Do humans perceive the velocity dependence of fingertip friction?

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I. Introduction

Friction between the fingertip skin and everyday objects is considered a key component of tactile perception. Deformation of the papillae and the induction of vibrations, e.g., due to intermittent slip, stimulate mechanoreceptors and initiate tactile perception. However, the velocity dependence of fingertip friction and how it might affect tactile perception is only rarely studied. Pasumarty et al. reported a variation of friction with sliding velocity on different materials [1], while Zhou et al. showed that texture perception can be improved by increasing the velocity [2]. We are interested in how material properties, skin properties, and exploration procedures affect friction and thus perception.

In our study, we investigate friction variations when using different sliding velocities for nine different structured surfaces made of three different materials, namely polyurethane, paper, and polyacrylate. We study whether humans perceive the velocity dependence of fingertip friction.

II. Experiments

We asked 28 participants (14 male, aged between 18 and 55) to explore the nine samples in a circular movement of the dominant straight index finger. The sample order was randomized for all participants. Two different velocities (1 and 3 circles per second) were prescribed simultaneously by circulating dots on a screen. The participants were allowed to switch between the velocities as often as they wanted and were not restricted in time to answer the question for which velocity the fingertip friction was higher. Normal force (F_N) and the friction force (F_F) were recorded during the tactile exploration and the friction coefficient $\mu = F_F/F_N$ was calculated. We also tracked the movement of the finger to determine the sliding velocity *v*. In the following analysis, we report median values $\tilde{v}$ and $\tilde{\mu}_{norm.}$, the latter normalized to the average friction coefficient of each participant.

III. Results

The participants maintained the specified angular frequencies well. Due to different radii of their circular movements, the median velocities varied between 21 and 78 mm/s for the slow and between 62 and 186 mm/s for the fast velocity.

Fig. 1a summarizes the change in the normalized coefficient of friction as a function of velocity. We found different tendencies for the three materials tested. While friction increases with increasing sliding velocity for polyurethane samples ($r = 0.67$), friction decreases for polyacrylate ($r = -0.38$). Friction on paper does not

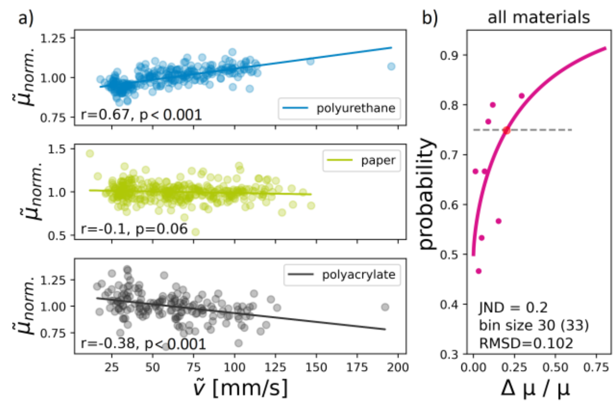

Figure 1. a) Differences in the velocity dependence of friction for three different materials. b) Binned histogram of relative differences in friction and the probability of detecting them.

depend significantly on velocity ($r = -0.1$). In future studies, we will investigate whether these differences in velocity-dependence of friction can be explained by the hydrophilicity of the material or by viscoelastic properties of the skin.

In a forced choice task, the participants perceived the friction to be higher at faster velocities for 29 %, 32.1 % and 76.2 % of the trials on paper, polyacrylate and polyurethane respectively. Our measurements show that friction coefficients were higher for 39.3 %, 33.9 % and 94 % of the trials in the same order.

To determine the just noticeable difference (JND) of friction differences caused by velocity variation, we plot the probability of answers that agree with the measurements as a function of the relative difference in friction in Fig. 1b. The fitted Weibull-function exceeds 0.75 at a difference of 20 %. We therefore consider 20 % to be the JND for friction variations caused by velocity changes. This result is consistent with the JND we found in our previous study on materials with varying microstructure [3] and we suggest that participants perceive friction variations without being distracted by different efforts to hold velocities.

References

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