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D. M. Shaffer

E. McManama

Frank H. Durgin
Swarthmore College, fdurgin1@swarthmore.edu

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Manual anchoring biases in slant estimation affect matches even for near surfaces

Dennis M. Shaffer and Eric McManama

The Ohio State University—Mansfield

Frank H. Durgin

Swarthmore College

Eric McManama and Dennis M. Shaffer, Department of Psychology, Ohio State University.

Frank H. Durgin, Department of Psychology, Swarthmore College.

Correspondence concerning this article may be addressed to Dennis M. Shaffer, Department of Psychology, The Ohio State University--Mansfield, 1760 University Drive, Mansfield, OH 44906. E-mail: shaffer.247@osu.edu.

Abstract

People verbally overestimate hill slant by ~15-25° whereas manual estimates (e.g., palm board measures) are thought to be more accurate. The relative accuracy of palm boards has contributed to the widely cited theoretical claim that they tap into an accurate, but unconscious motor representation of locomotor space. Recently, it was shown that a bias that stems from anchoring the hand at horizontal prior to the estimate can quantitatively account for the difference between manual and verbal estimates of hill. The present work extends this observation to manual estimates of near surface slant to test whether it derives from manual or visual uncertainty. As with far surfaces, strong manual anchoring effects were obtained for a large range of near surface slants, including 45°. Moreover, correlations between participants' manual and verbal estimates further support the conclusion that both measures are based on the same visual representation

Key words: Geographical slant, action measures, anchoring, two-systems

Manual anchoring biases in slant estimation affect matches even for near surfaces

For twenty years, people's estimates of slant have frequently been measured both verbally and manually (Bhalla & Proffitt, 1999; Bridgeman & Hoover, 2008; Durgin, Hajnal, Li, Tonge, Stigliani, 2010a; Durgin, Li & Hajnal, 2010b; Hajnal, Abdul-Malak & Durgin, 2011; Li & Durgin, 2011; Proffitt, Bhalla, Gossweiler, & Midgett, 1995; Shaffer, McManama, Swank & Durgin, 2013; Stigliani, Li & Durgin, 2013). Verbal estimates of hill slant have typically been quite exaggerated and are almost always much higher than estimates made by manual matching. It has sometimes been argued that manual measures tap into a more accurate motor representation (e.g., Proffitt et al., 1995) or are simply quite accurate (Feresin & Agostini, 2007; Taylor-Covill & Eves, 2013). An alternative view is that standard procedures used for manual measures have inadvertently been selected because they produce the theoretically-desired accuracy (Durgin et al., 2010a, 2011; Shaffer, McManama, Swank, Williams & Durgin, 2014). For example, egocentric biases in the haptic perception of orientation (Coleman & Durgin, 2014; Kappers, 2004) guarantee that palm boards set at waist level will produce lower estimates than those set higher (e.g., shoulder height). The standard procedure calls for setting the palm board at waist level. Moreover, we have recently shown that when palm boards are adjusted from horizontal they give much lower hill matches (by 15° to 30°) than when they are adjusted starting from vertical (Shaffer et al., 2014). Again, the standard procedure used in essentially every paper on perceived slant is to have participants start manual adjustment from horizontal. The present experiments seek to further investigate this anchoring effect.

Anchoring effects, including those found both with palm board adjustments and with free hand matching, are expected under conditions of uncertainty (Tversky & Kahneman, 1974). That is, biases like anchoring are not expected when an exact answer can be produced with certainty. For example, if asked "What is half of 90?", the answer "45" is not likely to be affected by first mentioning "0". When asked to match one's hand orientation to the slant of a visible surface there are two possible sources of uncertainty (or variance). There is (possibly unconscious) perceptual uncertainty about the slant of the surface to be matched, and there is (possibly unconscious) uncertainty about the orientation of one's own hand. Both of these forms of perceptual uncertainty can be thought of as the basis for making matching tasks susceptible to anchoring.

This dual source of variance in perceptual matching tasks raises the question whether, in the act of manually matching the orientation of visually-perceived hills, the primary source of uncertainty is manual or visual. In the present investigation we tested for manual anchoring effects when matching near surfaces because less visual error variance is expected in near space, whereas proprioceptive error variance should remain similar. It has been shown that near surfaces appear less exaggerated in slant than do farther surfaces (Bridgeman & Hoover, 2008; Hecht, Shaffer, Keshavarz & Flint, 2014; Li & Durgin, 2010). Li and Durgin (2010; 2013) argued that this effect of viewing distance could be explained by increasing stereoscopic depth compression at farther distances combined with the systematically exaggerated perceptual coding of slant (Durgin et al., 2010b). An alternative view is that there is greater visual uncertainty at far viewing distances, leading to greater bias. If the latter view were correct, and anchoring in manual matching tasks were due primarily to visual uncertainty, we might expect that manual anchoring effects would be greatly reduced for near surfaces. But if manual anchoring effects were due primarily to perceptual uncertainty in the haptic/proprioceptive system, then large anchoring effects (i.e., of about 20°) would be expected even for manual matches to near surfaces.

Manual slant underestimation found for near surfaces (e.g., Durgin et al., 2010a) can be predicted by the shallower verbal estimates that are found for near surfaces than for far surfaces (Durgin, 2013; Li & Durgin, 2011). Distance-related changes in perceived slant have been established using both explicit estimates and shape constancy tasks (Li & Durgin, 2010). Moreover, studies that have examined correlations between manual and verbal estimates for a single hill have reported that these correlations (ranging from about 0.2 to 0.5) are relatively high, considering the different sources of measurement variance that each type of measure contributes (Shaffer et al., 2014; Stigliani et al., 2013). These observations suggest that anchoring effects on manual estimates concerning near surface slant would likely continue to be quite large. This is of some importance to establish empirically, however, because it helps to clarify that manual estimates may be exceedingly noisy measures even in near space (Durgin, 2014; Durgin et al., 2010a). This is of theoretical importance because palm board measures have often been used to report null effects as one part of a dissociation with verbal measures, whereas these null effect might simply be due to measurement noise.

Method

We performed an anchoring experiment using an adjustable ramp in near space as the visual stimulus. Observers made six manual matches (either with a free hand or with a palm board) and then gave a verbal estimate of the slant of the ramp. Half the participants in each condition gave manual estimates starting from a horizontal hand position, while the other half gave manual estimates starting from a vertical hand position. Our primary hypothesis was that manual anchoring effects when matching visual surfaces in near space would be as large (about 20°) as those found for hills. In addition, we expected that manual estimates would continue to be correlated with verbal estimates within each group, even though verbal estimates are not typically affected by manual anchoring (Shaffer et al., 2014).

Design

There were four between-subject conditions representing the 2 x 2 crossing of initial hand orientation (vertical or horizontal) and type of manual measure (palm board or free hand). Six ramp orientations (6°, 18°, 30°, 42°, 45° and 54°) were tested in randomized order. For each ramp orientation, the manual estimate of slant was collected first, followed by the verbal estimate. The fixed order was intended to minimize the likelihood that the manual estimate was based on the verbal estimate given.

Participants

There were a total of eighty participants divided equally among the four conditions. All participants were undergraduates (43 male) from The Ohio State University at Mansfield who participated in fulfillment of an Introductory Psychology requirement.

Materials

We created a wooden ramp by attaching two pieces of wood (1m by 1m) with a hinge. Six pairs of pre-cut rods were used to hold the slanted portion of the ramp at the 6 different angles of inclination.

The same palm board used in Shaffer et al. (2014) was used here. It was situated at mid-torso level to afford vertical positioning and was set to either a vertical or a horizontal anchoring position in advance of each trial. For the free hand measure, a calibrated lightweight (0.084 kg) inclinometer (Digi-Pas DWL80e) was attached to the back of the hand of the observer with adhesive tape and held securely by elastic straps (see Shaffer et al., 2014). A vertical screen blocking the participants' view of their hand was adjusted to shoulder height so that participants could not see their hand when making their settings.

Procedure

Each participant stood 1 meter from the base of the ramp. In the free hand conditions, the participants were asked to set their hand to the appropriate anchor orientation (i.e., horizontal or vertical) at the beginning of each trial. Prior studies have shown that participants can manually represent horizontal and vertical with no reliable bias (e.g., Shaffer et al., 2014). Participants were then either told to adjust the orientation of their hand or the palm board to make it parallel with the slope of the ramp. After a digital reading was taken of the indicated orientation, participants were told to lower their hand to their side and then asked to estimate the slope of the ramp in degrees from horizontal. Participants turned their back to the ramp between each of the six different ramp orientation settings.

Analysis

Digital inclination recordings from the back of the hand for free hand estimates were adjusted by half the average angular hand width (i.e., 6.5°), as per the method of Durgin et al. (2010b). Using mixed-effects modeling, we expected to find an interaction between measure (manual or verbal) and manual anchoring (horizontal or vertical) because no effect of manual anchoring was expected for the verbal measure, whereas a large anchoring effect was expected in the manual measures.

At far distances, manual estimation data is typically found to be noisier (more variable) than verbal estimation when variance is scaled relative to the gain of the measure (e.g., Durgin, 2013). By dividing the standard deviations (SD) of estimates for each slant within each condition by the gain of the measure (change in estimated slant relative to changes in actual slant) within that condition, we can compute a mean scaled SD for the manual measures and for the verbal measures and compare their normalized variances (squared SDs) statistically.

Correlations between measures (with the physical stimulus held constant) may imply a common underlying perceptual representation. To test for the expected correlation between verbal and manual estimates of any particular slant we treated slant as a random variable, and calculated correlations at each physical slant value within each condition. We then fit a linear mixed-effects regression model to the correlation coefficients to see if they differed by measure type or anchor.

Finally, to compare the amount of anchoring in the present experiment with that reported by Shaffer et al. (2014) for hills, we sought to use the slant values that produced verbal estimates most similar to those measured by Shaffer et al.

Results

Analysis of anchoring effects in present data

Two linear mixed effects regression models with measure (manual or verbal) and anchor (horizontal or vertical) as fixed effects and subject and slant as random effects were computed. The model that included the interaction term between the two fixed effects was compared with the model that did not. This comparison produced a highly reliable Chi-Square statistic indicating a reliable interaction given that the model with the interaction term included provided a substantially better fit to the data, $X^2(1) = 66.1$, $p < .0001$.

As expected there was a large effect of anchoring on the manual measures. A linear mixed-effects regression on the manual estimates with anchor (horizontal or vertical) as a fixed effect and subject and slant as random effects estimated a substantial effect of manual anchoring on manual slant estimates (19.3°). Linear modeling indicated that average palm board estimates were 7.5° lower than free hand estimates (reliably lower: $t(75) = 5.0$, $p < .0001$). However, anchoring did not differ reliably between palm board and free-hand measures: A mixed-effects linear model that included the interaction between anchoring and measure type fit the data no better than a model that did not include the interaction, $X^2(1) = 0.8$, $p = .37$.

In contrast, and as expected, there was little evidence of anchoring affecting the verbal measures. A linear mixed-effects regression on the verbal estimates with anchor (horizontal or vertical) as a fixed effect and subject and slant as random effects estimated only a small (2.6°) effect of manual anchoring on verbal estimates. Applying the standard tools of null-hypothesis testing, the null hypothesis that there was no effect of anchoring on verbal estimation could not be reliably rejected, $t(72) = 1.8$, $p = .075$. In combination with the reliable interaction between anchoring and measure type, this indicates that anchoring had a much larger impact on manual measures than on verbal estimates.

Analysis of normalized measure variances in the present data

For each slant a mean manual scaled SD was computed by dividing the SD of the estimates by the gain of the estimates (i.e., the slope of the estimates shown in Figure 2) in each condition and averaging across conditions. Squaring this value gives a normalized variance score for the manual measure (variances did not differ consistently by manual measure type) at each slant. A similar normalized variance was computed for verbal estimates at each slant value. For each of the 6 slant values tested, the normalized variance for the manual measure was reliably greater than the normalized variance for the verbal estimates (all $p < .003$, except the 30° slant, $p = .0128$). Thus, even for near slants, the normalized variances of the manual measures were higher than the normalized variances of the verbal estimates.

Analysis of correlations between manual and verbal estimates

For each slant, each participant gave both a manual and a verbal estimate. Because the manual estimate was given first, and there was a large anchoring effect on the manual estimate, but practically no anchoring effect on the verbal estimates, it is clear that the manual estimates did not directly affect verbal estimates. Nonetheless, if observers making each of these estimates intended for them to represent the same perceived slant, individual variation in slant perception should produce correlations between the measures across participants. Table 1 shows the correlation coefficient between manual and verbal slant estimates for each slant in each of the four conditions. Note that these are correlations between two measures given by the same participants with physical slant held constant. Each measure has its own sources of measure variance (e.g., numeric rounding for verbal estimates). If the two measures reflected two different underlying perceptual representations, they should show no correlation. The presence of correlation shows that part of the variance in the two measures is in common. Presumably the common variance is that due to inter-subject variability in the underlying perceptual representations of the same physical slant.

Table 1. Correlations between manual and verbal estimates by slant and condition

Measure	Anchor	Slant (deg)						
		6	18	30	42	45	54	mean
Palm board	Horizontal	0.50	0.60	0.42	0.71	0.45	0.21	0.48
Palm board	Vertical	0.37	0.46	0.21	0.13	0.32	0.35	0.31
Free hand	Horizontal	0.40	0.14	0.39	0.20	0.12	0.10	0.22
Free hand	Vertical	0.50	0.35	0.62	0.45	0.59	0.58	0.52

A mixed-effects linear model of the correlation values with Measure Type (palm board or free hand) and Anchor (horizontal or vertical) as fixed effects and

Slant as a random effect found no significant effect of Measure or Anchor on the correlations (both $t < 1$). However, the average correlation in the data (0.38) was highly reliable, according to the model, $t(21) = 10.7$, $p < .0001$.

Comparisons to prior data

The verbal estimates of slant in the present experiment replicate the patterns observed by Durgin and Li (2011; Durgin, Li, & Hajnal, 2010b; Li & Durgin, 2010) in that verbal estimates of near surfaces appear to have a gain of about 1.5 relative to actual slant as shown in Figure 1. This somewhat simplifies the task of quantitatively comparing anchoring in the present experiment to anchoring in the data of Shaffer et al. (2014).

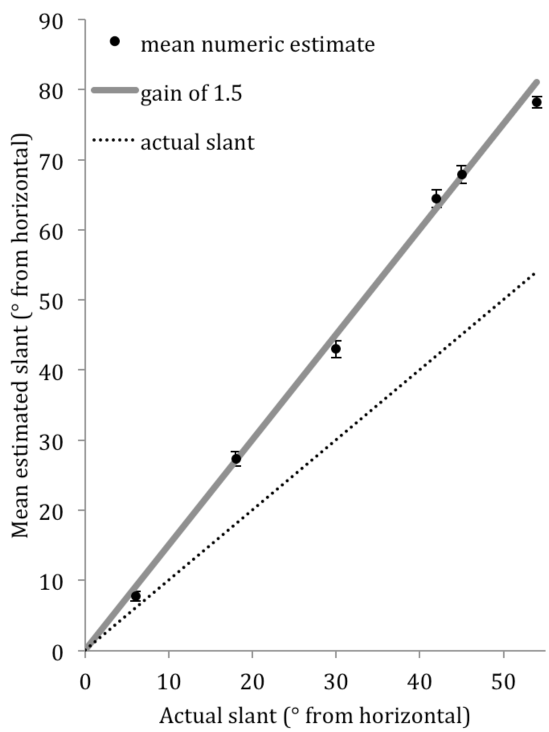

Figure 1. Verbal estimates of slant for near surfaces. Standard errors of the means are shown.

For the steeper (21.7°) of the two hills tested by Shaffer et al. (2014), the mean verbal slant estimate was 53.5°. Based on the 1.5 gain model, this corresponds to a near slant of about 36°. This falls halfway between the 30° and 42° ramps in the present experiment. For their palm board, Shaffer et al. estimated an anchoring effect for their steep hill that had a confidence interval from 25.2° to 33.3°. In the present data, the mean anchoring effect for the palm board (for slants of 30° and 42°) was 25.6°. For the corresponding free hand measure, Shaffer et al. reported an anchoring effect with a confidence interval of 8.1° to 23.1°. In the present data, the mean anchoring effect for the free hand measure (for slants of 30° and 42°) was 19.7°. In both cases, the present means are reasonably similar to those reported by Shaffer et al.

For the shallower (6.2°) of the two hills tested by Shaffer et al. (2014), the mean verbal slant estimate they reported was 24.6°. Based on the 1.5 gain model, this corresponds to a near slant of about 16.4, which is quite close to the 18° ramp in the present experiment. For their palm board, Shaffer et al. estimated an anchoring effect for their shallow hill that had a confidence interval from 16.4° to 29.8°; in the present data, the mean anchoring effect for the palm board for the 18° slant was 16.5°. For the corresponding free hand measure, Shaffer et al. reported an anchoring effect with a confidence interval of 11.3° to 16.3°; in the present data, the mean anchoring effect for the free hand measure (for slants of 18°) was 15.8°. In both cases, the present mean is similar in magnitude to that reported by Shaffer et al.

Overall, the anchoring effects found in the present experiment for near slants are similar in magnitude to those reported by Shaffer et al. (2014) for perceptually similar hills. This observation is consistent with the idea that these anchoring effects primarily reflect perceptual uncertainty in haptic/proprioceptive perception rather than in visual perception.

Moreover, note that the correlations between verbal and haptic measures persist even though only the haptic measures are strongly affected by anchoring. This is consistent with the idea that the correlation reflects a common intended estimate (based off the visual perceptual information). This common underlying representation is probably masked in many experiments by strong manual anchoring effects in addition to a difference in the scaling of manual measures and haptic measures.

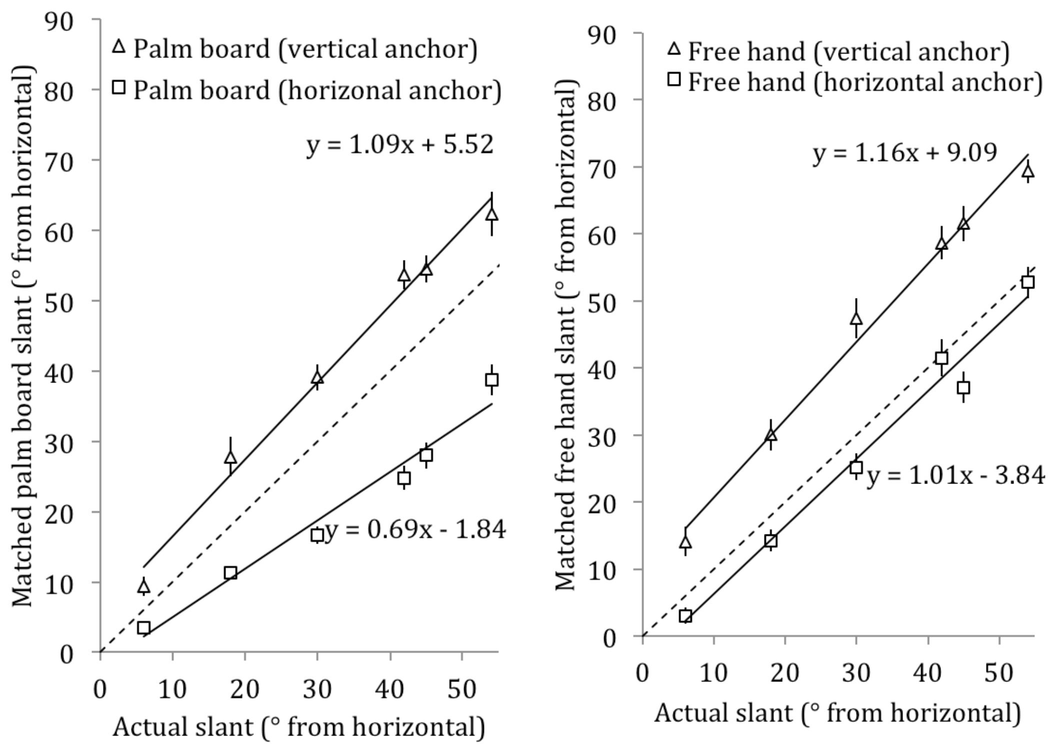

Figure 2. Manual estimates of slant for near surfaces. Standard errors of the means are shown.

As shown in Figure 2, the effect of anchoring on both of the manual measures in the present data is to make them straddle the true slant orientation. On the whole, manual slant estimates in near space are thus fairly accurate. This does not mean that these manual measures are based on a different, more accurate, underlying representation than the verbal measures (else the two measures would likely not be correlated), but it is consistent with the theory that manual actions must tend to be calibrated so that they are effective in acting on the world even when perceptual experience is distorted (Li & Durgin, 2012; Li et al., 2013). For example, participants asked to set their (unseen) hand to "45°" will only set it to about 34°, and this corresponds to the visual slant that they describe as appearing to be 45° (Li & Durgin, 2012). This can account for why their manual matches to a 34° surface can be accurate: If they think the 34° surface is about 45° and adjust their hand until it feels like it is 45°, they will match the surface pretty well.

The special case of 45°

Among the other orientations used for this study, we included 45° because it is geometrically special. If each manual measure were symmetrically affected by anchoring, we would expect symmetrical bias for matches to the physical 45°. But, consistent with prior findings of palm board underestimation for near space, palm board estimates from horizontal fell short of 45° by an average of 17°, which is reliably greater than the upward bias of 9° observed for palm board estimates made from vertical, $t(38) = 2.79$, $p = .0081$. In contrast, the free-hand measure when made from horizontal, fell short of 45° by only 8°, whereas free hand estimates initiated from vertical overestimated the 45° mark by 16°, which was a reliably greater upward deviation, $t(38) = 2.44$, $p = .0192$. In general, the asymmetric anchoring observed for the physical 45° slant indicates the complexity of trying to interpret manual estimates. Each of these manual estimation methods showed large anchoring effects, but neither was symmetrical about 45°. We can speculate that the biomechanics of the palm board interface contribute to the horizontal bias in its outputs (which has, in turn, produced the cognitive illusion of greater accuracy than verbal measure in past studies of hills).

Past research has shown that the actual 45° does not appear to be psychologically salient. That is, by asking participants whether physical surface orientations are closer to vertical or to horizontal, Durgin et al. (2010b) measured psychometric functions (in the absence of numeric estimation) that indicated that a much lower physical orientation (e.g., 34° from horizontal) appeared to be equidistant between vertical and horizontal. But even if an approximation of the psychological 45° point is selected for analysis (i.e., data for the 30° ramp), asymmetries persist in the manual estimates given. This shows that the manual anchoring asymmetries are not driven merely by perceptual asymmetries concerning the perceived 45°.

Discussion

Palm boards have previously been held up as privileged measures because of their apparent accuracy at matching hills. But a growing body of evidence suggests that palm boards are biased and potentially noisy methods for assessing perceived slant. Moreover, rather than dissociating from verbal measures, they actually correlate with them (across subjects for a given physical slant). Here we have shown that the anchoring effects we first reported for palm board and free hand slant estimates with outdoor hills generalize to indoor ramps and thus appear to primarily reflect haptic or proprioceptive uncertainty rather than visual uncertainty.

We tested ramps across a large range of angles, from 6°-54°. The anchoring effects for near surfaces were similar to those found for more distant hills outdoors by Shaffer et al. (2014). Manual anchoring biases are thus instrinsic to the use of manual measures and need to be taken into account when interpreting such measures. It is a logical error to interpret manual slant estimates as reflecting an underlying accurate slant representation on the grounds that their outputs correspond to actual slant values. Manual slant estimates are strongly affected by initial hand orientation. Nonetheless they also fluctuate with (i.e., are correlated with) verbal estimates given by the same subjects, which suggests verbal and manual estimates are based on the same perceptual representation of spatial layout.

Apparent matches between manual estimates and hills may be artifacts. As predicted by calibration theory, once anchoring is taken into account, manual slant estimates are better aligned with near surfaces than far surfaces. In order for manual estimates to match outdoor hills (which appear much steeper than similarly sloped near surfaces), a number of biases may need to be employed. Recent work has identified two sources of bias: (1) Manual adjustments signaling orientation that are made low in peripersonal space will tend to have a lower orientation than those made higher in peripersonal space (Coleman & Durgin, 2014). (2) Similarly, hand gestures and other manual adjustments initiated from horizontal will tend to produce lower slant estimates than manual adjustments initiated from vertical. By codifying a procedure that included a waist high palm board and a horizontal anchor, the pioneering work of Proffitt et al. (1995) may have acted as a sort of recipe for producing the cognitive illusion that manual hill slant estimation was accurate.

Among the present data, the closest condition to producing accurate estimates is the free hand measure initiated from horizontal. This may reflect that we are most likely to be well calibrated for reaching out to near objects with our free hands (e.g., Durgin et al., 2010a), and that most of our reaching involves lifting rather than lowering our hands. It is not that our hands have special access to a correct representation of the geometry of surfaces. Rather, our hands may be guided by the same geometrically-distorted visual information that produces exaggerated verbal estimates. The reason for manual accuracy in near space (i.e., accurate reaching actions demonstrated by Durgin et al., 2010b) could be based entirely on visuomotor adaptation of proprioception (Harris, 1963).

Conclusions

Manual estimates of slant are surprisingly noisy even in near space. The present data provide further evidence against the two-systems theory of geographical slant perception by showing that a large anchoring bias may explain why manual action measures have sometimes appeared to accurately represent hill slant. Moreover, the presence of consistent and reliable correlations between manual and verbal measures of slant lends converging support to the idea that a common underlying perceptual representation of surface layout controls both types of measure. The susceptibility of manual measures to large artifactual biases renders them an unreliable source of evidence regarding the accuracy or inaccuracy of underlying perceptual representations.

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