Roughness, Friction, and the Pleasantness of Touch

Sairam Saikumar[1,2], Maja Fehlberg[1,2] and Roland Bennewitz[1,2]

I. Introduction

Tactile exploration studies typically involve sliding the finger on a surface, known as ‘active touch’. According to the classical two-term description, fingertip friction originates from shear of the skin at the finger-material interface and from deformation of the skin due to roughness asperities. During sliding contact, mechanoreceptors located in the epidermis and the dermis, encode these interactions and allow for the perception of various physical aspects of the object such as shape, texture, coarse and fine roughness. In addition, affective or discriminatory tasks often elicit subjective emotions like (un)pleasantness. Klöcker et al., using the Rasch model, developed a pleasantness scale that allowed for a quantitative assessment of sensation of pleasantness in touch of different materials. They correlated the pleasantness scores for twelve different materials to parameters describing the fluctuations of frictional forces and to the average friction coefficient that are generated by the sliding finger [1]. Our study investigates in how far these findings on parameters influencing pleasant touch for different materials can be confirmed for one material with varying friction caused by different surface roughness.

II. Experimental Procedure

We sandblasted four aluminum and four glass surfaces, each measuring 50x50 mm^2 using fused alumina and glass beads (particle sizes of 250-355 µm and 150-250 µm, respectively) to introduce random roughness. To achieve extremely small roughness, one additional aluminum sample was polished with pastes consisting of diamond particles of sizes 6 and 3 µm. A fifth glass sample was used with commercial grade roughness (~ 0.1 µm) without any further treatment. Participants (17 for aluminum, and 10 for glass) aged between 18 and 55 were involved in both experiments and obtained no prior information about the nature of the surfaces. In each trial, they were presented with a pair of samples and instructed to explore the surfaces by circular movements of their straight index finger. In a forced choice task, they answered the question “Which of the two samples is more pleasant for you to touch?”. The samples were placed on a 3-axis-force plate that enabled us to record the forces during tactile exploration. To account for the variation of friction with skin hydration across participants, we report friction coefficients normalized by the average of each participant.

III. Discussion

We measured the variation of fingertip friction as a function of average surface roughness for the two materials, as shown in Fig. 1a. With increase in the roughness of a smooth surface, there is a reduction in the real contact area

[1]INM - Leibniz Institute for New Materials, Saarbrücken, Germany
[2]Department of Physics, Saarland University, Saarbrücken, Germany

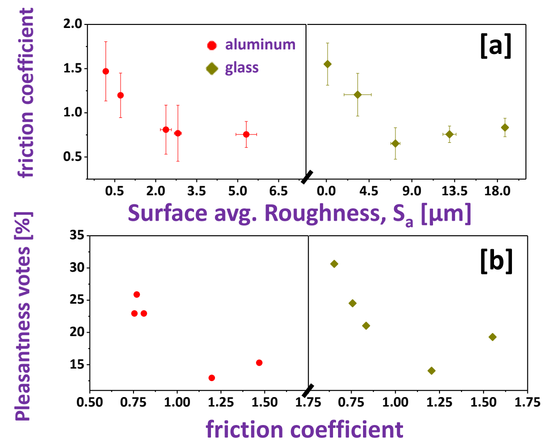

Figure 1. (a) Non-monotonic relationship between normalized friction coefficient and surface average roughness (average of 10 scan areas, each of 1600 x 1600 µm^2) for glass and aluminum (b) perceived pleasantness of the randomly rough samples plotted as a function of friction coefficients.

at the finger-material interface, resulting in decreasing friction. Beyond a specific roughness value (~ 4 µm for aluminum and ~ 9 µm for glass), we observe a slight increase in friction coefficient, owing to the deformation of the skin by surface asperities. The two effects ensue a minimum in friction for both the materials. Since a similar minimum in friction was also reported by Gee et. al [2], for steel with a roughness varying from 0.8 µm to 25 µm, we suggest that this characteristic is generic for all randomly rough surfaces. However, the shift in the surface roughness with minimal friction across different materials still requires additional investigation.

We combine psychophysics with material properties to enhance our understanding of perceived pleasantness upon touch. In Fig. 1b, we observe that perceived pleasantness decreases with increasing friction except for surfaces with extremely flat topographies that received higher pleasantness ratings compared to the slightly rougher surfaces. This suggests that although friction has a significant impact on the perception of pleasantness, there may also be contributions from material properties such as roughness.

The findings of this study indicate that varying the surface roughness for one single material provides a minimum friction regime that strongly influences the perception of pleasantness, offering interesting applications in material design.

References

[1] Klöcker A, Wiertlewski M, Theate V, Hayward V, Thonnard J-L (2013) Physical Factors Influencing Pleasant Touch during Tactile Exploration. PLoS ONE 8(11):79085 doi: .1371/journal.pone.0079085

[2] Gee, M.G., Tomlins, P., Calver, A., Darling, R.H., Rides, M.: A new friction measurement system for the frictional component of touch. Wear 259(7–12), 1437–1442 (2005)