INFLUENCE OF GROUND SURFACE ON SLANT PERCEPTION

Alen Hajnal, Blake Watkins, Nicholas Jordan, Jordan Morrow, David Bunch and Attila Farkas
Department of Psychology, University of Southern Mississippi, Hattiesburg, MS 39402, USA
alen.hajnal@usm.edu

Abstract

In past studies surprisingly little attention has been given to the potential influence of ground inclination on perception of geographical slant (Proffitt, Bhalla, Gossweiler & Midgett, 1995). Bridgeman and Hoover (2008) had participants estimate the steepness of hills that they stood on, but the ground slope was not manipulated. Our first experiment investigated the effects of standing on a ramp on the visual perception of surface orientation. Our participants stood on one of three slopes while estimating a separate large ramp in front of them: a 12.5 degree incline, the horizontal ground, or a 12.5 degree decline. For visually inspected surfaces near horizontal there was minimal effect, but for steeper surfaces (e.g. 28 degrees) the visually perceived surface orientation was distorted as if in contrast with the stood-upon surface. More specifically, standing on an incline resulted in less overestimation of the largest ramp slope, than standing on the horizontal ground or on a decline. We hypothesized that perception of slope in this configuration is the result of the interactive effects of at least two sources of information: the kinesthetic information about the ankle's orientation, and the visual information that specifies geographical slant. The second experiment was a test of how visual and haptic information about slant interact and influence perceived slope. Participants stood on the horizontal ground, or touched the ramp with one foot with eyes open or with a blindfold blocking eyesight. The haptic-only information resulted in highest exaggeration of reported slant as compared to the visual-only, and visual-haptic conditions. This confirms our previous findings (Hajnal, Abdul-Malak, & Durgin, in press) that ramps feel steeper than they look. Future studies will reveal whether additional sources of information (e.g. sense of balance or tilt) further influence estimates of geographical slant.

Perceiving the orientation of surfaces that we walk on is essential for getting around our everyday surroundings. Reliable and accurate perception of such surfaces is a basic requirement for safe bipedal locomotion, obstacle avoidance and navigation. The majority of results from past research shows that our conscious awareness of orientation is grossly inaccurate and highly exaggerated, however our actions (such as stepping onto and walking on slanted surfaces) are not. A solid theoretical framework is lacking to explain these remarkable differences between perception and action. Our current and future investigation aims to analyze the contribution of multiple sensory systems (vision, haptic perception, proprioception, balance) to the maintenance of upright stance and safe locomotion on horizontal and slanted surfaces. Our major hypothesis is that a complex interaction among various sensory systems is needed to maintain upright posture and safe walking patterns. There are many sources of sensory information that may specify the slant of ground surfaces that humans usually traverse. In recent years there have been many attempts to isolate the contributions of visual patterns (such as texture gradients, egocentric declination angles, etc.) to explain how slant of ground surfaces is perceived. In contrast, investigations of haptic and kinesthetic sources of information are few and far between. Our present goal was to offer a systematic empirical test of the usefulness of the aforementioned modalities to the perception of slant.

Experiment 1: The influence of ground on slant perception

When we walk we repeatedly make direct contact with the ground surface with our feet. As a consequence, our feet provide reliable information about the properties of the ground (e.g. slant). In past research surprisingly little attention has been given to the contribution of pedal haptic information to perception of geographical slant. The standard procedure in slope experiments has been to stand on flat horizontal ground at the base of large hills or ramps and make a verbal estimate of the apparent steepness or a haptic estimate using a palmboard. The studies by Kinsella-Shaw et al. (1992) are the only ones that used a pedal board to gauge whether a surface is stand-on-able, and Bridgeman and Hoover (2008) had participants stand on the hill that was to be estimated. However, their estimates were done using pantomime hand gestures, not pedal. In the present study we wanted to investigate whether the orientation of the surface that one is standing on has any bearing on the perception of large ramps in view of the observer. As seen in Figure 1 we had three groups of participants: observers either stood on a small flat podium on the horizontal ground, or on a raised platform that was sloped 12.5 degrees upwards or downwards. We hypothesized that the slope that one stands on should serve as a nonvisual information source for what is thought to be a mainly visual task of perceiving the slant of a ramp.

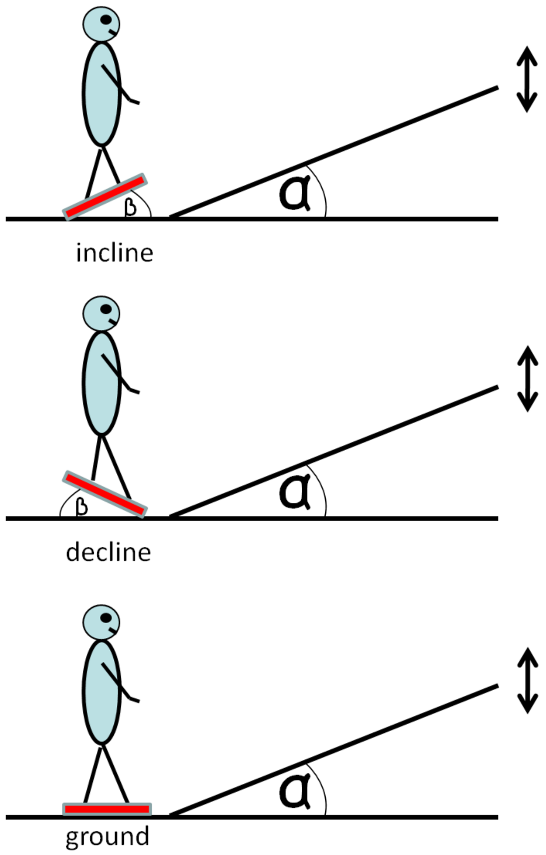

Fig. 1. Three conditions in Experiment 1: participants either stood on the ground, on a small incline or decline (β=±12.5º) near the edge of the large ramp. Curtains (not shown in figure) occluded the left and right side of the ramp, as well as the top end of the ramp. Participants were asked to estimate α, the geographical slant of the ramp. The far end of the ramp was connected to a pulley system that allowed easy resetting of the ramp angle (α).

Method

61 observers were distributed nearly evenly into three conditions (horizontal ground, incline, decline). The experiment was based on a 3x7 mixed ANOVA design with Angle (4º, 8º, 12º, 16º, 20º, 24º, 28º) a within subjects variable and Condition a between subjects independent variable. On each trial the participant saw a portion of a large wooden board in front of him or her. Participants were asked to provide verbal estimate of geographical slant and to respond within a few seconds of viewing the ramp. Each individual was standing at a set distance (50cm) from the near edge of the ramp, on a separate small wooden platform propped up at one of three angles (0º, +12.5 º, -12.5º). No feedback about accuracy was provided at any stage of the study. There were a total of 21 trials presented in random order (7 angles x 3 repetitions). All procedures were approved by the local IRB committee and all participants signed an informed consent form prior to starting the experimental session. The whole procedure lasted approximately 25 minutes per participant.

Results and discussion

There was a main effect of Angle, $F(6, 348) = 362.5$, $p<.001$, trivially indicating that perceived angles were ordered in accordance with physical angles. The Angle x Condition interaction was significant, $F(12, 348) = 3.11$, $p<.001$, revealing an increasing pattern of divergence between the incline group and the other two conditions as the physical angles increased. There was no main effect of Condition. The results are presented in Figure 2.

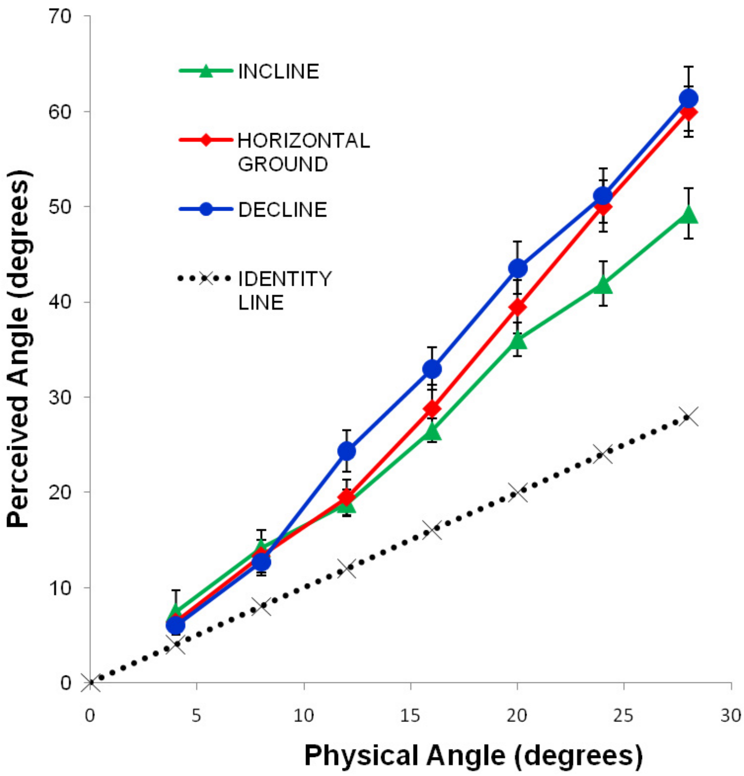

Fig. 2. Perceived slant (expressed verbally) as a function of three conditions and seven physical angles in Experiment 1. The error bars represent ±1 standard error. The identity line indicates undistorted, ideal perception.

All three groups exhibited linear fit between physical and perceived angles with all of the regression lines having significantly larger slopes than 1, suggesting overall exaggeration of perceived slant. The incline condition was less distorted than the other two, with a regression slope of 1.77 and an intercept of -0.6 degrees, whereas the horizontal and the decline groups produced higher slopes (2.27 and 2.34, respectively) and intercepts (-5.3 and -4.3 degrees, respectively). The variance explained was the same (r^2=.99) for all three conditions.

Our results show that the orientation of the surface that one stands on influences perception of slant. One possible interpretation of the results might be that participants implicitly use the ground as the reference surface for "measuring" the ramp's steepness. Our data fit this explanation somewhat, as revealed by the smallest distortion in the incline (forward slant) condition. The apparent similarity of the horizontal ground and decline (backward slant) conditions invites further speculation about the data. We suspect that participants in either both the horizontal ground and decline conditions, or the decline condition only were constrained by the nearness of the upper limit of the range of possible angles (90º), resulting in the two conditions showing virtually the same magnitude of distortion. Another possibility is that our results are simply due to demand characteristics. Even though during debriefing none of our participants were able to articulate why were they asked to stand on a small podium while observing the large ramp, and no one was able to guess what the experimental hypothesis was, a more systematic study is planned to check for the possibility that participants' judgments reflected demand characteristics (Durgin, Baird, Greenburg, Russell, Shaughnessy, & Waymouth, 2009). Our main focus stayed the same: to further investigate the influence of ground contact on slant perception.

Experiment 2: The influence of pedal contact with the ground on slant perception

In the first experiment we established that conscious awareness of the ground we stand on makes a difference in terms of how we perceive components of spatial layout, such as the steepness of large ramps. In the present study we wanted to get a more direct measure of perceived slant by having participants actually touch the slanted ramp surface with their foot. What is the nature of the foot-ground contact that may further bias perception of slant? Is haptic contact sufficient to get an idea of the steepness of the ramp? Would touching and seeing the ramp simultaneously provide added benefit to such perception? We see these various influences on a continuum that is reflective of an interactive, rather than additive relationship among multiple sensory modalities.

Our past research revealed that ramps feel steeper than they look (Hajnal et al., in press), and that visual inspection in itself also results in distortion of perceived steepness, although to a lesser extent than haptic sensory experiences. In the present experiment we tested three groups of participants. The first group was identical to the horizontal ground group from Experiment 1 in that participants were allowed to visually inspect the ramp without making physical contact with it (visual condition). The second group involved blindfolding the participants who were never allowed to see the ramp, but were permitted to make contact with the surface by placing one foot on the ramp while most of the body weight was still supported by the other foot on the horizontal ground (haptic condition). The third group of participants performed the same activity as the second group, and was allowed to look at their feet and the ramp during the task (visual-haptic condition).

Method

46 observers participated in the experiment distributed nearly evenly across the three experimental groups. The same experimental procedure and stimuli were used as in Experiment 1. In the visual condition participants simply stood on the horizontal ground at the edge of the ramp and provided verbal estimates of steepness. In the haptic condition participants were led into the experimental room blindfolded and asked to step onto the ramp with one foot without applying much force, that is, they were told to keep most of the body weight loaded on the other leg that was on the ground. The visual–haptic condition required participants to take a half step onto the ramp in the same way as the haptic group, but this time they were allowed to see their feet and the ramp. Again, no feedback about accuracy was provided at any stage of the study. Between trials a curtain was drawn to occlude the setup of the next ramp angle.

Results and discussion

There was a main effect of Angle, $F(6, 264) = 284.03$, $p<.001$, indicating that perceived angles were increasing in accordance with the increase in physical angles. The Angle x Condition interaction was significant, $F(12, 264) = 2.55$, $p<.003$, revealing differing patterns and magnitude of distortion among the three experimental groups as the physical angles increased. There was no main effect of Condition. The results are presented in Figure 3.

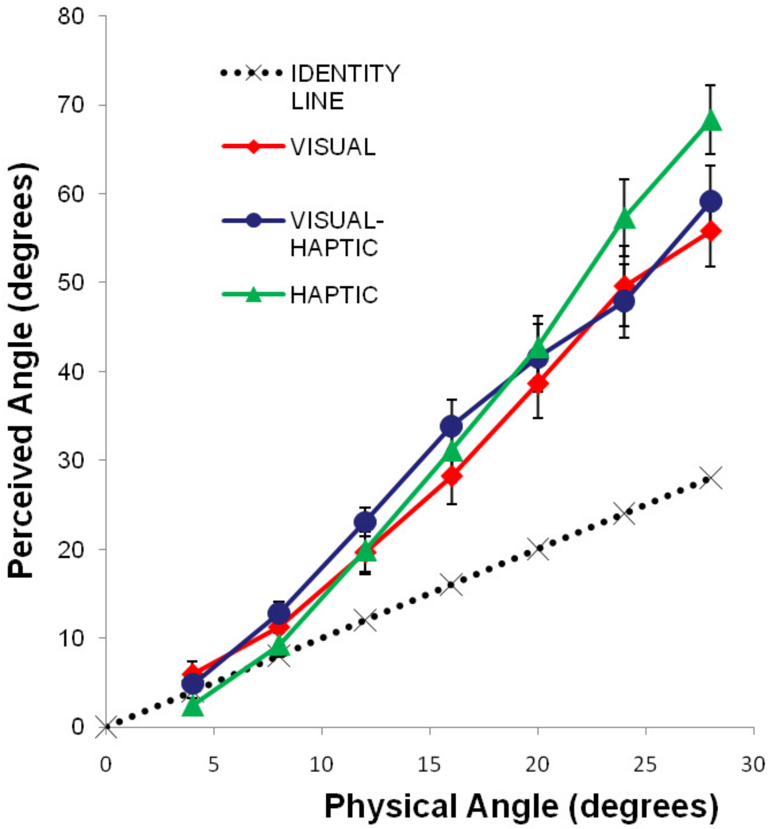

Fig. 3. Perceived slant (expressed verbally) as a function of three conditions (visual, visual-haptic, haptic) and seven physical angles in Experiment 2. The error bars represent ±1 standard error. The identity line indicates undistorted, ideal perception reflecting perfect calibration.

All three groups exhibited linear fit between physical and perceived angles with all of the regression lines having significantly larger slopes than 1, suggesting overall exaggeration of perceived slant. The visual and visual-haptic conditions were comparable (with regression slopes of 2.19 and 2.25, and intercepts of -5.2 and -4.1, respectively) and less distorted than the haptic, with a regression slope of 2.83 and an intercept of -12.3 degrees. The variance explained was the same (r^2=.99) for all three conditions.

One reason for the drastic distortion in the haptic condition (a 28 degree slant was judged on average to be 68 degrees) may be due to the disorienting effect of wearing the blindfold. A follow-up study is planned to test whether access to ambient light lessens the distortion or not. The interesting result is that adding haptic information to visual does not decrease or increase the pattern and amount of perceptual distortion. Future studies are planned to introduce the full cue condition that includes attempting to step onto the ramp with both feet and standing upright, along with designing a more functional task such as asking about action possibilities ("Could you stand on this surface?") instead of steepness, which leaves perception without a clearly defined purpose and goal.

References

Bridgeman, B., & Hoover, M. (2008). Processing spatial layout by perception and sensorimotor interaction. *Quarterly Journal of Experimental Psychology*, *61*, 851-859.

Durgin, F. H., Baird, J. A., Greenburg, M., Russell, R., Shaughnessy, K., & Waymouth, S. (2009). Who is being deceived? The experimental demands of wearing a backpack. *Psychonomic Bulletin & Review*, *16*, 964-969.

Hajnal, A., Abdul-Malak, D. T., & Durgin, F. H. (in press). The perceptual experience of slope by foot and by finger. *Journal of Experimental Psychology: Human Perception and Performance*.

Kinsella-Shaw, J. M., Shaw, B. & Turvey, M. T. (1992). Perceiving "walk-on-able" slopes. *Ecological Psychology, 4,* 223-239.

Proffitt, D. R., Bhalla, M., Gossweiler, R. & Midgett, J. (1995). Perceiving geographical slant. *Psychonomic Bulletin & Review*, *2,* 409-428.