# THE ROLE OF FRICTION AND THE RATE OF TANGENTIAL FORCE CHANGE IN THE SUBJECTIVE SCALING OF ROUGHNESS.

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Although friction was originally thought to be an important parameter in the subjective scaling of roughness [1], subsequent experiments by Lederman and Taylor [4] found no evidence to support this view and current opinion has ruled out friction as a significant determinant [2]. However, a recent study by Meftah et al [3] found a close correlation between the distance between rows of surface asperities and subjective roughness, again raising the question about whether friction co-varied with spatial period and roughness. The objective of the present study was to examine how normal and tangential forces at the fingertip were deployed in active tactile exploration of textured surfaces in order to determine the contribution of friction to the subjective magnitude estimations of roughness. In the first experiment, six volunteer subjects were asked to scale the roughness of 8 surfaces using a single stroke of the middle finger. The surfaces were 7.5 cm x 2.4-cm polymer strips embossed with truncated cones 1.8 mm high with a spatial period of 2.0 mm in the transverse direction and 1.5-8.5 mm in the longitudinal, scanning direction. The surfaces were mounted on a 6-axis force and torque sensor that measured the perpendicular, contact force, normal to the skin surface, and the tangential force along the axis of stroking. The results confirmed the findings of an earlier study that magnitude estimates of perceived roughness increase approximately linearly up to a longitudinal spatial period of 8.5 mm. Despite stroking speeds that ranged from 10 mm/s for the slowest subject to 157 mm/s for fastest subject, there was no discernable relation between the stroking speeds and the roughness estimates. The mean tangential forces varied from 0.42 to 1.28 N and the mean normal forces varied from 0.29 to 1.01 N. However, there were no correlations that were consistent for all subjects between perceived roughness and either the mean tangential or normal force alone for each spatial period. In contrast, the correlations between roughness estimates and mean friction (the ratio of the tangential to normal force) varied between 0.65 and 0.88 for the six subjects, and were all statistically significant ($p<0.01$). Examination of the trial-by-trial tangential force traces revealed oscillations whose amplitude increased with the longitudinal spatial period and the frequency was determined by a combination of the spatial period and the stroking velocity. These oscillations were even more conspicuous in the rate of change of the tangential force which was quantified as the root mean square (RMS) of the tangential force rate. The mean normalized RMS proved to be strongly correlated with subjective roughness averaging 0.88 for all subjects. In order to dissociate the fluctuations in tangential force from the mean kinetic friction, a second experiment was performed on 6 additional subjects who estimated the roughness of identical lubricated and unlubricated surfaces. Lubrication with liquid soap respectively reduced the mean kinetic friction, the RMS of the tangential force rate and also the subjective estimates of roughness. Taken together, the results suggest that in tactile exploration, the RMS of the tangential force rate may be an important determinant of subjective roughness and

a significant parameter in guiding tactile exploratioin. According to these results a physiological study of the sensitivity of glabrous skin mechnaoreceptors to the rate of change in tangential forces would seem warrented. Research supported by the Canadian Institutes for Health Research.

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