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Evolved navigation theory and the *plateau illusion*

Russell E. Jackson[a,*], Chéla R. Willey[b]

[a] Psychology and Communications Department, University of Idaho,MS 3043 Moscow, ID 83844-3043, United States
[b] Psychology Department, University of California Los Angeles, 1285 Franz Hall, Box 951563, Los Angeles, CA 90095-1563, United States

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A B S T R A C T

Most people anecdotally feel that the distance extending toward a cliff or slope appears shorter than the same distance extending away from it. This odd impression persists, despite the distance being equal across both conditions and humans encountering such a scenario daily in the navigation of stairs, slopes, curbs, and vertical surfaces protected by handrails. We tested three sets of competing predictions about this previously uninvestigated phenomenon. Data from two experiments coincided with the well-established predictions from evolved navigation theory. Contrary to anecdotal expectations, observers perceive the distance extending toward the edge of a steep slope to be longer than the distance extending away from it. We title this the *plateau illusion* and suggest that it may be an embodied process that arose over evolutionary time in response to navigation risks.

1. Introduction

Imagine standing in two different positions at either end of a fixed distance (Fig. 1 *toward* versus *away*). In one position, you stand at the top of a cliff or steep slope, facing away from it, while you view a flat distance extending in front of you across level ground. In the other position, you stand at the other end of that same distance, facing toward the edge of the steep slope, while you view the distance in front of you. From which position does the distance look shorter: when facing toward the edge or when facing away from it?

Anecdotally, most people think that the distance toward a slope edge will appear too short, certainly shorter than the same distance leading away from it. Indeed, an empirical survey of anecdotal impressions suggests that most people feel that distances toward a cliff edge should appear shorter than distances away from it ($p = 0.035$ from a sample of 38 adults). Tremendously odd about this situation is that the distance is objectively identical in both positions. Why should the direction that one faces alter distance perception? An intuitive anecdotal answer is that the cliff looks dangerous and so heightened arousal causes the distance to loom closely in one's vision when facing it. Regardless of reason, humans' general anecdotal impression is that the distance toward a cliff edge should appear shorter than the distance away from it.

This scenario is an important recurrent feature of normal human navigation and visual perception because the average person encounters this type of environment several times per day in the form of stairs, small rises such as curbs, large rises protected by handrails, and sloped surfaces. Further, given the broad anecdotal impressions about this situation, it is odd that, to our knowledge, no research has addressed this broad observation prior to the current investigation.

The above situation falls under the purview of a specific evolutionary approach to human behavior. evolved navigation theory, or ENT (see Jackson, 2005; Jackson & Cormack, 2007), focuses on how navigation risks or costs over evolutionary time, such as falling, energetic expenditure, and

* Corresponding author. Address: Psychology & Communication Studies Department, University of Idaho, Moscow, ID 83844-3043, United States.

E-mail address: rjackson@uidaho.edu (R.E. Jackson).

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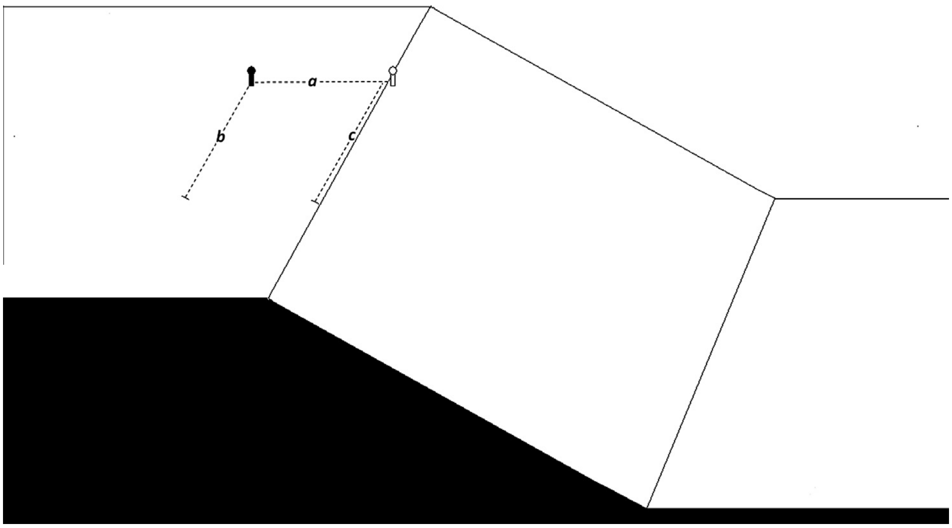

Fig. 1. Observer positions and estimated surfaces. Distance *a* indicates the *toward* estimate while standing at the solid icon and the *away* estimate while standing at the outlined icon. Distance *b* indicates the *ground* estimate (from the solid icon) and *c* indicates the *edge* estimate (from the outlined icon). Figure not to scale.

predation, may shape physical and cognitive capacities. Distance perception is a specific perceptual mechanism that ENT researchers have suggested weights navigational decisions by navigation risks (Jackson, 2005, 2009). Humans tend to prefer the nearest of otherwise equivalent navigational goals; i.e. we navigate overestimated routes less than other routes (Jackson, 2013; also indirectly observed in rats by DeCamp, 1920). Thus, selection pressure from navigating dangerous features in the environment might result in distance overestimation of such features over evolutionary time (Jackson & Cormack, 2007, 2008).

This ENT logic contains a significant departure from the earlier anecdotal reasoning. Anecdotal impressions suggest that the distance toward a slope or cliff should appear shorter than the distance away from it. ENT suggests the exact opposite: The distance toward the edge should appear longer than the distance away from it. Navigating the distance toward a cliff would move the observer toward a falling risk, while navigating in the opposite direction would move the observer away from such risk. If overestimation decreases the navigation of dangerous surfaces, as suggested under ENT, then observers should overestimate the distance toward the edge because navigating it would increase their likelihood of falling. The distance heading away from the edge would move observers away from the falling risk and so should appear shorter than the distance toward the edge or even shorter than the actual distance, under ENT. Such evolutionary logic directly contradicts anecdotal expectations.

These ENT predictions are the obvious and exact reasoning appearing in empirical articles for several years. Jackson (2005) and Jackson and Cormack (2006, 2007, 2008) outlined the ENT reasoning above and presented data that tested this idea in a variety of circumstances, including discoveries of the *descent* and *environmental vertical illusions*. Further, Jackson (2009) found that observers who (unknowingly) most overestimate the length of surfaces from which they could fall also most overestimate the risk of falling. Jackson and Cormack (2010) found that removal of falling risk removes these overestimations, while Jackson and Willey (2011) found that adding falling risks to otherwise correctly estimated surfaces induces these overestimations. This ENT logic appears in print repeatedly and unambiguously over years prior to the current study.

The above anecdotal and evolutionary predictions address a fundamental issue in cognition. Embodied cognition is the idea that physical interaction, or capacity to interact, with the environment can shape the processing of that environment (Barsalou, 2008; Kiefer & Pulvermüller, 2012; Wilson, 2002). How or if embodied processing appears in humans is an open question and one fundamental to our understanding of the nature of human processing (Gibson, 1986; Marr, 1982). The embodiment issue addressed by ENT in the current work is whether a navigation risk affects perception of distances extending toward or away from a cliff.

Contrary to embodied and anecdotal interpretations of visual perception is a widely used approach sometimes identified as the Retinal Image Hypothesis (see Gilinsky, 1951; Kudoh, 2005; Loomis, Da Silva, Fujita, & Fukusima, 1992). This interpretation of visual processing suggests that the proximal visual stimulus (e.g. the image of the object that appears on the retina) determines the majority of the perception of that stimulus. This approach suggests that stimuli occupying equal distances on the retina should generally appear to be of equal length. Certainly the image on the retina is of unparalleled importance, however, proponents of this approach have suggested that even highly disparate distances, such as a short vertical surface and a long receding horizontal surface, can appear equal (Segall, Campbell, & Herskovits, 1966). As in the current study, distances that are equidistant, fall along the same plane relative to the observer, and contain nearly identical visual