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Influence Of Orientation On The Haptic After-Effect Of Cylindrical Surfaces

Ingrid M. L. C. Vogels, Astrid M. L. Kappers, & Jan J. Koenderink

Helmholtz Instituut, Universiteit Utrecht, The Netherlands

The perceived curvature of a surface is strongly influenced by a previously touched surface (Vogels et al., 1996). The judged sign of the curvature (convex/concave) is biased in the direction opposite to that of the preceding curvature. The magnitude of this haptic after-effect of curved surfaces increases with curvature: after a spherical surface has been touched for 5 s the after-effect on a subsequently touched surface is about 20% of the curvature of the first surface. The strength of the after-effect is also enhanced by the duration of contact with the first surface: the time constant of buildup is about 2 s. The after-effect decreases with increasing time-lapse between the touching of the two surfaces: the time constant of decay is about 40 s.

So far, only the after-effect of spherical surfaces has been investigated. In the experiments reported here we study the after-effect of cylindrical surfaces. These surfaces can be described as:

$$z(x,y) = -1/2\ k\, x^2 \qquad (1)$$

where k is the principal (extreme) curvature of the surface which has the largest absolute value. The curvature along the y-axis is 0/m[1], i.e., flat. Since cylindrical surfaces are not rotation invariant about the surface normal, the curvature distribution, and therefore the posture of the hand, depend on the orientation of the surface. We investigated whether the after-effect of a cylindrical surface depends on its orientation relative to the hand.

[1] Curvature is defined as reciprocal radius.

Method

Three naïve paid subjects participated (WR, RR and WH). The stimuli had a cylindrical upper surface, according to equation 1. The size of the stimuli was such that the edges of the surfaces could not be felt. Stimulus curvature ranged from -4/m (concave) to 4/m (convex).

In each trial subjects had to touch two surfaces presented successively: a conditioning surface (for 10 s) and a test surface. The orientation of the two surfaces was the same within one trial but was varied between trials. Blindfolded subjects were asked to judge the curvature of the test surface along the axis of the principal curvature with the largest absolute value. Their judgments were restricted to "convex" or "concave". The axis could be oriented either along the middle finger (0 deg) or across the middle finger (90 deg). Subjects were not allowed to move their hand over the surfaces.

The conditioning curvature could be: -4, -2, -1, 0, 1, 2, or 4/m. Each conditioning surface was combined with seven differently curved test surfaces and each combination was presented 10 times. A psychometric function was fitted to the percentage of convex judgments for each conditioning surface. We refer to the 50% point of the psychometric curve as the "phenomenal flatness", since we assume that the surface which is judged to be convex in 50% of the cases is perceived as flat. The difference between the 50% and 85% points is called the threshold.

Results

In Figure 1 the phenomenal flatness is given as a function of the conditioning curvature for the two orientations and for all subjects. We fitted linear functions to the data points, which yielded correlation coefficients of about 0.9 (see Table 1). The offset corresponds to the phenomenal flatness after the touching of a flat surface and is subject-dependent. For subject RR the offset depends on the orientation of the test surface. The slope represents the magnitude of the after-effect and is on average 0.18. Although the slope is always larger in the case of an orientation of 90 deg, this is only significant for one subject (RR). When we plot the phenomenal flatness for 0 deg against the phenomenal flatness for 90 deg and fit a linear function we find that the ratio of the after-effects for the two orientations are 1.20 (WR), 1.39 (RR) and 1.26 (WH).

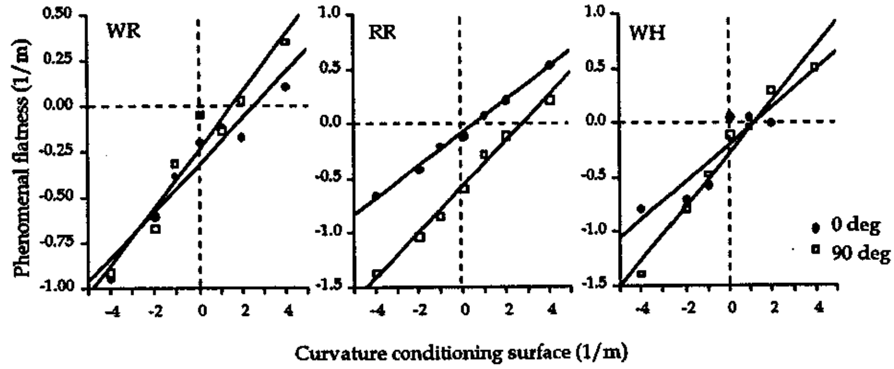

Figure 1. Phenomenal flatness as a function of the conditioning curvature for a surface orientation of 0 deg (filled circles) and 90 deg (open squares).

The thresholds of the psychometric curves did not vary systematically with the conditioning curvature. For subject RR the threshold was significantly larger when the curvature to be judged was oriented along the middle finger (90 deg).

Discussion

Our experiment shows that the perception of curvature along the axis of the largest absolute curvature of a cylindrical surface is influenced by the conditioning curvature of a previously touched surface. The influence tends to be slightly larger when the curvature is presented across the middle finger than when it is presented along the middle finger. However, this anisotropy is rather weak and not always significant. Therefore, this experiment demonstrates that orientation does not have a strong influence on the haptic after-effect of curved surfaces. Since the posture of the hand and the pressure on the skin depend on the orientation of a surface, we conclude that these stimulations are only of minor importance for the after-effect.

Table 1
Offsets (1/m), Slopes and R^2-values of the Linear Functions Fitted to the Data Points of Figure 1.

	0 deg			90 deg		
subject	offset	slope	R^2	offset	slope	R^2
WR	-0.33	0.13	0.92	-0.24	0.16	0.94
RR	-0.08	0.15	0.99	-0.57	0.21	0.98
WH	-0.20	0.17	0.88	-0.28	0.24	0.96

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References

Vogels, I. M. L. C., Kappers, A. M. L., & Koenderink, J.J. (1996). Haptic after-effect of curved surfaces. *Perception, 25,* 109-119.