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# Effects of symmetry, texture, and monocular viewing on geographical slant estimation

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ABSTRACT

Hills often appear to be steeper than they are. The unusual magnitude of this error has prompted extensive experimentation. The judgment mode, such as verbal vs. action-based measures, the state of the observer – whether exhausted or well rested – all can influence perceived geographical slant. We hold that slant perception is inherently shaky as soon as the slope in question is no longer palpable, that is if it is outside our personal space. To make this point, we have added symmetry, texture, and depression to the list of factors that might modulate slant perception. When the frontal slope of a hill is to be judged, it appears steeper when the side slopes are steep. We have used model hills close to the subject. Their slopes were judged most accurately when binocular stereoscopic vision was permitted. When closing one eye, observers grossly overestimated all slopes. This error was larger for verbal judgments than for judgments made by indicating the slope with their forearm, however, the pattern of the overestimation remained unchanged. Surface texture mattered surprisingly little. Depressed subjects produced exactly the same results as healthy controls. We conclude that in action space and in vista space (outside immediate personal space), slopes are overestimated because the visual system attempts to turn the 2D retinal stimulus into a regular 3D object, akin to the erection tendency (Aufrichtungstendenz) found in diminished or 2D-stimuli. This tendency is inherently instable and can be swayed by a large number of variables.

## 1. Geographical slant perception

Gibson and Cornsweet (1952), Gibson (1979) distinguish optical and geographical slant. Optical slant is specified by the relation of the given surface and the observer's line of sight, whereas geographical slant is defined as an inclination of a surface relative to earth horizontal. Observers typically and often grossly overestimate geographical slant (Ross, 1974). The error increases when observers leave the canonical position on level terrain and look down from an elevation or lower their eye height (Ross, 1974, p. 67ff.). Ross attributed the effect of slant overestimation to misperception of distance. If distance is perceptually compressed, then a slope should appear steeper than it does when distance is perceived accurately. When looking down from a hill-top into a valley below, the downhill slope appears flattened, the flat valley rises up and the opposite slope rises steeply, which is caused by the "terrestrial saucer" effect (Ross, p. 71). Fig. 1 illustrates the latter point. The terrestrial saucer or concave earth effect is the converse effect of the flattened dome effect, which is one of the manifold theories to explain the moon illusion (Hershenson, 2013).

Interestingly, this slant overestimation is not limited to terrain but it extends to objects (Rausch, 1952). With reference to objects, this has been called Aufrichtungstendenz, the tendency of objects to right or erect themselves in perception. We have discussed this

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**Fig. 1.** A view of Bolzano, Italy once at nighttime (left panel) and once during the day (right panel) taken from similar view points. Photos Daniel Oberfeld. Note that the runway in the center does not look level in either picture. It looks even more sloped at night. We refer to this effect as Aufrichtungstendenz (erection tendency).

phenomenon extensively with Bruce Bridgeman and had in fact started to experiment with such objects in the lab shortly before his untimely death. The above examples imply that the perceiver can relate the slope in question to the earth-horizontal. Accurate perception of the geographical slant of objects quite obviously requires some reference that tells the observer about the true horizontal. Fig. 2 shows that objects appear to tilt upward when visual reference cues are absent or minimal, and extra-retinal cues, such as vestibular cues are not yoked to the image. The side-walk appears sloped upward. For such cases, where there is uncertainty about the true horizontal, various hypotheses have been put forth.

For instance, Helen E. Ross points out that the raised apparent height of mountains and the apparently raised horizon are caused by such uncertainty and typically cause error of about 6° (Ross, 1974, p. 68). Observers may fail to realize that they are standing on a descending slope or that their eye-level or line-of-sight points lower than normal (Ross, 1974, p. 68), which amounts to the mistaken slope theory, and the mistaken eye-level theory respectively (see Fig. 3).

The mistaken slope theory predicts that the observer (O, ↑) will overestimate the height of T and perceive T′ because the slope OV appears flatter (OV′) than it really is, so that the inclination angle of the opposite slope is raised from VT to V′T′. The mistaken slope and the mistaken eye-level theory demonstrate that distance and slope estimations are intertwined.

In the following, we focus on slope overestimation for cases where information about true horizontal is available. Note, however, that the degree of its availability has to be considered to evaluate the size of the "illusion" when it arises. Note also that the method of assessing perceived slope has in impact on the size of the error. Next to verbal estimates, researchers have used palm boards or elevation of the forearm (see Bhalla & Proffitt, 1999; Chiu, Hoover, Quan & Bridgeman, 2011). The forearm method introduced by Bruce seems to produce the smallest errors, however, the illusion can be captured by all of the above measures (see also Section 9).

Since Ross' publication, a large number of experiments have been conducted to determine the size of this slant estimation error in various contexts (e.g. Bhalla & Proffitt, 1999; Bridgeman & Hoover, 2008; Durgin, Hajnal, Li, Tonge & Stigliani, 2010; Proffitt, Creem & Zosh, 2001; Stefanucci, Proffitt, Banton, & Epstein, 2005). Although a large number of – sometimes controversial – hypotheses have been put forth as to the causes of this unusually large error, the latter is much reduced in personal space (Hecht, Shaffer, Keshavarz & Flint, 2014). Thus, monocular viewing or larger viewing distances beyond the range of effective stereopsis are prerequisite for the error to become spectacular (in the presence of a sufficiently defined horizontal). In the current study, we report three experiments to

**Fig. 2.** This section of paved sidewalk appears to slope upward for lack of reference cues.