Roughness and spatial density judgments on visual and haptic textures using virtual reality

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Abstract. The purpose of this study is to investigate multimodal visual-haptic texture perception for which we used virtual reality techniques. Participants judged a broad range of textures according to their roughness and their spatial density under visual, haptic and visual-haptic exploration conditions. Participants were well able to differentiate between the different textures both by using the roughness and the spatial density judgment. When provided with visual-haptic textures, subjects performance increased (for both judgments) indicating sensory combination of visual and haptic texture information. Most interestingly, performance for density and roughness judgments did not differ significantly, indicating that these estimates are highly correlated. This may be due to the fact that our textures were generated in virtual reality using a haptic point-force display (PHANToM). In conclusion, it seems that the roughness and spatial density estimate were based on the same physical parameters given the display technology used.

1 Introduction

Surface texture is a multidimensional and multimodally perceived property. However neither the interplay between different textural dimensions nor the contribution of different modalities is well understood as yet. When the same set of textures was presented visually, haptically and visuo-haptically, participants could differentiate either texture roughness or element density well by either touch or vision unimodally. In the bimodal conditions, density judgments were more strongly influenced by vision than by haptics, whereas roughness judgments were more strongly influenced by haptics [1]. According to a "modality appropriateness" interpretation, the bimodal estimates may have been influenced differently by the different *visual and haptic on-*

line reliabilities for judging spatial density and roughness [1, 2], and/or by *biases* due to the *long-term experience with* the relative effectiveness of these modalities [1].

The present study extends the topic of multidimensional textural perception to virtual reality. Using magnitude estimation [3], we explored the dependency of roughness and spatial density judgments on modality by presenting a broad range of textures. We expected that judgments would differ between vision and haptics, and that in the bimodal display the more appropriate modality would influence the judgments to a greater extent.

2 Methods

A total of 16 persons participated for pay. The participant sat in front of a visuo-haptic workbench comprising a PHANToM 1.5 haptic force-feedback device and a 21”-computer screen (Fig. 1a). The right index finger was connected to the PHANToM. Simultaneously, the participants looked via a mirror at the screen. The mirror aligned the visual and haptic stimuli and prevented the participant from seeing his or her hand.

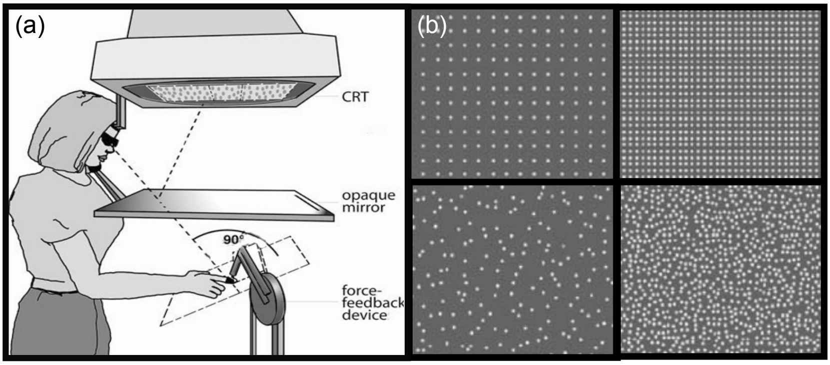

Fig. 1. (a) Visuo-haptic workbench and (b) sections of textures with lowest and highest density (left and right) and lowest and highest jitter (upper and lower; reduced).

Our stimuli were raised-dot patterns (Fig. 1b). Haptically, dot shape was defined by radial sine-functions on an otherwise planar surface (amplitude 0.5 mm, radius 1 mm). Visually, height values of the dots were converted into luminance values (between 5 [surface] and 61 cd/m^2 [0.5mm]). Each texture was defined in terms of the average number of dots/cm^2 and “dot jitter”: we started with a regular dot matrix (0 % jitter); each dot was then randomly “jittered” within a circular area (radius was defined as percentage of average dot distance).

We used a four-variable, mixed design with three within-participant variables: *dot density* [5, 10, 15, 20, and 25 dots/cm^2], *dot jitter* [0, 25, 50, and 75%] and *display mode* [haptic, visual, visuo-haptic]. Between participants we varied the *judged texture dimension* [spatial density vs. roughness]. During each trial, a texture was displayed