(23) Cue Integration in the haptic perception of virtual shapes

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The sense of presence in virtual environments may be greatly improved by the display of haptic virtual reality. Current haptic display technology, however, mostly remains unsatisfying and expensive. One way to overcome existing technical limitations might be to "cheat" the haptic system by exploiting its principles. Importantly, human perception of an environmental property normally relies upon the integration of several different cues, which technologically may - at least partly – be substituted to one another. A recent promising starting point for such substitution is the experimental demonstration that haptic perception of three-dimensional shapes can be evoked by just two-dimensional forces (Robles-de-la-Torre & Hayward, 2001: Nature). The experiment dissociated positional and force cues in the perception of small-scale bumps: When sliding a finger across a bump on a surface, the finger follows the geometry of the bump providing positional cues for the shape. At the same time the finger is opposed by forces related to the steepness of the bump. Participants in this experiment reported to feel the shape indicated by the force cues and not by the positional cues.

The present study extended this research. We aimed to disentangle the contributions of force and position cues to haptic shape perception more systematically and to explore their integration principles. For that purpose, we constructed a set of virtual standard curves, where we intermixed force and position cues related to curvatures of 0, 8 and 16 /m using the PHANToM haptic device. Participants compared these to curves in which both cues were correlated (i.e., "natural" curves) following the method of constant stimuli. We fitted psychometric functions to the data set from each participant and each standard curve, thus, obtaining PSEs (points of subjective equality) and 84%-discrimination thresholds. Most importantly, both force and position cues of the standard curves systematically contributed to the perceived curvature indicated by the PSEs. Moreover, for each participant perceived curvature could be well described as a weighted average of the curvature as conveyed by the force and by the position cue. The appropriateness of this simple linear model fits with previous findings from visual and visuo-haptic cue integration (see, e.g. Ernst & Banks, 2002: Nature). Note, that in our experiment, force cues on objects that according to position cues were planes evoked the impression of curves. Moreover, for haptic display these results imply that – at least partly – one cue may be substituted for the other in a predictable manner.