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Elucidating the ground-based mechanisms underlying space perception in the intermediate distance range

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Background

Human observers can make accurate egocentric distance judgments on the continuous ground surface in the intermediate distance range up to about 25 m (Loomis et al. 1996). What depth information is used by the visual system to accomplish this perceptual feat? About half a century ago, J. J. Gibson (1950) proposed the ground theory of space perception, which emphasizes the eminent role of the ground surface. Recent studies have provided substantial empirical supports for Gibson's theory, and propelled extended empiricaldriven hypotheses of the ground-based mechanisms underlying space perception (e.g., Sedgwick 1986; Sinai et al. 1998; He et al. 2004; Ooi et al. 2001, 2006; Wu et al. 2004, 2005). Together these mechanisms entail that the visual system constructs a ground surface representation for use as a reference frame to determine the object location. Here, we present our empirical findings that led to the formulation of the proposed ground-based mechanisms.

Main contribution

The construction of the ground surface representation

(1) The visual system depends on the weighted contributions of both the intrinsic bias and extrinsic depth information to construct the ground surface representation. The contribution of the intrinsic bias increases when the extrinsic depth information is insufficient, which leads to a ground surface being represented as slanted with the far-end upward.
(2) The global representation of the ground surface is achieved through a sequential surface integration process (SSIP). The SSIP begins by sampling the near ground surface, which contains reliable near depth cues, to ensure an accurate representation of the near ground surface. The SSIP then uses the near ground surface representation as a template to sequentially integrate the farther patches of the ground surface using the texture gradient information contained on those distant local surface patches. It is essential for the SSIP to integrate from near to far to achieve an accurate global ground surface representation.
(3) The accuracy of the ground surface representation also depends on how, or what, depth cues on the ground surface are selected. This suggests that the SSIP is not an entirely automatic process but can be influenced by the information selection process that samples the ground surface information.

Localizing an object with reference to the global ground surface representation

(4) Using the global ground surface representation as a reference frame, the visual system trigonometrically localizes an object on the ground by relying on the angular declination of the object below the horizon and the observer's eye height. The angular declination is referenced to the eye level, which can be influenced by various visual cues including linear perspective and optic flow information.
(5) An object suspended above the ground surface can be localized using the relative depth cues between the object and ground surface (e.g., binocular disparity and motion parallax) in conjunction with the global ground surface representation.

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Implications

The above-mentioned mechanisms lay the foundation for our appreciation of the perceptual space in the intermediate distance range, as well as for the visual guidance of actions. They also explain a number of empirical observations, such as why one cannot judge distance accurately when gaps, obstacles, texture discontinuity, etc, disrupt the ground surface.

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