Reorientation by Slope Cues in Humans

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Animals are remarkably skilled in their capacity to use a range of environmental features to orient in space once they have lost track of where they are, a process called *reorientation*. Among the types of cues that animals can use, one that has received little attention is the information extractable from a terrain extending in the vertical dimension, such as a geographical slant or slope (Miniaci et al., 1999; Proffitt et al., 1995; Restat et al., 2004). A slope gradient is a source of directional information (Jacobs & Schenk, 2003), enabling a navigator to establish an allocentric reference frame based on the vertical axis (up and down) and the derived orthogonal axis (left-right) of the slope (Restat et al., 2004).

The use of slope for reorientation and goal location has been shown in non-human animals (rats: Miniaci et al., 1999; pigeons: Nardi & Bingman, 2009). The present research aimed to study, for the first time, if humans can reorient by a geographical slant in a real-world environment. This is an ecologically relevant question because terrain slope is part of the lay of the land in natural environments. Furthermore, although it is a perceptually salient cue, as it provides potentially redundant, multimodal sensory activations (visual, proprioceptive, kinesthetic and vestibular stimuli), hill slants tend to be misjudged, and the conscious awareness of slope seems to be highly variable, depending, for example, on physiological and psychosocial resources (Proffitt et al., 1995; Schnall et al., 2008).

The experimental enclosure used consisted of an 8 x 8 ft, wooden platform with a PVC pipe frame on top (see Figure A). The enclosure was tilted to a 5° inclination by raising one side on wooden blocks. Twenty male and twenty female Temple undergraduate students took part to the experiment. Subjects saw the experimenter hide a target in one of the four corners of the experimental enclosure. After having lost their sense of orientation by being spun blindfolded on a swivel chair, they had to find the target. This procedure was repeated for 4 trials, with the target always in the same corner.

Because the enclosure was completely symmetrical and featureless, and no external cue could be seen or heard (participants wore earphones to cover outside noise), the only way to locate the goal was using the slope gradient.

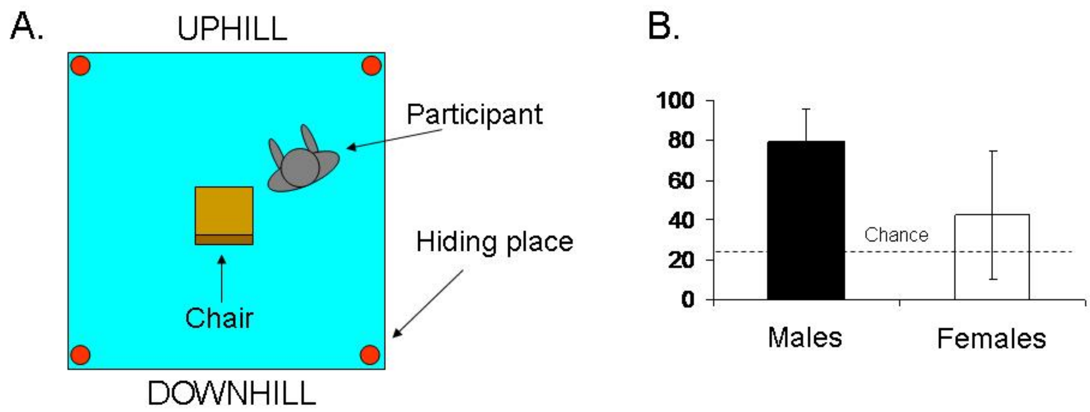
Both genders performed significantly above chance, males: $t(19) = 14.33$, $p < .0001$; females: $t(19) = 2.41$, $p < .05$ (see Figure B). In order to do so, subjects not only were able to encode the goal's vertical coordinate (up-down axis), but also its orthogonal coordinate on the slope (left-right axis). Only by using such an allocentric, bi-coordinate representation was it possible to successfully locate the goal. This ability has been shown in rats and pigeons (Miniaci et al., 1999; Nardi & Bingman, 2009), therefore it was not a surprise that also humans could succeed in such a task.

However, surprisingly males performed substantially and significantly better than females, $t(38) = 4.43$, $p < .0001$ (see Figure B). This effect size is large, $d = 1.4$, with means differing for more than 1 SD.

The psychometric test literature shows, in general, a male superiority in visual perception tasks that require engaging the horizontal-vertical reference frame, such as the Water-level Task and the Rod-and-Frame Test (Linn & Peterson, 1985). However, these gender differences are often eliminated under haptic and proprioceptive versions of the tests, where vision is irrelevant (Proffitt et al., 1995; Robert & Longpre, 2005). This suggests that males might surpass females in spatial tasks that emphasize visual stimuli.

In the present experiment, the four corners of the enclosure were visually almost identical. On the contrary, vestibular and kinesthetic cues could be readily used to perceive the slope gradient and solve the task. Therefore, the fact that females were outperformed by males is remarkable because it shows a robust gender effect in the use of a multimodal cue in which kinesthetic and vestibular information – as opposed to visual information – play a crucial role.

Current research is investigating the factors underlying such a gender difference in slope use. One line of research is examining whether drawing attention to the tilt of the floor might eliminate the male advantage. Another line is testing if the gender difference is related to a differential perception of the kinesthetic and vestibular cues of the sloped floor.



A. Schematic representation of the experimental enclosure viewed from above. The experimenter hid the target under one of the bowls in the corners. Participants were spun on the swivel chair blindfolded and then had to find the target. Note that the chair's axis of rotation was perpendicular to the earth. B. Mean percentage of correct choices (± SD) during the 4 trials on the slope (chance is 25%). Both genders performed above chance. However, males performed significantly better than females ($p < .0001$).

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