finest specimen.

B. Task: Magnitude estimation of pleasantness perception

Magnitude estimation tasks were conducted to measure the pleasantness experienced from the specimens. We tested two parts of the hand: fingertip and palm. For the fingertips, the experiment was conducted with the first 14 of the finest roughness specimens. The smallest dot scale was used as the modulus. The participants were required to place their index finger pad on randomly presented specimens and press with a force of 200 gf, referring to an electric scale. Each specimen was tested 3 times, and 96 trials (42 trials for the fingertip and 54 trials for the palm) were conducted for each participant. For our subsequent analysis, we used the median values of the three trials for each roughness scale. The roughness values were then normalized to scale their geometric mean to be 1 for each individual. To ensure that they could not visually judge

978-1-6654-1903-1/22/$31.00 2022 IEEE

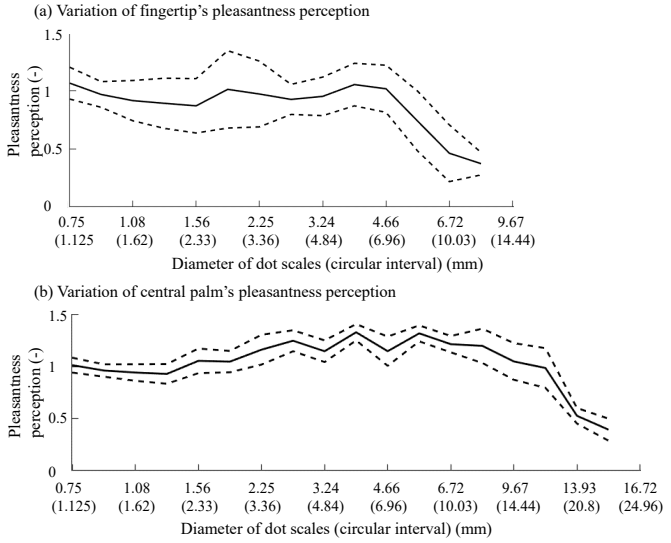

Fig. 2. Variation of mean pleasantness experienced at the (a) fingertip and (b) palm with 95% confidence intervals.

the specimens' surfaces, all participants wore glasses whose lenses were partially blurred (upper part) using translucent tape.

C. Participants

Seven university students in their 20s participated in the task after providing written informed consent. The objectives of this study were not explained to the participants before the experiments.

III. Results

The mean values of the pleasantness experienced at the fingertip and central palm are shown in Fig. 2. The dotted lines indicate 95% confidence intervals. For the fingertips, the pleasantness exhibited the highest value for the finest surface texture. However, considering the confidence interval, the true peak may range from 0.75 to 3.89 mm. For the palm, the pleasantness reached a moderate peak at a diameter of 3.89 mm.

It is generally believed that finer surfaces are more comfortable to the touch than rougher ones [1], [2], [3]. Therefore, we compared the pleasantness values associated with the finest surface having a diameter of 0.75 mm with those that exhibited the highest pleasantness values. For the fingertip, the finest surface exhibited the highest pleasantness value; hence, we compared the finest surface with the 3.89 mm diameter surface. For the fingertip, there was no significant difference between $d = 0.75$ mm and $d = 3.89$ mm ($t = 0.36$, $p = 0.73$). However, for the palm, the specimen of $d = 3.89$ mm exhibited a larger pleasantness value than the finest scale of $d = 0.75$ mm ($t = -3.47$, $p = 0.018$).

IV. Discussion

Two suggestions were obtained from the present experiment regarding the difference in pleasantness perception between the fingertip and central palm.

For the fingertips, our results are largely consistent with previous studies [1], [2], where finer, smoother specimens were shown to be more pleasant. However, our research indicates a different result for the palm. This may be explained by the fact that previous studies involved active or passive rubbing motions, whereas our study involved pressing motions without sliding. Therefore, the mechanical receptors mediating the roughness perception and pleasantness feeling are also different between the present and earlier studies. For the pressing motion, slowly adapting receptors are considered as the main mediators, whereas, for the rubbing motion, fast-adapting receptors are chiefly involved [5], [6].

As suggested by the confidence intervals that are shown in Fig. 2, individual differences were greater for the fingertip than for the central palm. The individual differences in tactile perception may be caused by the individual differences in mechanical and biological characteristics, including finger size [7]. However, it is unclear why these differences are less significant for the palm. Because our experiment focused on pushing behavior, for which the neural activity is mainly mediated by slowly adaptive units [6], we suggest that individual differences in the units' density are higher in the fingertip than in the palm.

V. Conclusion

The mechanical and anatomical properties of body tissues vary among body parts; hence, the pleasantness felt when touching surfaces might also vary accordingly. However, earlier studies did not thoroughly investigate this point, and it is generally believed that finer surfaces feel more pleasant irrespective to body parts. We investigated the pleasantness felt at the fingertip and central palm using specimens with 14 or 18 levels of roughness. The relationships between the pleasantness and surface parameters were substantially different between the fingertip and palm. At the fingertip, similar to the results of previous studies, smoother specimens were judged more pleasant, and there were no clear differences between the results of fine and moderately rough specimens. In contrast, for the palm, a moderately rough specimen with a dot diameter of 3.89 mm was determined to yield the highest pleasantness value. These findings are expected to contribute to the design of pleasant surfaces.

References

[1] G. K. Essick, F. McGlone, C. Dancer, D. Fabricant, Y. Ragin, N. Phillips, T. Jones, and S. Guest, "Quantitative assessment of pleasant touch," *Neuroscience & Biobehavioral Reviews*, vol. 34, no. 2, pp. 192–203, 2010.

[2] A. Klöcker, C. M. Oddo, D. Camboni, M. Penta, and J.-L. Thonnard, "Physical factors influencing pleasant touch during passive fingertip stimulation," *Plos One*, vol. 9, no. 7, p. e101361, 2014.

[3] R. Etzi, C. Spence, and A. Gallace, "Textures that we like to touch: An experimental study of aesthetic preferences for tactile stimuli," *Consciousness and Cognition*, vol. 29, pp. 178–188, 2014.

[4] J. C. Stevens, “Perceived roughness as a function of body locus,” *Perception & Psychophysics*, vol. 47, no. 3, pp. 298–304, 1990.
[5] R. Lundström, “Vibration exposure of the glabrous skin of the human hand,” Ph.D. dissertation, Umeå universitet, 1985.
[6] J. R. Phillips and K. O. Johnson, “Tactile spatial resolution. ii. neural representation of bars, edges, and gratings in monkey primary afferents,” *Journal of Neurophysiology*, vol. 46, no. 6, pp. 1192–1203, 1981.
[7] R. M. Peters, E. Hackeman, and D. Goldreich, “Diminutive digits discern delicate details: fingertip size and the sex difference in tactile spatial acuity,” *Journal of Neuroscience*, vol. 29, no. 50, pp. 15 756–15 761, 2009.