Evolution and Human Behavior 29 (2008) 299–304

Evolution and Human Behavior

Original Articles

# Evolved navigation theory and the environmental vertical illusion

Russell E. Jackson[a,*], Lawrence K. Cormack[b]

[a]Psychology Department, California State University at San Marcos, San Marcos, CA 92096-0001, USA
[b]Department of Psychology, University of Texas at Austin, Austin, TX 78712

Initial receipt 16 December 2006; final revision received 4 March 2008

**Abstract**

This study outlines a previously unknown, large illusory component to one of the most common psychological experiences. Evolved navigation theory (ENT) suggests that perceptual and navigational mechanisms reflect navigational costs over evolution. Vertical surfaces pose a distinct cost of falling not present in horizontal navigation. However, horizontal surfaces sometimes form retinally vertical images and researchers often assume that retinal image determines distance perception. We tested ENT-derived predictions suggesting that observers would overestimate surface lengths based on environmental, not retinal, verticality. Participants drastically overestimated environmentally vertical surfaces only and did so at a magnitude related to surface length. These results replicate across multiple settings and methods and are supported by previous studies. Although researchers often assume that selection pushes perceptual mechanisms toward objective accuracy, this study suggests that genetic fitness can sometimes benefit from systematic illusions.


*Keywords:* Evolved navigation theory; Distance perception; Navigation; Vision; Height perception; Signal detection theory

## 1. Introduction

It is often assumed that perceptual mechanisms function identically across most environmental features, especially basic visual perception of line or surface orientation, length, and location. However, evolved navigation theory (ENT) is a research approach that predicts specializations in the perception or navigation of environmental features that are reliably associated with navigational costs over evolutionary time (Jackson, 2005; Jackson & Cormack, 2007a). ENT is primarily an application of signal detection theory to navigation costs over evolutionary time as a means to predict the type and magnitude of specific navigational adaptations. A more general approach of looking at how decision consequences pose selection across domains has been summarized by Haselton and Buss (2000) as error management theory.

ENT focuses on understanding the selective forces particular to navigation as a means to predict unknown locomotor, visual, and other navigational adaptations. For example, vertical and inclined surfaces present a navigation risk of falling that is unmatched in horizontal surfaces. Falls of a few meters produce serious injuries that would be exceedingly rare when navigating a few horizontal meters. Vertical navigation likely posed a strong selective factor in the evolution of terrestrial organisms, certainly those with arboreal ancestors, such as humans. Thus, an implication under ENT is that some perceptual or navigational mechanisms might be specialized to lessen the risks of falling.

One possible method of establishing navigational route preferences is by exaggerating distance perceived from costlier routes because organisms prefer nearer navigational goals (Somervill & Somervill, 1977). A process that exaggerated perceived vertical surface length could thereby decrease vertical navigation in the presence of less costly alternatives. This would result in vertical surfaces perceived as longer than equidistant horizontal surfaces, which would decrease vertical navigation frequency and its associated falling costs. This simple mechanism could dynamically weight navigational decisions in real time across all surfaces by exaggerating perceived length based upon initial surface length and orientation. Such a mechanism captures both navigation difficulty and a primary predictor of falling costs: distance from the ground. This would also flexibly weight navigational decisions by cost without outright prevention of

* Corresponding author.
*E-mail address:* rjackson@csusm.edu (R.E. Jackson).

1090-5138/$ – see front matter © 2008 Elsevier Inc. All rights reserved.
doi:10.1016/j.evolhumbehav.2008.03.001

vertical navigation, which is beneficial for organisms such as humans, who have derived important benefits from vertical navigation over evolutionary time.

A previous investigation of ENT-derived predictions demonstrated that participants unknowingly overestimated vertical surface length at a magnitude corresponding to the potential falling risk (Jackson & Cormack, 2007a). However, many surfaces cast images that are oriented vertically with respect to the observer's head or eyes (i.e., egocentrically vertical) — including surfaces with trivial falling risk. For example, looking down at the distance from one's feet to a distant point ahead on horizontal ground casts an egocentrically vertical image on the retinae, yet poses negligible falling risk. Although researchers commonly assume that the retinal image largely determines perceived distance, it obviously does not predict falling costs accurately enough to decrease them.

The feature that does predict falling cost is environmental, or exocentric, verticality: the extent to which a surface parallels the direction of primary gravitational force. In order for the vertical overestimation derived from ENT to result in appropriate falling cost avoidance, it should exaggerate exocentrically vertical surface length, with little regard for egocentric verticality.

We addressed this question in the current study by comparing real-world distance estimates across effectively equal egocentric images that nonetheless had different exocentric orientations corresponding to very different falling costs. We predicted from ENT that participants would overestimate distance only from exocentrically vertical surfaces because such surfaces posed distinct falling costs over evolutionary time.

We also varied stimulus length in the current study, which we predicted could affect the hypothesized overestimation in one of two ways. First, participants might overestimate by a constant percentage of the stimulus length (i.e., Weber's law) because such a simple algorithm might provide sufficient falling cost avoidance. Alternatively, participants might overestimate by an ever-greater magnitude as stimulus length increases because longer vertical surfaces at these distances pose both greater likelihood and overall cost of falling.

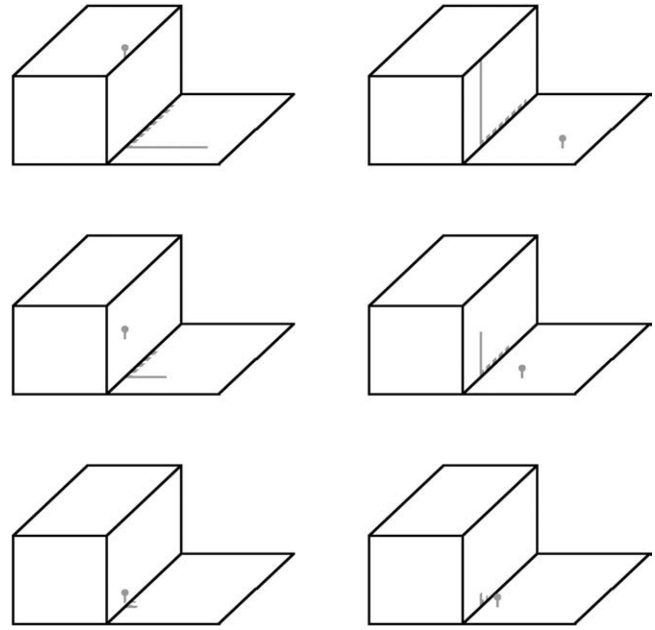

Fig. 1. Observer (dotted icon) position while estimating egocentrically vertical distances (solid gray lines) by showing an equivalent egocentrically horizontal distance (dashed gray lines). Exocentrically horizontal distance estimates are depicted in the left column, whereas vertical estimates are shown in the right column. Long distance (14.39 m) appears in the top row, medium distance (8.37 m) is shown in the middle row, and short distance (2.35 m) appears in the bottom row. Figures are not to scale.

## 2. Methods

Thirty-eight introductory psychology participants reporting normal (20:20) or corrected-to-normal vision estimated distances in an outdoor testing site. Fig. 1 schematically illustrates participants' distance estimates.

### 2.1. Procedure

On each trial, participants saw three dots configured in an "L" shape. The two dots defining the egocentrically vertical segment (the solid lines in Fig. 1) were fixed, and the dot defining the remaining end of the horizontal segment (the dashed lines in Fig. 1), which was a bright green spot formed by a laser pointer held by a research assistant (RA), was adjustable. The participant instructed the RA to move the adjustable dot until the two segments of the L appeared equal in length. In one condition, the two fixed dots were placed exocentrically vertically on the side of a building, and the judgments were made from the ground (Fig. 1, right column). In the other condition, the two fixed dots were placed along an exocentrically horizontal line extending away from the base of the building, and judgments were made from upon the building (Fig. 1, left column). Participants could take as much time and make as many adjustments as they liked. After a participant was satisfied with his or her estimate, the RA determined the corresponding length by comparing the position of the estimate in the real scene to a high-resolution digital photograph of the scene that had a calibrated distance scale superimposed upon it.

We modeled these procedures after similar previous research in order to study this phenomenon in an ecologically valid outdoor setting with rich stimuli. In Chapanis and Mankin's (1967) research on the vertical–horizontal illusion in a realistic setting, they had participants direct an experimenter to move out at a right angle from a vertical surface until the distance looked equal to the height of the vertical surface. Yang, Dixon, and Proffitt (1999) also used this procedure in their work on distance estimation differences between reality and photographs. In other