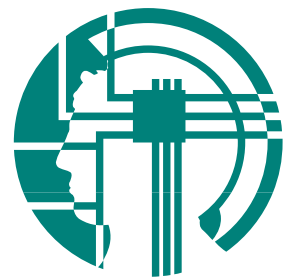# Texture and haptic cues in slant discrimination

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1 Introduction

In vision science the currently most popular models for depth perception are weak fusion models in which the final depth estimate results from a weighted average of the independent depth estimates obtained from each cue [2]. In these models a more reliable cue has a larger weight in the combined estimate. Furthermore, recent studies report that human observes combine depth cues as to obtain the minimal variance unbiased estimator of depth [1].

Different texture types can elicit different performance in a slant discrimination task [3]. In the present study we ask whether the reliability-sensitive weighting is observed in slant discrimination based on texture and haptic cues, when interchanging the texture type on the stimuli (see figure below). In the first experiment, with texture and haptic cues depicting slant consistently, we tested a minimal variance unbiased estimator of slant. That is, whether performance for the haptic and texture cues combined followed:

$$\tau_{th}^2 = \frac{\tau_t^2 \tau_h^2}{\tau_t^2 + \tau_h^2} \tag{1}$$

Where τ denotes the threshold defined as the difference in stimulus intensity between the PSE and the comparison stimulus judged 84% of the trials as more slanted than the standard. In the second experiment, we perturbed the cues in order to estimate the weights assigned by the observers to each cue.

2 Experiment one

2.1 Methods

A temporal two-alternative-forced-choice design was used, in which the stimuli depicted slanted planes. The stimulus could represent a textured plane with no haptic cue (texture-only condition), a textured plane with haptic information (texture-and-haptic condition) or a gray plane with no texture, but containing haptic information (haptic-only condition). The subjects, viewing the stimulus monocularly and touching the (virtual) surface by means of a PHANToM device (SensAble Technologies), had to report which of the two stimuli appeared more slanted in depth. Three subjects participated in the experiment. We tested discrimination around two standards: 27 and 40 degrees slant.
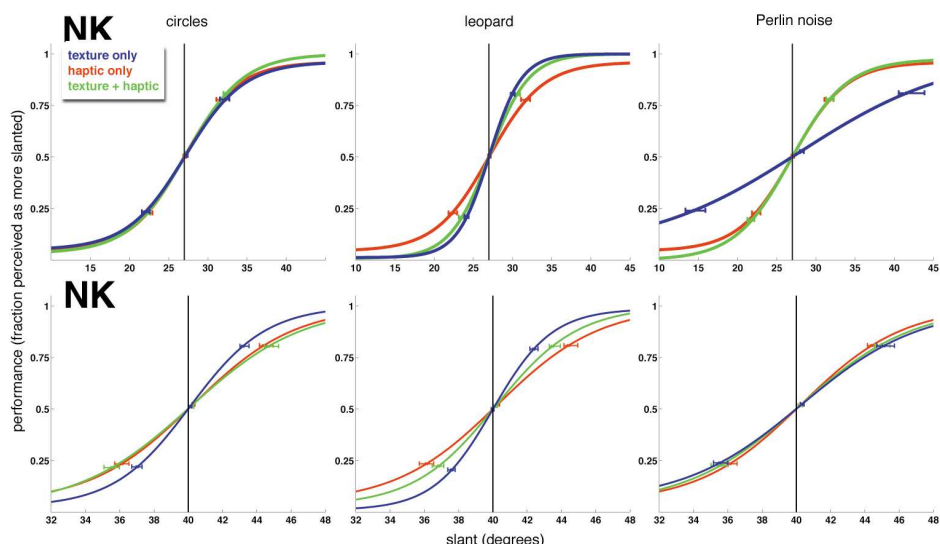
2.2 Results

2.2.1 Texture type effect revisited

An example of the texture type effect on slant discrimination is shown. Error bars represent 68% confidence intervals. The standard (27 degrees of slant) is depicted as a solid vertical line. At the bottom, the patterns used to obtain the data are displayed. From left to right: circles, leopard-skin like and perlin noise textures. For this subject, the task was easiest when a leopard-skin like texture was mapped onto the slanted planes, reflected in the steepest psychometric function. Her worst performance was obtained using Perlin noise. For subjects MB and PR the best texture for the task was circles, followed by leopard-skin as second best.
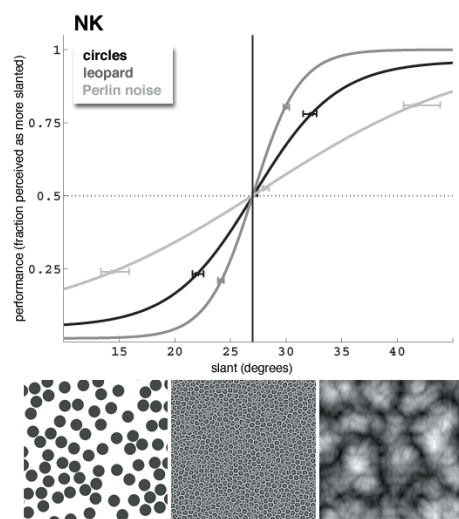

2.2.2 Is there an minimum variance unbiased cue combination?

The results of one subject with the three cue conditions are shown. The top row represents the data for standard 27 degrees and the bottom row for standard 40 degrees. Each column contains the performance for a particular texture type.

Measured (gray) and predicted (black) thresholds for slant discrimination with haptic and texture information provided by three different texture types. Results for the three subjects tested are presented. The predicted thresholds were computed using Equation 1. Error bars represent 68% confidence intervals.
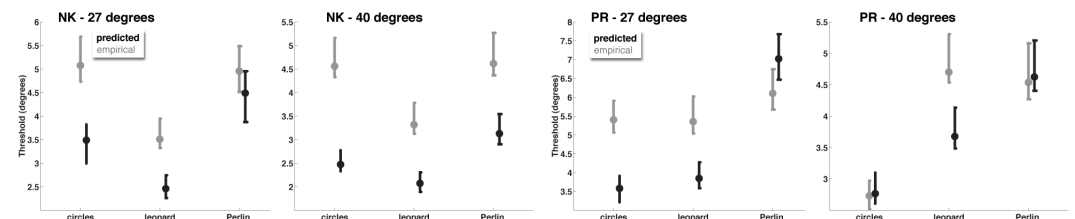

3 Experiment two

3.1 Methods

The methods were similar to the ones described for the previous experiment, but a small discrepancy was introduced in the slant depicted by each cue in the stimuli to allow the estimation of weights according to perturbation analysis. Two subjects participated in this experiment. Only one slant level was tested per subject (27 degrees for NK and 40 degrees for PR).

3.2 Results

Example of results for the perturbation analysis experiment. On the top row the left panel shows the effect of a change in the slant depicted by the texture cue while the haptic cue was fixed at 40 degrees. The right panel shows the opposite. The bottom row shows the PSEs obtained from the psychometric functions from the top row. The left panel shows the data for texture perturbation and the right panel the data for the haptic cue perturbation. The slope, indicated as "m" in the plot, represents the weight given to the perturbed cue. It was obtained with a least-square fit, constrained to obtain weights that add up to unity.
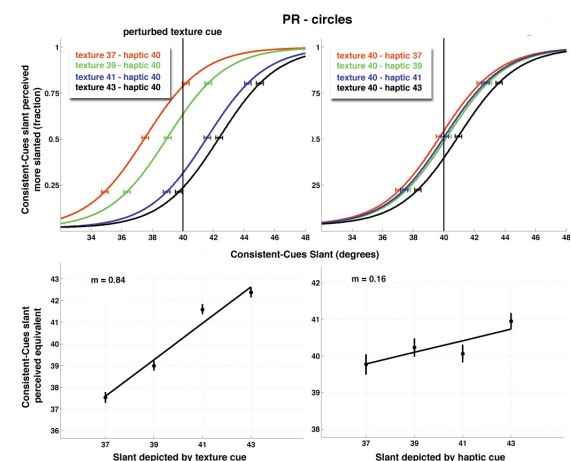
Texture	PR		NK	
	ω_t	ω_h	ω_t	ω_h
Circles	0.84	0.16	0.03	0.97
Leopard	0.58	0.42	0.10	0.90
Perlin noise	0.49	0.51	0.00	1.00

Texture and haptic weights for both subjects.

4 Conclusions

Our data suggest that the visual system is sensitive to the reliability of cues to depth when constructing a depth percept. However, the weights are not statistically optimal in the sense of constructing an unbiased minimum variance estimator of depth. In comparison with [1], besides the task difference (grasping versus touch), Ernst and Banks changed the reliability of the visual cue by jittering the disparity of the random dots used in their stimulus. One could speculate that the difference in our results is due to the visual system being better at measuring the reliability of a stimulus when it can be interpreted as "signal plus noise" than at estimating the reliability of the "signal" itself.

5 Acknowledgement

References

[1] Marc O Ernst and Martin S Banks. Humans integrate visual and haptic information in a statistically optimal fashion. *Nature*, 415(6870), 2002.

[2] Michael S. Landy, Laurence T. Maloney, Elizabeth B. Johnston, and Mark Young. Measurement and modeling of depth cue combination: in defense of weak fusion. *Vision Research*, 35(3), 1995.

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