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Sugar and space? Not the case: Effects of low blood glucose on slant estimation are mediated by beliefs

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Abstract. There is a current debate concerning whether people's physiological or behavioral potential alters their perception of slanted surfaces. One way to directly test this is to physiologically change people's potential by lowering their blood sugar and comparing their estimates of slant to those with normal blood sugar. In the first investigation of this (Schnall, Zadra, & Proffitt, 2010), it was shown that people with low blood sugar gave higher estimates of slanted surfaces than people with normal blood sugar. The question that arises is whether these higher estimates are due to lower blood sugar, per se, or experimental demand created by other aspects of the experiment. Here evidence was collected from 120 observers showing that directly manipulating physiological potential, while controlling for experimental demand effects, does not alter the perception of slant. Indeed, when experimental demand went against behavioral potential, it produced judgmental biases opposite to those predicted by behavioral potential in the low blood sugar condition. It is suggested that low blood sugar only affects slant judgments by making participants more susceptible to judgmental biases.

Keywords: geographic slant perception, blood sugar, experimental demand characteristics.

1 Introduction

Does our perceptual experience of space reflect our behavioral potential (Proffitt, 2006; Proffitt, Bhalla, Gossweiler, & Midgett, 1995)? Several studies regarding the perception of geographical slant (i.e., surface pitch relative to horizontal; Sedgwick, 1986; see also Stevens, 1983) have shown that this may indeed be the case (Proffitt et al., 1995; Bhalla & Proffitt, 1999). These studies have suggested that wearing a heavy backpack or being fatigued increases participants' estimates of hill slant above and beyond the well-established overestimation of hill slant that is known to already occur in perception (e.g., Kammann, 1967; Proffitt et al., 1995).

However, alternative theories of slant misperception suggest that the stable perceptual exaggeration of slant (a 5° hill is typically judged to be 20°) helps to retain greater precision in the coding of spatial variables (Durgin & Li, 2011; Hajnal, Abdul-Malak, & Durgin, 2011). Durgin and Li observed that many angular variables thought to be quite central to perception, such as the perceived declination of gaze, and optical slant (surface orientation relative to the direction of gaze) seemed to be exaggerated in perceptual experience whether judged explicitly (by verbal estimation or vertical/horizontal bisection) or implicitly, as when judging surface slant along different lines of sight. They argued that many perceptual biases, including distance underestimation and slant overestimation, could be understood in terms of efficient coding of angular variables that could more precisely guide both cognition and action (see also Li & Durgin, 2012). Such stable-coding theories argue against there being an advantage to slant being transiently affected by such things as backpacks or fatigue (Durgin, Hajnal, Li, Tonge, & Stigliani, 2010).

Indeed, recent evidence has explained many of the results originally attributed to manipulations of behavioral potential as being caused instead by subtle experimental demands. It is now well documented that most people who are asked to wear a heavy backpack during psychology experiments involving spatial judgments (whether indoors or out) assume that the experimenter intends for them to provide a higher estimate of slant or distance (Durgin et al., 2009; Durgin, Klein, Spiegel, Strawser, & Williams, 2012). For example, Durgin et al. (2009) found that when a backpack was presented to participants without explanation as part of a study of perceived surface slant, essentially all participants believed that the backpack had been intended to elevate their estimates, and many cooperated. However, when participants were told that the same backpack was weighted down with electromyography equipment to monitor their motor responses (Durgin et al., 2009), or were simply told to ignore the backpack when making their estimates (Durgin et al., 2012), participants' slant estimates did not differ from those of unburdened participants. These studies showed that elevated estimates of the slants of hills (Durgin et al., 2012) and ramps (Durgin et al., 2009) could be the result of experimental demand characteristics of the backpack, and not its weight (see also Woods, Philbeck, & Danoff, 2009).

Shaffer and Flint (2011) approached this problem differently. They manipulated the distal stimulus (observed surface) as opposed to the proximal stimulus (e.g., putting a backpack on an observer). Shaffer and Flint reasoned that if slant perception reflected behavioral potential, then escalators ought to appear less steep than stairs and both ought to appear less steep than a similarly sloped hill. However, what they found was that observers estimated the slant of all of these surfaces equally, contradicting the hypothesis that behavioral potential influences perception. By testing more than 300 participants, Shaffer and Flint were able to provide strong evidence that large changes in behavioral potential did not produce corresponding changes in perceived slant.

While Shaffer and Flint (2011) found no differences in overestimates of slant when manipulating the behavioral potential of the environment, there has also been debate over what happens with direct physiological manipulations of behavioral potential. Specifically, can reduced levels of blood sugar affect the perceived slant of locomotor surfaces? Schnall, Zadra, and Proffitt (2010) reported effects on slant from a hidden sugar manipulation in which participants who arrived at the laboratory after fasting for several hours gave elevated slant estimates of a hill if they received a placebo drink with no sugar. The authors concluded that blood sugar levels affected slant perception. However, whereas Schnall et al. sought to measure effects of a hidden sugar manipulation on their participants, they did so while also requiring all their participants to wear heavy backpacks. Because heavy backpacks are interpreted by participants as evidence that the experimenter wishes for them to give higher estimates of slant, it may be that participants who were particularly low in blood sugar were simply more compliant with the experimental demand created by the heavy backpack. This would be sufficient to explain the larger slant estimates.

Durgin et al. (2012) replicated Schnall et al.'s (2010) experiment by asking participants to wear a heavy backpack while manipulating blood sugar, and also verbally manipulating experimental demand: They told half the participants to ignore the backpack while making their judgment. These participants gave estimates identical to those without a backpack and showed no evidence that their judgments were altered by blood sugar levels. In contrast, participants who were in the normal backpack condition (under experimental demand to elevate their estimates) showed evidence of judgmental effects that were similar to those reported by Schnall et al. For example, some participants in the low-sugar condition elevated their slant estimates, consistent with the results of Schnall et al., but this only happened with participants who believed that they had received sugar when in fact they had not. Based on these observations, it appeared that not only might there be effects on judgments of beliefs about the purpose of the experiment (i.e., experimental demand), but also of beliefs about the content and purpose of the drink. We therefore conducted an experiment to more directly test these ideas about the role of belief.

1.1 Reversing the direction of demand in a glucose study

In the paradigms used by both Schnall et al. (2010) and Durgin et al. (2012), the slant judgments were separated from the sugar manipulation by an interval of time designed to allow sugar to be absorbed into the blood stream (for those provided with sugar). This interval was filled in both cases by a demanding cognitive task (Stroop task). The Stroop task would probably have further fatigued all their participants, but might also have served to obscure the experimental relationship between the drink received by participants at the beginning of the experiment and the estimates of slope done later on. Instead, in both of these studies, the slant judgments were immediately preceded by the introduction of the backpack manipulation. This may have caused participants to think about the slant-estimation portion of the experiment as a backpack experiment rather than a sugar experiment.

Durgin et al. (2012), who thoroughly surveyed their participants, found that among those who reported that they had not been able to tell by taste whether the drink had contained sugar or not, nearly all had assumed that it had. Thus, if experimental demand were at work with respect to the drink, these participants should have lowered their estimates rather than raising them. This raises an interesting possibility. If the cognitive task were removed and the backpack were either left out of the experiment or provided with a plausible explanation, might we find that participants who believed the drink was a sugared drink that was intended to lower their estimates actually provide lower estimates even in the case when the drink was actually a sugar-free placebo? If compliance with even this alternative experimental demand were mediated by blood sugar levels, this situation would make a prediction opposite to that of the effort hypothesis: Participants with lowered blood sugar should give lower estimates in compliance with their (false) beliefs about the intended purpose of the drink.

In the present experiment, we sought to use a very large number of participants so as to effectively cross a disguised manipulation of blood glucose and a disguised manipulation of burden. Both previous "sugar" studies of slant had required all participants to wear a backpack, but neither had disguised the purpose of the backpack. To minimize the demand of the backpack, we had half of our participants wear a heavy backpack, but we told them it contained equipment to monitor their muscles during the experiment and we attached an electrode to their leg. We used an actual electrocardiogram (EKG) machine that participants saw working while we attached the electrode and prior to putting it in the backpack. The other half of the participants received the same cover story and also wore an electrode, but the experimenter carried the backpack.

We crossed this burden manipulation with a hidden sugar manipulation and had participants make slant estimates of a large outdoor hill (16°) that extended well above eye height. If we found that slant estimates were elevated by low blood sugar in an experiment controlling for backpack demand, this could provide strong evidence in favor of perception being influenced by physiological or behavioral potential. However, if reducing the demand of the backpack (or eliminating it altogether) tends to allow an opposite direction of judgmental effect to emerge, this would be further evidence for the stable coding hypothesis that perception is not affected by changes in physiological or behavioral potential, but that cognitive susceptibility to experimental demand is.

2 Method

2.1 Participants

The participants were 120 undergraduates (59 male) who participated to fulfill a research requirement. They were each assigned to one of four cells of two crossed manipulations (30 per cell). All were required to fast for at least three hours prior to their participation. All participants were treated in accordance with the Ohio State University's institutional review board.

2.2 Hill

The hill was a steep grassy surface sloped at 16° on the campus of the Ohio State University, Mansfield. As in many other studies of outdoor slant (e.g., Proffitt et al., 1995; Schnall et al., 2010), the hill was easily accessible by foot from our laboratory. There was a stairway up another part of the hill to the right of where the experiment was conducted. Due to the location and steepness of the hill, no one walks on the hill.

2.3 Design

Half the participants wore a heavy backpack that contained EKG equipment and half were unburdened. All participants arrived at the laboratory after having fasted for at least three hours, and half of each group were given a drink that contained sugar, while the other half were given a drink that did not.

2.4 Survey

A survey was administered at the conclusion of the experiment. One question asked participants about their beliefs about the reason they had been given a drink. A later question asked if participants thought there was sugar in the drink.

2.5 Procedure

Participants were required to arrive at the experiment after fasting for at least three hours (so as to be low in blood sugar). After the general procedure was laid out (including the details used as a deception), they signed a consent form and were given the appropriate drink. They then waited for 10 minutes for the drink to take effect. After this the EKG leads were attached to one leg and the participant was either asked to wear the backpack carrying the EKG and led to the hill or simply led by an experimenter who carried the EKG to the hill. There they made a verbal slant estimate and were also asked to give a manual ("free hand") estimate using a custom inclinometer (Li & Durgin, 2011). After this was complete, they returned to the laboratory and completed a brief survey.

2.6 Sugar manipulation check

Fasting is an established method for lowering blood sugar levels (e.g., Gonder-Frederick et al., 1987). In order to confirm that our sugary drink would actually raise blood sugar levels after fasting (and subsequently increase physiological potential), we had 20 additional participants fast for three hours (under the same instructions as those in the main experiment). When they came to the laboratory, we tested their blood sugar with a One Touch Ultra blood glucose monitoring system. We next gave them either the sugary drink (N = 10) or the non-sugary drink (N = 10), waited 10 minutes, and tested their blood sugar again. We computed the difference in pre-drink and post-drink blood-sugar levels for each individual. Those administered the sugary drink had significantly increased blood sugar ($M = +5.6$ mg/dL, $SD = 1.9$ mg/dL) relative to those administered the control drink ($M = -1.6$ mg/dL, $SD = 2.16$ mg/dL), $t(18) = 2.503$, $p = 0.022$.

3 Results

The overall mean verbal estimate of the slant of the hill ($M = 49.8°$; $SD = 13.6°$) grossly overestimated its true slant, $t(119) = 27.1$, $p < 0.0001$, as is typically observed. In order to assess the effect of sugar on verbal estimates, independent of the backpack, and without taking participant beliefs into account, a univariate analysis of covariance (ANCOVA) was conducted to determine the effects of sugar on verbal estimates, while controlling statistically for the effect of the backpack. The ANCOVA results indicated no main effect of sugar on verbal estimates, $F(1, 119) = 0.514$, $p = 0.60$. In short, there was no effect of blood sugar when controlling for the backpack demand both experimentally and statistically.

3.1 Beliefs

When asked about the purpose of the drink, 32 participants (27%) explicitly expressed the idea that the drink had been intended to affect their slant estimates, while 73 (61%) repeated the cover story or expressed no suspicions about it. The statements of 15 participants (13%) were ambiguous, but suggested the possibility of suspicion. These three categories were coded as 2, 0, and 1, respectively, to indicate the level of evidence of suspicion about the drink.

When asked if the drink had contained sugar, 94 of the participants (78%) believed it had. The proportion was similar whether sugar had actually been administered (75%) or not (81%).

Participants were not directly asked about the purpose of the backpack, but when asked if they thought that any aspect of the procedure had affected their slant estimates, five participants (8% of those wearing the backpack) mentioned that they thought the weight of the backpack had affected them, suggesting that a larger set may have been suspicious of the weight despite the deception. Durgin et al. (2009) reported that 25% of their participants involved in a similar deception were still suspicious that the weight of the backpack was intended to alter their perception. This is consistent with the rate of suspicion in the present experiment concerning the drink (27%).

3.2 Verbal estimation data

A multiple regression analysis on the verbal data in which sex, burden, sugar, and suspicion were included as factors along with all two-way interactions revealed two reliable main effects. As is often found, male participants gave reliably lower estimates of slant than female participants, $\beta = 11.9°$, $t(109) = 2.58$, $p = 0.0113$. More important to the present investigation, the belief that the drink had been intended to affect slant perception (i.e., experimental demand) also produced reliably lower slant estimates, $\beta = 6.0°$, $t(109) = 2.11$, $p = 0.0368$. Thus, when participants believed that the sugary drink was intended to affect their judgments of the hill, they tended to give lower estimates overall. Consistent with the aforementioned ANCOVA, there was no reliable effect of burden, $t(109) < 1$, nor any reliable statistical interactions with burden (all $p > 0.15$).

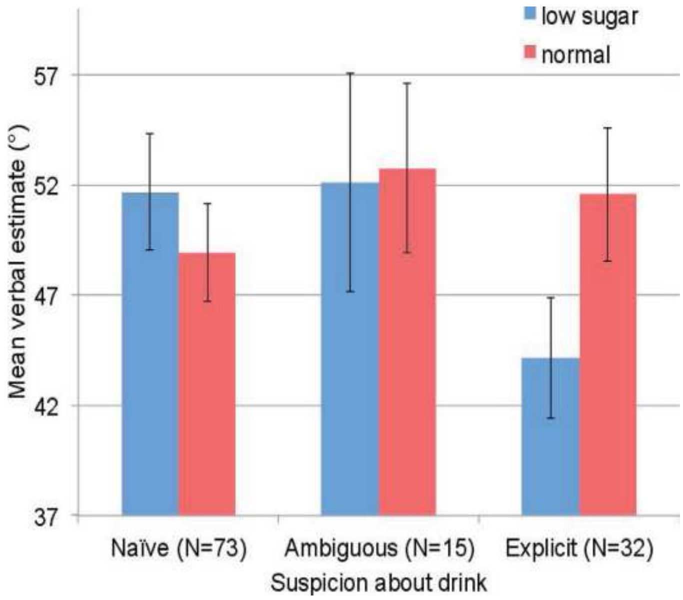

Figure 1. Slant estimates are plotted as a function of evidence of belief about the purpose of the drink, split by whether the participant had actually ingested sugar (normal) or not (low sugar).

3.3 Splitting the data by blood sugar condition

Before further interpreting these results concerning participant belief, however, we split the data by blood sugar condition (whether sugar had actually been ingested or not) because the full regression equation had included a marginal interaction between sugar and suspicion, $\beta = 5.8°$, $t(109) = 1.97$, $p = 0.0510$. This interaction is depicted in Figure 1. In a previous study (Durgin et al., 2012), it was found that participants with lowered blood sugar (also as a result of fasting) were more susceptible to experimental demand effects (i.e., more compliant) than those who were in a state of normal blood sugar.

Consistent with the implications of prior reports of greater susceptibility to experimental demand when blood sugar is low (Durgin et al., 2012), the effects of demand (suspicion) differed by sugar administration. Participants in the present study who were in a lower state of sugar as a result of fasting (and had not been given sugar in their drink) gave reliably *lower* estimates of the slant of the hill if they believed that the drink had been intended to affect their judgments, $\beta = -4.3°$, $t(56) = 2.21$, $p = 0.0312$, showing a clear effect of experimental demand based on their belief that the drink was intended to affect their perception. In contrast, those who had actually been given sugar in the drink showed no evidence of an effect of suspicion, $t(56) = 0.76$, n.s.

When the data are split the other way, we can state that among those who remained naïve to the intended purpose of the sugar manipulation (coded 0; N = 73), there was no evidence of any effect of blood sugar level, $t(69) = 0.54$, n.s. However, among the 32 who clearly articulated the hypothesis that the drink was intended to affect their estimates, those with low blood sugar tended to give marginally *lower* estimates, $t(29) = 1.80$, $p = 0.0813$. Note that this marginal trend is opposite to that predicted by the effort hypothesis, but is in agreement with an experimental demand explanation because most participants believed the drink had contained sugar. Overall, these analyses show that experimental demand based on beliefs about sugar provide an adequate explanation of the current effects.

3.4 Manual estimation data

Durgin et al. (2012) reported effects of experimental demand on “free-hand” manual estimates as well. The overall manual estimates ($M = 35°$) were reliably lower than the verbal estimates ($M = 50°$), $t(119) = 9.27$, $p < 0.0001$, but much higher than the actual slant of the hill, $t(119) = 17.8$, $p < 0.0001$, as is typically observed (e.g., Bridgeman & Hoover, 2008; Durgin et al., 2010; Li & Durgin, 2011). For the manual data we again conducted a multiple regression with sex, burden, sugar, and suspicion included as factors along with all two-way interactions. Similar to the verbal data, those in the low blood sugar condition gave *lower* manual estimates than those in the normal blood sugar condition, $\beta = -7.2°$, $t(109) = 2.00$, $p = 0.0484$. There was no reliable effect of sex, $t(109) = 0.67$, $p = 0.51$, or of burden,

$t(109) = 1.41$, $p = 0.16$, but there was a reliable interaction between burden and sugar, $t(109) = 2.05$, $p = 0.0428$. Because wearing a backpack might interfere with manual estimation, we analyzed the burdened and unburdened participants separately. Among participants asked to carry the heavy backpack ($M = 32°$), there was no effect of blood sugar levels on manual estimates, $t(56) = 0.03$, but among participants who did not wear a backpack ($M = 38°$), manual estimates were (again) marginally lower for those in a reduced state of blood sugar, $\beta = -8.3°$, $t(56) = 1.96$, $p = 0.0554$. Thus, the main results of the manual data are consistent with those of the verbal data. When effects of blood sugar are found in the present study, they go in a direction predicted by experimental demand, but opposite to that predicted by behavioral potential.

When the manual data were split by sugar condition, there was no reliable effect of burden among participants in the low sugar condition, $t(56) < 1$, and the effect of burden in the normal sugar condition went in a direction opposite to that predicted by the effort hypothesis, $\beta = -11.0°$, $t(56) = 2.45$, $p = 0.\ 0175$.

4 Discussion

Do hills look steeper when our blood sugar is low? No. When the experimental demand of wearing a heavy backpack is experimentally controlled, blood sugar does not, in itself, seem to have had any particular impact on the perception of slant. Thus, directly manipulating physiological potential does not alter our perception of slant. So what might explain past findings? Our data are most consistent with the alternative hypothesis proposed by Durgin et al. (2012) and Durgin, Hajnal, Li, Tonge, and Stigliani (2011) that low blood sugar only affected slant judgments by making participants more susceptible to judgmental biases. When aspects of the present experiment were experienced as biasing, participants in a state of lowered blood sugar were apparently either more cooperative or less able to exclude biasing information from their judgments.

Participants in our study, many of whom believed that they had been given a sugary drink in order to affect their judgments, gave *lower* slant estimates if and only if their blood sugar was low, as shown in Figure 1. This results in a finding contrary to the effort hypothesis because it led people to provide lower estimates (theoretically consistent with greater behavioral potential) when the drink they had ingested had not actually contained sugar (theoretically indicative of reduced behavioral potential). Durgin et al. (2011, 2012) suggested that lowered blood sugar from fasting might be making people more susceptible to the demand characteristics of the backpack. Here we reversed the direction of perceived experimental demand by removing the intervening task between drinking the sweet drink and making the slant estimate. Reversing the direction of demand reversed the direction of the observed bias in the low blood sugar condition.

We have shown that effects previously described as direct evidence for the economy of action are moderated by one's beliefs (see also Job, Dweck, & Walton, 2010). We showed that there were no direct effects of blood glucose levels on estimates of slant when experimental demands (e.g., of the backpack manipulation) were minimized (either by removing the backpack or by providing a plausible explanation for its purpose), but that participants who were low in glucose seemed more susceptible to the experimental demand to *lower* their judgments if they believed (falsely) that they had received sugar and also believed that the purpose of the study concerned the effects of sugar on slant estimates. In other words, when in a condition of low blood sugar, beliefs about the purpose of a slant experiment can push estimates either up or down, depending on the content of those beliefs.

What explanations other than behavioral potential might account for the more general observation of slant overestimation documented by Proffitt et al. (1995)? The studies of Li and Durgin (2010) and Durgin and Li (2012) have shown that Proffitt et al.'s hill data can be quantitatively modeled, as shown in Figure 2, by taking both slant and viewing distance into account. Their model was based on explicit estimates of slants viewed at different distances and on implicit measures of slant (aspect-ratio judgments of L-shaped configurations on slanted surfaces viewed at different distance). Durgin and Li (2011) and Hajnal, Abdul-Malak, and Durgin (2011) have proposed that the exaggeration of surface orientation may be part of a more general angular coding strategy that is designed to maintain greater coding precision for action. This alternative account emphasizes that actions can be calibrated to our distorted perceptions so long as those distortions are either stable or change predictably, such as based on changing perspective (Li & Durgin, 2009).

While the possibility that effects of action capability may affect the perceived geometry of surface layout (e.g., Witt, 2011) cannot be ruled out, caution is appropriate in interpreting reports of such

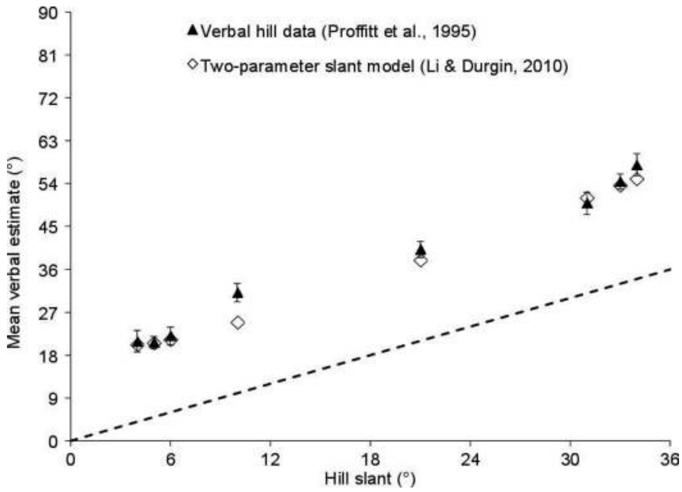

Figure 2. Model and actual estimates of slant. The empirical data (including standard errors of the means) are from Proffitt et al. (1995), as reported in Bhalla and Proffitt (1999). The model is adapted from Li and Durgin (2010), based on a parametric manipulation of slant and viewing distance. The empirically derived model supposes that perceived slant, $\beta' = 1.5 * \beta + 4.5 * \ln(D)$, where D is the viewing distance to the hill surface, and β is the actual surface orientation.

effects. Many are susceptible to interpretations in terms of judgmental effects in memory (e.g., Cooper, Sterling, Bacon, & Bridgeman, 2012) or experimental demand (e.g., Woods et al., 2009) or have proved difficult to replicate in other laboratories (e.g., de Grave, Brenner, & Smeets, 2011).

Here we have shown that direct manipulations of behavioral potential in terms of a sugary drink do not, in fact, destabilize slant perception. We have done this by controlling for confounds like the experimental demands imposed by the requirement to wear a heavy backpack during a psychology experiment and by assessing participant beliefs. When the experimental demand introduced by a sugary drink competed with predictions of energetics (blood sugar), changes in slant estimation followed experimental demand rather than following energetics. Although energetic considerations are certainly important, it may be that people evaluate the energetics of a slanted route by imagining how fatiguing it will feel rather than by seeing it as steeper or shallower.

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References

Bhalla, M., & Proffitt, D. R. (1999). Visual–motor recalibration in geographical slant perception. *Journal of Experimental Psychology: Human Perception and Performance, 25,* 1076–1096.

Bridgeman, B., & Hoover, M. (2008). Processing spatial layout by perception and sensorimotor interaction. *Quarterly Journal of Experimental Psychology, 61*, 851–859. doi:10.1080/17470210701623712

Cooper, A. D., Sterling, C. P., Bacon, M. P., & Bridgeman, B. (2012). Does action affect perception or memory? *Vision Research, 62*, 235–240. doi:10.1016/j.visres.2012.04.009

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. doi:10.3758/PBR.16.5.964

Durgin, F. H. Hajnal, A., Li, Z., Tonge, N., & Stigliani, A. (2010). Palm boards are not action measures: An alternative to the two-systems theory of geographical slant perception. *Acta Psychologica, 134*, 182–197. doi:10.1016/j.actpsy.2010.01.009

Durgin, F. H., Hajnal, A., Li, Z., Tonge, N., & Stigliani, A. (2011). An imputed dissociation might be an artifact: Further evidence for the generalizability of the observations of Durgin et al. 2010. *Acta Psychologica, 138*, 281–284. doi:10.1016/j.actpsy .2010.09.002

Durgin, F. H., Klein, B., Spiegel, A., Strawser, C. J., & Williams, M. (2012). The social psychology of perception experiments: Hills, backpacks, glucose and the problem of generalizability. *Journal of Experimental Psychology: Human Perception and Performance, 38,* 1582–1595. doi:10.1037/a0027805

Durgin, F. H., & Li, Z. (2011). Perceptual scale expansion: An efficient angular coding strategy for locomotor space. *Attention, Perception & Psychophysics, 73*, 1856–1870. doi:10.3758/s13414-011-0143-5

Durgin, F. H., & Li, Z. (2012). Spatial biases and the haptic experience of surface orientation. In A. El Saddik (Ed.), *Haptics rendering and applications* (pp. 75–94). Rijeka: Intech. http://www.intechopen.com/books/haptics-rendering-and-applications/spatial-biases-and-the-haptic-experience-of-surface-orientation

Gonder-Frederick, L., Hall, J. L., Vogt, J., Cox, D. J., Green, J., & Gold, P. E. (1987). Memory enhancement in elderly humans: Effects of glucose ingestion. *Physiology & Behavior*, *41*, 503–504. doi:10.1016/0031-9384(87)90087-4

de Grave, D. D. J., Brenner, E., & Smeets, J. B. J. (2011). Using a stick does not necessarily alter judged distances or reachability. *PLoS One 6*(2), e16697. doi:10.1371/journal.pone.0016697

Hajnal, A., Abdul-Malak, D. T., & Durgin, F. H. (2011). The perceptual experience of slope by foot and by finger. *Journal of Experimental Psychology: Human Perception and Performance, 37*, 709–719. doi:10.1037/ a0019950

Job, V., Dweck, C. S., & Walton, G. M. (2010). Ego depletion – Is it all in your head? Implicit theories about willpower affect self-regulation. *Psychological Science, 21*, 1686–1693. doi:10.1177/0956797610384745

Kammann, R. (1967). The overestimation of vertical distance and slope and its role in the moon illusion. *Perception & Psychophysics, 2*, 585–589. doi:10.3758/ BF03210273

Li, Z., & Durgin, F. H. (2009). Downhill slopes look shallower from the edge. *Journal of Vision, 9(11):6*, 1–15. doi:10.1167/9.11.6

Li, Z., & Durgin, F. H. (2010). Perceived slant of binocularly viewed large-scale surfaces: A common model from explicit and implicit measures. *Journal of Vision, 10*(14), 13 (1–16).

Li, Z., & Durgin, F. H. (2011). Design, data and theory regarding a digital hand inclinometer: A portable device for studying slant perception. *Behavior Research Methods, 43*, 363–371. doi:10.3758/s13428-010-0047-7

Li, Z., & Durgin, F. H. (2012). A comparison of two theories of perceived distance on the ground plane: The angular expansion hypothesis and the intrinsic bias hypothesis. *iPerception, 3*, 368–383.

Proffitt, D. R. (2006). Embodied perception and the economy of action. *Perspectives on Psychological Science*, *1*, 110–122. doi:10.1111/j.1745-6916.2006.00008.x

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

Schnall, S., Zadra, J. R., & Proffitt, D. R. (2010). Direct evidence for the economy of action: Glucose and the perception of geographical slant. *Perception, 39,* 464–482. doi:10.1068/p6445

Sedgwick, H. A. (1986). Space perception. In K. R. Boff, L. Kaufman, & J. P. Thomas (Eds.), *Handbook of perception and human* (pp. 21.1–21.57). New York: John Wiley.

Shaffer, D. M., & Flint, M. (2011). Escalating slant: Increasing physiological potential does not reduce slant overestimates. *Psychological Science, 22,* 209–211. doi:10.1177/0956797610393744

Stevens, K. A. (1983). Slant-tilt: The visual encoding of surface orientation. *Biological Cybernetics, 46*, 183–195. doi:10.1007/BF00336800

Witt, J. K. (2011). Action's effect on perception. *Current Directions in Psychological Science, 20*, 201–206. doi:10.1177/0963721411408770

Woods, A. J., Philbeck, J. W., & Danoff, J. V. (2009). The various perceptions of distance: An alternative view of how effort affects distance judgments. *Journal of Experimental Psychology: Human Perception & Performance, 35,* 1104–1117. doi:10.1037/a0013622

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