12-1-2012

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Recommended Citation

Frank H. Durgin; Brennan James Klein , '14; Ariana Michelle Spiegel , '13; Cassandra Joy Strawser , '13; and Morgan James Christopher Williams , '14. (2012). "The Social Psychology Of Perception Experiments: Hills, Backpacks, Glucose, And The Problem Of Generalizability". *Journal Of Experimental Psychology: Human Perception And Performance.* Volume 38, Issue 6. 1582-1595. DOI: 10.1037/a0027805
https://works.swarthmore.edu/fac-psychology/49

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Published in final edited form as:
J Exp Psychol Hum Percept Perform. 2012 December ; 38(6): 1582–1595. doi:10.1037/a0027805.

The social psychology of perception experiments: Hills, backpacks, glucose and the problem of generalizability

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Abstract

Experiments take place in a physical environment but also a social environment. Generalizability from experimental manipulations to more typical contexts may be limited by violations of ecological validity with respect to either the physical or the social environment. A replication and extension of a recent study (a blood glucose manipulation) was conducted to investigate the effects of experimental demand (a social artifact) on participant behaviors judging the geographical slant of a large-scale outdoor hill. Three different assessments of experimental demand indicate that even when the physical environment is naturalistic, and the goal of the main experimental manipulation was primarily concealed, artificial aspects of the social environment (such as an explicit requirement to wear a heavy backpack while estimating the slant of a hill) may still be primarily responsible for altered judgments of hill orientation.

Students of perception are often concerned about the ecological validity of experimental procedures. Although it is perfectly clear that one can study principles of dark adaptation in the laboratory without concern for the ecological invalidity of the indoor environment (Mook, 1983), it remains rather controversial how best to study the perception of space. The study of space perception in reduced-cue environments can often form the most effective basis for testing theories of cue combination (e.g., Knill & Saunders, 2003), and thus developing our scientific understanding. However an outdoor, full-cue environment is often preferred when testing the calibration of large-scale space perception (e.g., Loomis, Da Silva, Fujita & Fukusima, 1992). Indeed, many studies of space perception have adopted outdoor environments because they preserve the normal structure to which people can be expected to be already calibrated (Li, Phillips & Durgin, 2011; Ooi & He, 2007; Palmisano, Gillam, Govan, Allison & Harris, 2010; Proffitt, Bhalla, Gossweiler & Midgett, 1995). However, to be ecologically valid, it is not sufficient that an experiment be conducted outdoors. There is also reason to be concerned that the social context of being in a psychology experiment can affect responses, but the ecological validity of the social environment is rarely discussed in studies of space perception.

Consider the debate about the effect of a heavy backpack on perception. One group of researchers has frequently employed heavy backpacks as a method intended to manipulate the perception of space (Bhalla & Proffitt, 1999; Proffitt, Stefanucci, Banton & Epstein, 2003; Schnall, Harber, Stefanucci & Proffitt, 2008; Schnall, Zadra & Proffitt, 2010). Although there has been some recent controversy about the interpretation of these kinds of findings (Durgin, Hajnal, Li, Tonge & Stigliani, 2010; de Grave, Brenner & Smeets, 2011; Hutchison & Loomis, 2006; Russell & Durgin, 2008; Shaffer & Flint, 2011; Woods, Philbeck & Danoff, 2009), it may be that the fragility some have attributed to these effects

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reflects differences in social aspects of the experimental contexts used (Woods et al.). Our current concern is therefore with the generalizability of these effects to natural social contexts.

There is existing evidence from laboratory experiments that participants elevate their slope estimates when asked to wear heavy backpacks in experiments because of what Orne (1962) has called *experimental demand*. When Durgin, Ruff & Russell (in press) sought to remove experimental demand, they did so by telling participants that they had to wear a heavy backpack containing graphics equipment used as part of the computer hardware while making slant judgments in an immersive virtual environment (VR). Under such a deception, estimates of slant while wearing the heavy backpack were no different from those of other participants who wore no backpack at all. In contrast, participants in a third condition of the study who were asked to wear a heavy backpack without any explanation gave significantly higher estimates of the slants of the same virtual surfaces. This suggests that it is not the backpack itself that induces the demand, but the transparent implication that the researcher who requires that a backpack be worn must have some experimental goal in mind. Evidently participants raise their estimates because they think the backpack is meant to have this effect.

Could such a finding using VR generalize to an outdoor environment? We propose that the generalizability of these observations depends on the verisimilitude of the social context. For example, if the military wishes to know whether soldiers are likely to perceive hills differently when carrying a heavy backpack, the ecological validity of Durgin et al.,'s (in press) manipulation is relatively clear: It appears that implicit social aspects of the experimental context may be sufficient to account for previously reported elevated estimates, whereas the weight of the backpack itself may not matter. Since soldiers don't normally conceive themselves as being part of a psychology experiment, it is not clear from existing evidence that they would tend to perceive hills as steeper when they are burdened. However, it must be admitted that the use of a virtual environment might affect the generalizability of the results if it turned out there was an interaction between the social context and the visual context. Moreover there might be effects of both experimental demand and of the weight of the backpack.

To ensure that this demand-based interpretation was not limited to contexts employing virtual environments, Durgin, Baird, Greenburg, Russell, Shaughnessy and Waymouth (2009), collected estimates of the perceived slant of a sturdy wooden ramp from participants who were either (1) unburdened, (2) required to wear a heavy backpack without explanation or (3) wearing a heavy backpack that was described as carrying equipment used to monitor their ankle muscles. In this third, deception, condition, electrode leads were attached to their ankles during the experiment. As in the virtual environment, participants only gave elevated estimates in condition 2, when the backpack was presented as simply something to be worn during the experiment. Moreover, essentially all participants in this condition, when asked why they thought they had been asked to wear the backpack, reported that they thought it was intended to affect their perception. One way of characterizing these kinds of findings is that, despite the full-cue, normal physical environment, the social environment is unusual. That is, it may be that social factors in the experiment contribute to backpack effects through the implicit demand to comply with the experimenter's hypothesis. In support of this view, Durgin et al. found that the elevated mean estimate was due to a subset of participants in the normal backpack condition who both (1) articulated the hypothesis (that backpacks were intended to increase perceived slant) and (2) stated that they thought they had been affected. (If they had actually been affected, how would they have known?)

Although the magnitude of the backpack effect reported by Durgin et al. (2009) was identical to the magnitude of the backpack effect reported previously with hills (Bhalla & Proffitt, 1999), it still could be questioned whether the results obtained with an indoor ramp could be generalized to hills in the outdoors. Proffitt (2009) suggested that his effort theory only applied to extended surfaces for which substantial effort might be required and for which extended effort was possible. In essence, Proffitt argued that Durgin et al. found no influence of a backpack effect in their deception conditions because they used a visual stimulus with low ecological validity. On the face of it, this argument seems to overlook an important point: The social context created by Durgin et al.'s experiment was designed to reproduce the social context created by Bhalla and Proffitt when they asked Introductory Psychology students to wear a heavy backpack during their study. Because the magnitude of the demand effect observed by Durgin et al. indoors when no deception was used was identical to the backpack effect observed by Bhalla and Proffitt outdoors when no deception was used, experimental demand appears to be a sufficient explanation of the entire backpack effect Bhalla and Proffitt reported. But, perhaps when confronted with a large hill, experimental demand would be less salient or have no effect. In this paper we sought to test directly whether experimental demands of backpacks could be recognized by -- and influence -- participants in an outdoor hill study.

We modeled our outdoor experiment on studies conducted by Schnall et al. (2010) in which a heavy backpack was used as part of a study of effects of blood glucose. Schnall et al. reported that a manipulation of blood glucose levels had a reliable effect on estimates of hills. That is, estimates of hill orientation were higher among participants who were in a state of reduced blood sugar than participants who were not. Schnall et al. proposed that the hidden nature of their sugar manipulation obviated concerns about experimental demand. However, experimental demand was also present in both of the experiments Schnall et al. reported in the form of a heavy backpack: Rather than simply manipulating blood sugar, Schnall et al. additionally asked all participants to wear a heavy backpack while making their judgments of hill orientation.

The explicit inclusion of a heavy backpack in their procedure would seem to threaten the ecological validity of their social context. After all, normally people wear backpacks for a specific purpose. In an experiment, participants asked to wear a heavy backpack commonly deduce that the explicit purpose of the backpack is to affect their perception. The best way to know whether the backpack imposed an experimental demand might be to ask participants after the experiment why they thought they were asked to wear the backpack. Instead, Schnall et al. (2010) argued that the backpack was a constant across participants, and thus could not explain the effects they attributed to blood sugar. However, based on the research reviewed above, it remains probable that requiring people to wear a heavy backpack while estimating slant places them in an unusual social context that includes a clear experimental demand to elevate their estimates of slant. If participants vary in their compliance with that demand, as Durgin et al. (2009) have shown is likely, then the effects Schnall et al. ascribe to sugar could be effects on the rate of compliance rather than on the perception of geographical slant (Durgin, Hajnal, Li, Tonge & Stigliani, 2011). Perhaps participants tested with lowered blood sugar were less motivated to resist the social demand to elevate their estimates (more compliant). In other words, perhaps blood sugar levels influenced self-control mechanisms (Galliot et al., 2007) rather than perceptual mechanisms.

Our main concern is therefore that whereas Schnall et al. (2010) used an outdoor hill for this experiment (an ecologically valid physical environment), the social context in which participants were placed does not seem to conform to the class of contexts (no experimental demand present) to which one would wish to be able to generalize their result. Wearing backpacks is normal in itself, but being requested to wear a heavy backpack by an experimenter implies that the experimenter has a reason for requiring it. Even if the experimenter suggests that the reason is because people normally wear them, this implies that the experimenter expects that the backpack might affect the perceptual judgment that is to follow. Because Schnall et al.'s experimental procedures required fasting in advance, and then emphasized the backpack manipulation (by asking people their weight and then loading a backpack with weights and making them wear it while judging a hill), we believe it likely that most participants in the study felt encouraged to elevate their estimates of slant. A purpose of the present study was to document that such experimental demand exists even for outdoor hills.

One way of controlling experimental demand is to manipulate what participants think the experimenter wants them to take into account in making their judgment. For example, Woods et al. (2009) used an instructional manipulation in a related task in which participants were shown three instructions and asked to follow one of them in particular. One instruction told them to report the objective distance (their belief), one told them to report the apparent distance (their perception) and the third told them to provide an estimate that took more than just their vision into account (post-perceptual influences). It was only under the third instructional condition that the behavioral potential effect that Woods et al. had failed to replicate in three other attempts was finally replicated. Although Woods et al. used an explicit manipulation to mimic experimental demand in their experiment, Durgin et al. (2009) had demonstrated that backpack manipulations introduce a spontaneous experimental demand. We therefore decided to attempt to manipulate demand by trying to explicitly remove demand and also to implicitly measure the effect of demand by giving participants a chance to revise their estimates later without any new perceptual information.

In short, in an attempt to assess the experimental demand of a heavy backpack in an outdoor environment, we mimicked most of the experimental procedures of Schnall et al. (2010), but we adopted three kinds of strategy to try to measure possible effects of demand:

1. Manipulate Demand. To reduce the experimental demand of wearing a heavy backpack, we adopted an instructional manipulation in which, just prior to being asked to judge the steepness of the hill, half the participants were instructed that they should ignore the backpack when making their judgment. To minimize reactance to this instruction, we used a very specific instruction designed to explain exactly why we wanted them to ignore the backpack. The instruction acknowledged the possibility of experimental demand in the experiment and asked participants to resist responding to it. In this way we left behavioral potential constant while we manipulated only the socially-signalled demand of the situation.
2. Measure Beliefs. In addition to this explicit instructional manipulation, we also included a questionnaire at the conclusion of the experimental procedure to try to assess participant beliefs about the procedure, including the sugar manipulation and the backpack. This would allow us to assess the extent to which these experimental manipulations imposed experimental demand characteristics.
3. Ask Again. At the end of this questionnaire we gave participants a second chance to answer the question of how steep the hill was. To the extent that experimental demand induced people to inflate their estimates during the main experiment, we expected that the questionnaire would tend to remove this demand. Specifically, we expected that in the context of a computerized questionnaire that asked them their beliefs about the experiment and about the hill, participants who had intentionally elevated their responses initially (i.e., those in the normal backpack condition) might interpret the question as an opportunity to provide a less biased assessment when asked how steep they thought the hill actually was. Specifically, we expected

that participants in the normal backpack condition would tend to revise their original estimates downward when asked again, reflecting their awareness that they had originally elevated them in response to the social context.

If wearing a backpack elevates slope estimates outdoors independent of the demand characteristics that have been shown to influence slant estimates in indoor settings and virtual environments, then there should be little or no effect of telling people to ignore the backpack in making their judgment. That is, if demand is irrelevant to the interpretation of prior backpack studies outdoors, then the manipulation of experimental demand in the current experiment should have no impact as well. If the effect of the weight of the backpack is truly perceptual, participants should still show that effect when they are encouraged to report their perception.

Method

Participants

The participants were recruited from among first-year undergraduate students early in their first semester on the campus (weeks 4–6 of the semester), with the intent that they would be less likely to be familiar with the path in question and less likely to be aware of the nature of our research program. Thirty-nine students participated in the experiment (i.e., about the same number as were analyzed in each experiment by Schnall et al., 2010), but the data of two participants were lost because of a failure to complete the study. There remained 21 in the normal backpack condition (9 female) and 16 participants in the low-demand condition (11 female).

Manual matching

In addition to verbal estimates of slant, we had participants represent the slant of the hill by gesturing with their hand (Durgin, Hajnal, Li, Tonge & Stigliani, 2010). This *free hand* method of manual matching has been shown to be much more sensitive than the traditional palm board -- perhaps because it removes many of the artificial biomechanical constraints associated with palm boards. Li and Durgin (2011a) showed that free hand manual matching techniques were correlated with verbal reports (see also Li & Durgin, 2011b). For near surfaces manual gestures tend to be quite well calibrated whereas, like verbal methods, they overestimate far surfaces (see Li & Durgin, 2010). We used a custom inclinometer (Li & Durgin, 2011a) to measure hand orientation relative to a horizontal baseline, using the central axis of the hand to represent the response (Durgin, Li & Hajnal, 2010).

The hill

The hill was a long paved path, viewed at eye-level from a level surface. The path extended well above eye level. A prior study of this hill (N=30) recorded an average verbal estimate of 29° and an average manual matching gesture of 22° (Stigliani, Durgin & Li, 2010). The actual slant was 8.6°.

Design

Replicating Schnall et al. (2010; Experiment 2), blood glucose level was manipulated by having all participants arrive at the experiment without eating for at least three hours prior. Half were then given an (unmarked) sugary drink (Coke Classic). The other half were given an (unmarked) sugar-free drink (Coke Zero). These drinks have nominally equal amounts of caffeine: 35 mg. All participants then did a Stroop task to allow time for those in the sugar condition to absorb the sugar into their bloodstream.

After the Stroop task all participants were taken outside to a second experimenter at a hill. An innovation of our procedure was that we kept our outdoor experimenter blind to the sugar manipulation. This experimenter asked the participant to put on a heavy backpack. We then manipulated the level of demand of the backpack: About half the participants were told to ignore the backpack (low backpack demand) when making their estimate of the slope of the hill (see below), while the others were simply asked to estimate the slope of the hill (normal backpack demand). Participants gave both a verbal and a manual response. About half first made a verbal estimate and then made a free-hand manual gesture with their hand to represent the slant of the surface. The other half made the manual gesture first. The gesture was conducted with the hand occluded behind a screen and was measured with a custom inclinometer (Li & Durgin, 2011a).

Following the slant judgments, participants returned indoors and completed a questionnaire on a computer (a different computer than the one on which they performed the Stroop task). The questionnaire asked them questions about their beliefs about the purpose of the experiment and also asked them to estimate the actual slant of the hill in order to further test for evidence of experimental demand characteristics and judgmental bias. A fatigue questionnaire was administered at the very end.

The instruction

To offset the experimental demand character of the backpack, the following instruction was used:

> "In a moment I'm going to ask you to estimate the slant of that hill/path. Before you do that, though, I want to explain that we are studying compliance effects in psychology. In a previous experiment we found that if we asked people to wear a backpack they nearly all assumed that we intended the backpack to affect their judgments. Since most subjects want to be cooperative, many of them altered their estimates to try to help us out. We are trying to find out if there is a way to make people just report what they see rather than trying to be compliant with what they think we want them to say. As far as we know, wearing a heavy backpack does not affect your visual system, so please simply estimate the slope of the hill. That is, make the best estimate you can based only on what you see."

Although the instruction states the hypothesis that wearing a backpack does not affect perception, the idea that participants could "comply" with this instruction presupposes that they either know what effect the backpack is going to have or that they know how to foil the effect of the backpack. We intended for their simplest strategy to be to comply with the specific request made at the end of the instruction to report their true perception.

Procedure

Participants were scheduled via an online system that informed them they were not to eat or drink anything except water for three hours prior to the experiment. Participants were run between 8:30 and 11:30 in the morning. An e-mail the night before reminded them not to eat or drink anything except water. On arrival, they were asked if they had complied with this requirement.

The general procedure was then explained and participants signed a consent form. They were then given 12 oz of chilled soda in an unmarked cup and asked to drink it as quickly as was comfortably possible. Once they had finished the soda they were shown to a computer where they were instructed in a Stroop task which they then performed for 8–10 minutes.

After completing the Stroop task each participant was led out of the building to a nearby location at the base of a hill to be instructed by a second experimenter waiting there. Standing on level ground the participant was given the heavy (25 lbs; 11.3 kg) backpack to put on and, if appropriate, given the instruction to ignore the backpack in making his or her judgment. Once fitted with the hand-inclinometer the participant stood in position and gave the verbal estimate and the manual match in the requested order. Prior to making the manual match the participant's hand was on a horizontal reference surface so that the change in orientation could be recorded.

Once the slant data were collected, the participant returned inside to complete a short online survey about the experiment that probed their beliefs about the experimental situation (see Appendix A). Following this they completed a fatigue questionnaire (MFSI-SF; Stein, Jacobsen, Blanchard & Thors, 2004), adapted to assess their present fatigue (rather than their fatigue over the past 7 days). The entire procedure took about 25 minutes.

Results

Backpack Effects

Our principal question concerned the role of the backpack, and we start with consideration of the questionnaire data regarding the backpack conditions.

Explicit Evidence of Experimental Demand

When asked why they thought they had been asked to wear the heavy backpack during the judgment of the hill, a majority of participants (29/37) indicated that they thought the weight of the backpack was intended to make the hill either look or be judged different. Most indicated an increase (14) or were not specific about the direction of the effect (13); only two predicted a decrease. Thus, as we expected, most participants, when asked, articulated the hypothesis that the backpack was intended to affect their judgment, and those who specified the expected direction of the effect were apparently in agreement. The frequencies of various response types, separated by Demand, are shown in Table 1. The complete responses of all participants are shown in Appendix B.

Implicit Evidence of Experimental Demand

When later asked in the questionnaire how steep the hill actually was, participants who had not been told to ignore the backpack provided reliably lower estimates (31°) than they had initially (34°), $t(20) = 2.28$, $p = .0328$. This downward revision in verbally estimated slant is consistent with the idea that they knew that their initial estimates were intentionally inflated: Nearly half of those in the standard backpack condition lowered their estimates later (10/21); only two raised them. Note, in contrast, that those told to ignore the backpack gave essentially the same estimate when asked again (28°) as they had initially. These data are shown in the right panel of Figure 1.

Are these revisions lower in the standard backpack condition because participants are able to somehow remove the backpack effect from their remembered perception of the hill? Creem and Proffitt (1998) found that estimates of slant from visual memory/imagery tended to be about 5° higher than estimates from perception. Because our participants did not raise their estimates from memory, the revisions found here are unlikely to be estimates based on remembered visual imagery. More likely they are revisions based on explicit memories of a prior verbal estimate and a decision process that included awareness of the experimental demand.

Effect of Explicitly Manipulating Demand

We had hypothesized that telling participants to ignore the backpack could serve to release them from the experimental demand character of the backpack manipulation. Consistent with this view, verbal estimates of hill orientation were numerically lower when participants were instructed to ignore the backpack when making their judgment (28°) than they were in the standard backpack condition (34°). Moreover, mean verbal estimates in the *ignore* condition were essentially identical to judgments of the same hill collected in a previous experiment without a backpack (29°, Stigliani et al., 2010). These data are shown in the left panel of Figure 1. Although this magnitude of verbal difference (~5°) was similar to that in prior studies of backpack effects (Bhalla & Proffitt, 1999; Durgin et al, 2009), a 2 (demand) × 2 (sex) × 2 (sugar) ANOVA found that it was not reliably different from chance, $F(1, 29) < 1$. However, a similar analysis of manual estimates showed that these were reliably higher when experimental demand was high (M = 31°) than when demand was low (M = 21°), $F(1, 29) = 4.90$, $p = .0347$. Neither analysis showed a reliable effect of sex or of sugar condition (all $F(1,29) < 1$). Again, the manual estimates in the low demand condition were essentially identical to those in a prior study without a backpack (22°, Stigliani et al.).

Our free hand manual measure has been shown to be more sensitive than the more typical palm board measure (Durgin, Hajnal, Li, Tonge & Stigliani, 2010). Moreover, free hand measures also have been found to be tightly correlated with verbal measures (Li & Durgin, 2011a). For example, the correlation between manual matches and verbal estimates in the present experiment ($r = 0.58$) is highly reliable, $t(35) = 4.24$, $p = .0002$. Thus, the reliable effect on the free hand measure is consistent with a judgmental bias. It is also consistent with the results of Schnall et al. (2010). Even though their palm board measure did not record a reliable change, Durgin et al. (2011) noted that Schnall et al. measured a shift in their palm board measure that was proportional to the shift in their verbal measure (i.e. 20%), but was not statistically reliable because of the greater proportional variability in the palm board measure.

The exaggerated effect on the analog hand matching measure is also consistent with intentional bias. Participants also tend to exaggerate deviations from categories (like vertical and horizontal) using a free hand measure, as if trying to clearly differentiate their response from those categories (Durgin, Hajnal, Li, Tonge & Stigliani, 2010). To the extent that participants are trying to comply with demand, the defining category might become the actually-perceived matched orientation to the hill -- from which they intentionally deviate.

Overall, the present experiment provides evidence that (1) people asked to wear a heavy backpack guess that it is intended to elevate their estimates. Moreover, (2) those in the normal backpack condition tend to revise their estimates downward later, suggesting that they are aware that they have intentionally overestimated the slant of the hill. In contrast, if they have been told to ignore the backpack, they provide estimates that (1) they do not revise later and that (2) are similar to estimates of the same hill by other participants who did not wear a backpack. Given that the size of the backpack effects are similar to those found indoors in the absence of a deception about the purpose of the backpack, these findings suggest that the backpack results reported by Bhalla and Proffitt (1999) were likely due to experimental demand rather than to the weight of the backpack.

Sugar Effects

Although our main manipulation concerned the socially-mediated effect of the backpack, we were also curious about participant perceptions of the role of sugar in this experiment.

Awareness of Sugar Manipulation

When asked in the questionnaire to judge whether the drink they had been given had contained sugar, participants' judgments on a 6-point scale (from "definitely contained sugar" to "definitely did not contain sugar") were quite sensitive to the actual manipulation of sugar. A 2 (demand) × 2 (sex) × 2 (sugar) ANOVA showed that ratings were highly dependent on whether or not the drink had contained sugar, $F(1, 29) = 20.2$, $p < .0001$. Because about half the participants indicated they had based their judgment on taste, a second ANOVA was conducted in which this rating was used as a predictor of belief in conjunction with the presence of sugar. This 2 (taste) × 2 (sugar) ANOVA showed a reliable interaction between these factors, $F(1, 33) = 9.46$, $p = .0042$. Those who said they could taste the difference were excellent at discriminating between the sugar and non-sugar conditions, $F(1, 17) = 24.6$, $p = .0001$, with a mean shift of 2.57 points on the 6-point scale. In contrast, the ratings of those who did not report using taste, though they trended in the correct direction (with a mean shift of only 0.60), were not reliably predicted by the actual sugar content manipulation, $F(1, 16) = 2.00$, $p = .1765$. Participants who indicated that they thought they could taste the difference were about equally likely to be in the sugar (8/17) condition as in the no-sugar (11/20) condition. Schnall et al. (2010) used these same drinks in their Experiment 2.

Hypotheses about Sugar

In contrast to the backpack manipulation, few of our participants believed the sugar manipulation was relevant to the estimation of slant. When asked if they thought their slant estimates had been affected by the initial drink, only six participants (16%) thought they might have been, and only 1 articulated the theory that a sugary drink might make the hill seem shallower. Note that this paucity of beliefs about sugar helps show that their beliefs about backpacks were not simply manufactured in compliance with a question. In contrast, 20 of the participants (54%) thought that the drink might have affected their performance on the Stroop task. Five others pointed out that there had not been sufficient time for the drink to have been absorbed (into their blood stream) when they did the Stroop test, but several participants emphasized the unpleasantness of being required to drink soda at that time of day (all tests were done in the morning) and some indicated experiencing a residual level of discomfort during the Stroop task.

Interactions between sugar, knowlege and demand

There are at least three routes by which manipulations of sugar might influence slant judgments. One of these, direct effects of physiologial potential on perception, should act independently of (be additive with) the backpack demand. A second pathway, based on altered susceptibility to demand, should be moderated by the presence of demand (a normal backpack). A third pathway might involve misattribution, in which a lack of knowledge about one's physiological state might lead to attributive error in making slant judgments. This pathway should be moderated by an absence of knowlege, such as the presence of uncertainty about whether one has ingested sugar, but to the extent that it affects perception, rather than judgment, it should not be moderated by demand.

A misattribution account seems particularly plausible because most participants who were unable to identify the diet soda by its flavor tended to assume that it contained sugar. Specifically, of the 18 who did not think they had tasted a difference, all but 3 (i.e. 83%) guessed they had had sugar, including 7 of the 9 in the no-sugar condition (77%). Thus, participants in the diet conditions who were not able to identify the diet soda by taste would be mostly likely to be susceptible to influences of misattribution due to erroneous beliefs about their own physiological state.

To test this account, we included sensory knowledge of the sugar manipulation (Taste: defined as reporting having used taste to judge whether they had had sugar or not) as a predictor in a multiple regression analysis along with Sugar and Demand[1]. Both for verbal and for manual estimates there were reliable 3-way interactions between Demand, Sugar and Taste, verbal $t(29) = 2.41$, $p = .0223$; manual $t(29) = 2.75$, $p = .0102$. Graphs of the eight cells for each measure are shown in Figure 2. We first split the data by Demand.

In the High Demand (standard backpack) condition, there were reliable interactions indicating an effect of Sugar that differed as a function of Taste, both for verbal estimates, $t(17) = 3.03$, $p = .0076$, and for manual estimates, $t(17) = 2.74$, $p = .0140$. As is suggested by the left panels of Figure 2, verbal estimates and manual estimates of participants in the High Demand condition varied quite a bit from the baselines (i.e. the data of Stigliani et al., 2010) indicated by the gridlines on the graphs. This variation was related both to their sugar condition and to their sensory knowledge (Taste) of the sugar condition they were in.

Specifically, those in the High Demand conditions who also reported sensory uncertainty about whether they had received sugar or not gave reliably higher verbal estimates if they had not received sugar (Demand+, Sugar−, Taste−; verbal M = 42°) than if they had received sugar (Demand+, Sugar+, Taste−; verbal M = 16°), $t(7) = 2.46$, $p = .0432$. The same pattern was true for manual estimates: Those in the High Demand condition who reported that they could not taste whether they had received sugar or not, gave reliably higher estimates when not given sugar (Demand+, Sugar−, Taste−; manual M = 44°) than when given sugar (Demand+, Sugar+, Taste−; manual M = 22°), $t(7) = 3.37$, $p = .0119$. Thus, in both the verbal estimation data and the manual matching data, there is evidence of an effect of sugar among the people who report not having been able to tell by taste which condition they were in. There were no reliable effects of sugar among those who reported using taste.

However, these sugar effects are limited to the High Demand condition. As suggested by the graphs on the right side of Figure 2, separate analyses of the Low Demand (ignored backpack) participants showed no evidence of any effect of Sugar or Taste, nor of any interaction between them either for verbal or for manual measures (all p's > .10). In other words, when told to ignore the backpack and report their perceptions, participants show no evidence of physiological effects on perception nor even of misattribution effects: They simply show no reliable evidence of any influence of sugar or even beliefs about sugar on estimates. Moreover, if we examine all the participants who do not report using taste, we find a reliable interaction between Demand and Sugar in the manual data, $t(15) = 2.59$, $p = .0207$, confirming that the effects of sugar were moderated by our instructional manipulation of experimental demand.

This pattern supports the idea that sugar effects are moderated by compliance with experimental demand or with other non-visual influences in the normal backpack condition. We have found that there are effects of the ingestion of sugar (or lack thereof) on both verbal and manual estimates that are eliminated not only by (1) the instruction to ignore the backpack and report one's perception, but also by (2) sensory certainty (Taste) about whether or not sugar was ingested. This is consistent with the idea that effects of the hidden sugar manipulation on slant estimation are related to participants' beliefs about the experiment including the demand characteristics of the situation. These data are inconsistent

[1]We first tried using ratings (beliefs) about whether the drink had contained sugar as a predictor, assuming that misattribution would depend on beliefs about sugar. Those analyses failed to reveal any reliable differences or interactions. Because nearly everyone who could not taste the difference assumed they were given sugar, that first analysis lumped together most No Taste participants with the Taste participants who received sugar. Sensory knowledge seems to be the more important predictor.

with the alternative claim that a participant's physiological state has a direct influence on slant perception, which is then modified by additive effects of experimental demand (e.g., of the instruction).

Self-reported fatigue

In order to unveil effects of blood glucose in their second experiment, Schnall et al. (2010) used data from questionnaires that were concerned with levels of mood, fatigue, and sleep quality intending to account for individual variability in Experiment 2 of their paper. They reported that "Importantly, it was only when also taking into account these individual differences that the effect of the glucose manipulation became apparent." (p. 447). In other words, the sugar effect became reliable when (in effect) several other self-report measures were included in the analysis. This is not unlike our analysis above, which depended on including participant knowledge about the drink. Although it might be that taking these measures into account is necessary to detect the effects of glucose by reducing variance due to individual differences, an alternative interpretation is that measures of perceived fatigue, for example, are not strictly measures of individual differences. They may serve as surrogates for participant beliefs about the experiment. Because the mood and fatigue questionnaires were filled out in the same social context as the main experiment (an experiment that had explicitly required fasting and wearing a heavy backpack) it would be intriguing to know how questionnaire responses interacted with participant beliefs about the experiment. Given the number of possible ways of modeling their self-report measures, there is a legitimate concern that Schnall et al.'s unveiling of the effect of sugar by the use of these measures may represent a Type I error.

We used the five subscales of the MFSI-SF (Physical, Emotional, Mental, and General fatigue as well as the reverse-coded subscale of Vigor) in combination with Sex, Demand, and Sugar to try to predict slant estimates, using multiple regression. By removing factors one by one we determined that, among the measures of fatigue, only the sub-scale representing Physical fatigue was correlated with manual slope estimates, $t(34) = 2.44$, $p = .0199$. However, the effect of sugar, per se, was not reliable under any combination of factor inclusions that did not include Taste. The effect of Demand on manual estimates was reliable whether self-rated Physical fatigue was included in the multiple regression, $t(34) = 2.53$, $p = .0165$, or not, $t(35) = 2.58$, $p = .0144$.

Note that we do not interpret the correlation between slant judgments and self-reports of Physical fatigue as evidence in favor of the effort theory, because both measures might have been artificially elevated in response to the overall demand characteristics of the experiment (Durgin et al., 2009). The six items in the MFSI-SF that make up the Physical fatigue subscale are: "My muscles ache", "My legs feel weak", "My head feels heavy", "My arms feel weak", "I ache all over", and "My body feels heavy all over". Participants who tended to assent to these statements at the conclusion of the experiment might well see a connection between these statements and the backpack manipulation, for example. In support of this interpretation we tested whether the relationship between slant estimates and Physical fatigue was equally well supported in each of the two demand conditions. Among participants in the low-demand condition (who were told to ignore the backpack), self-reported Physical fatigue did not reliably correlate with slant estimates $t(14) = 1.1$, $p = .301$. Among participants in the normal backpack condition, however, slant estimates were reliably correlated with self-reported Physical fatigue, $t(19) = 2.3$, $p = .0327$. This pattern is precisely consistent with the idea that responses to the Physical fatigue subscale may themselves be the product of compliance with experimental demand characteristics in the normal backpack condition. Thus, self-reports of Physical fatigue in the normal condition might actually serve, in some sense, as proxies for evidence of compliance with the experimental demand of the backpack.

Conclusions regarding participant compliance

Participating in this study required compliance with a number of unusual explicit demands, such as getting up early, not eating, and then drinking a carbonated beverage first thing in the morning. In Schnall et al.'s (2010) second study, participants had also to agree to have their blood drawn during the experiment. Having invested so much of their own cooperation in participating in such a study, it would not be surprising that participants would wish for the experiment to succeed (and thus be more likely to cooperate with the perceived intent of the experiment). In contrast, we have found that telling participants to ignore the backpack and report their perceptions eliminated not only (1) the backpack effect, but also (2) the effects of sugar and of beliefs about sugar, and additionally eliminated (3) any association between slant estimates and self-reported fatigue. Figure 2, in particular, suggests that our instructional manipulation did not simply depress slant estimates, but returned them to normal.

Discussion

Our experiment was conducted with the primary goal of establishing whether or not backpack effects on slant judgments of outdoor hills were susceptible to the same experimental demand characteristics as we had observed indoors. We found that backpack effects on explicit slant judgments for an outdoor hill could be abolished by merely asking participants not to comply with the experimental demand characteristic of the backpack. We documented that, even when outdoors, participants are sensitive to the experimental demand characteristic of being asked to wear a heavy backpack. Most participants thought that the backpack manipulation had been intended to affect their judgments. Participants in the standard backpack condition tended to later revise their estimates downward, as if they knew that they had been exaggerating their initial estimate.

By sorting participants according to whether or not they reported that they had sensory knowledge (via taste) of which soda they had received (diet or regular), we further found that in both the verbal data and the manual data, there was evidence of effects of the sugar manipulation only among those in the high demand condition who were uncertain about the soda they had been given. Because these participants were strongly biased to believe that they had probably been given sugar, the results within the high demand condition are consistent with misattribution affecting their explicit slant estimates. However, because no such pattern emerged in the low-demand condition, it seems unlikely that the effects are visual in nature. These data are consistent, however, with the hypothesis that blood sugar levels affected the rate of compliance with demand. That is, for those in the high demand, low knowledge condition, it may be that their rate of compliance with the implicit demand of the backpack was elevated by a depleted level of blood sugar.

It is of some interest that these effects of sugar (perhaps on rate of compliance) seem to have been limited to participants who were not armed with sensory knowledge of whether they had been given sugar. Such an observation suggests that effects of hidden sugar manipulations may depend more on cognitive factors (not knowing whether or not one has received sugar or believing, falsely, that one has received sugar) than has heretofore been appreciated.

Distorted but stable

Whereas a number of theorists have proposed that the geometry of visual surfaces is distorted in perception, there are two distinct camps on whether these distortions are stable or not. For example, hills certainly appear much steeper to humans than they are (Li & Durgin, 2009, 2010; Proffitt et al., 1995; Ross, 1974), but do hills look even steeper when we are burdened (Bhalla & Proffitt, 1999) or low in blood sugar (Schnall et al., 2010)? We think the present evidence suggests they do not.

Li and Durgin (2009, 2010; Durgin & Li, 2011; Durgin, Li & Hajnal, 2010) recently showed that systematic distortions in the perceptual experience of the orientations of small wooden surfaces are continuous with those of large-scale surfaces, like hills, and that a fairly simple geometrical model provides a good description of a variety of findings of systematic (but stable) distortions in the perceptual experience of visual slant. The continuity between large and small scale surfaces calls into question the claim that hills appear steep because our perceptions represent our behavioral potential (Proffitt et al., 1995; see also Shaffer & Flint, 2011). Li and Durgin have proposed that alternative functional goals of enhancing coding precision are served by these stable and systematic distortions.

In particular, Li and Durgin (2009, 2010; Durgin & Li, 2011) identified systematic errors in the perception of both gaze declination and of optical slant. The quantitative predictions of their models have been shown to generalize to a variety of findings in the space perception literature including the outdoor hill data of Proffitt et al. (1995; see Li & Durgin, 2010), the distance perception data of Loomis et al. (1992; Loomis & Philbeck, 1999; see Durgin & Li, 2011) and the height-perception data of Higashiyama & Ueyama (1988; see Li, Phillips & Durgin, 2011). Durgin and Li (2011; Hajnal, Abdul-Malak & Durgin, 2011) have argued that the systematic distortions of space indicated by their data may be functional adaptations that derive from coding advantages specific to angular variables. They emphasize that such advantages would be undermined if non-visual factors such as heavy backpacks actually affected the perceived geometry of locomotor surfaces.

The success of the geometric models at capturing patterns of bias across a variety of methods and labs (eg., Li & Durgin, 2010; Li, Phillips & Durgin, 2011) provides important evidence in favor of the idea that human perceptual experience is not entirely divorced from the true geometry of the physical world -- even if that geometry is distorted in a systematic and stable manner in human perceptual experience. It remains possible that humans have access to a dual awareness (one geometrical; one conceptual or action-based), but a simpler account would be that many of the behavioral-potential-based distortions that have been observed in perceptual judgments are cognitive rather than visual.

Objections and answers

Several kinds of objection have been suggested regarding our methods and conclusions that are worth addressing here. First, some reviewers have argued that wearing a backpack is ecologically valid because students often wear backpacks. The concern we have is not with wearing the backpack per se, but with the social message sent by the presentation of the backpack by the experimenter as if it were intended to affect perception. As we have pointed out above, in two prior studies we saw no effect on judgments when backpacks were presented as useful things for carrying lab equipment during experiments. Backpacks worn as useful things do not seem to affect judgments (or perception). Our argument is that backpacks worn in the understanding that they are meant to alter perception often cause people to elevate their estimates of slant or distance. These are socially-induced effects that involve basic theory of mind judgments by participants concerning the experimenter's intentions.

Second it has been objected that our current instructional manipulation places an experimental demand on subjects to lower their estimates. We acknowledge that our instruction states a specific hypothesis: That backpacks have no influence on perception. However, our use of this kind of direct statement is analogous to the process-dissociation strategy used by Jacoby (1991). In order to demonstrate the existence of implicit (automatic) memory processes, Jacoby instructed participants not to use words from a prior list when doing a stem completion task. Jacoby knew that pitting explicit (controlled) memory against implicit (automatic) memory risked underestimating implicit memory, but also argued that it would represent a strong test of the existence of implicit memory. The point of explicitly pitting the “no effect” instruction against the standard backpack manipulation is to perform a strong test of the claim that backpacks (and sugar) affect perception. If backpacks really do affect perception (rather than cognitive estimation processes), it is not clear that participants should be able to know how to suppress their effect. It is true that participants might deduce from the instruction that we want them to lower their estimates, but should they know by exactly how much? Indeed, comparison of the left and right panels of Figure 2 disconfirms the idea that the instructional manipulation simply lowered estimates across the board.

Moreover, participants should only be able to deduce that we want them to lower their estimates if they assume that the backpack generally elevates estimates. That is, because our instruction does not specify the direction in which past participants have altered their estimates, it would be up to our participants to deduce this. We therefore think that the claim that our instruction induces a signed demand character can only be made if it also assumed that the backpack also induces a signed demand character that the participants can deduce. But if this is admitted, then our main point (that backpack manipulations impose demand characteristics even when administered in the outdoors) is also admitted.

The pattern of data in Figure 2, in which our instruction seems to remove both overestimation and (relative to baseline) underestimation, is inconsistent with the idea that participants lowered their estimates to comply with our instruction. Rather, we think those data strongly suggest that our instruction was mostly successful in focusing participants on reporting their actual visual experience. Demand characteristics have previously been demonstrated in indoor backpack experiments where we have used deceptions that are not susceptible to the objection that we have introduced a signed demand. Thus, while we appreciate that our instruction might be interpreted as having an experimental demand, we think the present evidence is more consistent with the view that the net effect of the instruction was generally as intended: to encourage participants to report their visual experience rather than modifying their reports based on trying to guess what we wanted them to say.

A third objection that has been raised by those whose work we are reinterpreting is the argument that we do not get backpack effects because we do not want to get them. But this concern might apply to all experiments. We have tried to avoid experimenter bias as much as possible by using neutral affect and fixed instructions (see Woods et al., 2009). We also kept our outdoor experimenter blind to the sugar manipulation in the present experiment. If participants told to ignore a backpack give slant estimates that are essentially identical to participants who wear no backpack, the case for backpacks actually affecting perception seems quite tenuous. Moreover, if effects of sugar disappear when experimental demand is altered, this seems to imply something important about the nature of these sugar effects. Our working hypothesis is that the effects of sugar and backpacks are probably not visual, but alternative interpretations are always possible. At present we think it is accurate to state that there is simply no evidence for effects of backpacks or of sugar on slant perception that are not attributable to uncontrolled experimental demand. Conversely there is clear evidence from our prior studies that spontaneous experimental demand is sufficient to account (quantitatively) for backpack effects. There is clear evidence in the present study that participants were aware of the experimental demand of the backpack manipulation and there is strong evidence that any effects of sugar were moderated by the presence of experimental demand.

A fourth objection that has been raised in the review process is the first-person and anecdotal evidence of hills appearing steeper at the end of a bicycle race, such as discussed by Proffitt et al. (1995). We have not studied biking or hiking in this paper. To the extent that these anecdotal phenomena are perceptual, our data suggest that they are not due to changes in behavioral potential or in blood sugar. Could there be alternative explanations for effects of biking and hiking besides the backpack-style hypotheses guessed by nearly all our participants? One alternative explanation that may apply to hiking and biking, for example, is that the maintenance of a posture in which the head is facing somewhat downward for extended periods of time could produce errors (aftereffects) in the perceived direction of gaze. There is existing evidence that misperceptions of gaze direction affect perceived slant (e.g., Li & Durgin, 2009). As illustrated in Figure 3, postural aftereffects from biking or hiking that lower the perceived straight-ahead would tend to elevate estimates of perceived geographical slant. Moreover, there is evidence for such aftereffects. Shebilske (1986) had baseball players do handwork in order to adapt them to a lowered head posture. When he then had them swing at pitched balls, they tended to misperceive the balls as higher than they were and hit a disproportionate number of ground balls. A similar error could easily occur in the estimation of slant following athletic activities that tend to encourage downward gaze.

Although it is appealing to believe that our perceptual experience is a kind of conceptual guide to our future behavioral selections (Proffitt et al., 2003), there is a natural tension between this view and the view that momentary distortions of perceived space might tend to place the action capabilities of an individual in jeopardy. For example, Balcetis and Dunning (2010) recently argued that participants underthrew a bean bag when tossing it toward a valuable target because the value of the target made it appear nearer. Their conclusion has been questioned on empirical grounds, because people do not throw short when instructed to "hit" valuable targets (Durgin, DeWald, Lechich, Li & Ontiveros, 2011). That is, throwing short has been suggested to be the result of a strategic response, employed by motivated participants to the instruction to end up closest to the target. In the present context it is worth emphasizing the drawbacks of a hypothesized visual coding strategy that makes actions less effective for objects of value.

Generalizability

We have framed the current paper in terms of generalizability and we return now to that theme. When people in psychology experiments are asked to wear heavy backpacks, they typically suspect that the backpack is intended to affect their behavior in particular ways. We have reported in the past that camouflaging the purpose of the backpack can be sufficient to remove that experimental demand and return their estimates to normal (Durgin et al., 2009; Durgin et al., in press). In the present experiment we have shown that perceptual judgments seem to return to normal when participants are persuaded to ignore the backpack. Consider now a person wearing a backpack in normal life. We think if the conditions are such that the person is carrying his or her pack for a legitimate reason and does not think that the purpose of the backpack is to affect his or her perception, then that person's perception and that person's judgment are unlikely to be affected by the backpack.

Because Schnall et al. (2010) required all their participants to wear heavy backpacks, we simply cannot know from their results whether blood glucose levels affected their participants' perception of the hill. Our findings here and previously (Durgin et al., 2009, in press) suggest that many of their participants were probably providing estimates that were artificially inflated in response to the social aspect of the backpack manipulation. But our present data suggest that two social/cognitive factors may have been necessary to producing sugar effects: (1) experimental demand (though not necessarily in the form of a backpack; demand may be induced simply by confronting participants with a steep hill as part of a psychology experiment), and (2) uncertainty on the part of participants about the content of the drink. As illustrated in Figure 2, participants in our study who reported recognizing by taste whether the soda contained sugar or not seem to have been unaffected by the sugar manipulation, though they were still affected by the experimental demand of the backpack. Conversely, those told to ignore the backpack and report their perceptions were apparently unaffected by sugar whether or not they had figured out by taste which kind of soda they had received. Our findings imply that Schnall et al.'s results simply may not generalize to situations in which an experimental demand to elevate slant estimates is not a prominent feature of the social context.

The goals of someone evaluating the spatial layout of their surroundings do not usually include the purpose of trying to help a researcher, and yet many researchers continue to set up experiments in which (1) helping the researcher is the participant's primary social goal, and (2) the experimental hypotheses are transparent or experimental demand characteristics are otherwise unnecessarily left uncontrolled. We think that experiments that involve complex but socially fraught situations in which participants are motivated to deduce and possibly comply with the experimenter's theoretical goals (real or imagined) tend to lack an important form of external validity (Adair & Spinner, 1981; Weber & Cook, 1972). We may learn little or nothing about normal perception from experiments which do not control for such social factors. The idea that space perception is readily affected by things like blood sugar and backpacks is an attractive one to many students of perception, but our study adds to the evidence that when careful controls are implemented, these effects tend to be linked to cognitive and social factors rather than to unconscious modifications of visual experience.

Acknowledgments

This research was supported by Award Number R15 EY021026-01 from the National Eye Institute. The content is solely the responsibility of the authors and does not necessarily represent the official views of the National Eye Institute or the National Institutes of Health. Zhi Li provided technical assistance.

Appendix A

The post-experiment questionnaire.

Note: Only one question was visible at a time, and participants could not go back.

1. You were given a drink at the beginning of the experiment. Do you think that this drink contained sugar or do you think it was sugar-free? (Choose one.)
    1. definitely contained sugar
    2. almost definitely contained sugar
    3. probably had sugar
    4. probably did not have sugar
    5. almost definitely did not contain sugar
    6. definitely did not contain sugar
2. Why did you think this? (Check all the apply)
    1. I could taste the difference
    2. I can feel the difference now
    3. Just guessing
    4. Other

3. Why do you think you were given the drink?
4. Do you think that the drink you were given affected your performance on:
    a. The color identification task? (Explain)
    b. The outdoor spatial judgment task? (Explain)
5. Why do you think you were asked to wear the backpack?
6. How heavy (specify pounds or kilos) do you think the backpack was?
7. Do you think the backpack affected your judgment of the steepness of the hill?
8. What is the steepest possible realistic estimate that you think would be a reasonable estimate for that hill when looking at it?
9. What is the shallowest possible realistic estimate for that hill you might consider reasonable?
10. How steep do you think the hill really is?

Appendix B

Answers to Question 5, "Why do you think you were asked to wear the backpack?" sorted by demand condition and type of response:

High demand condition (simply told to wear backpack)

Purpose was to increase perceived or judged slant (N = 7)

- With a weight pulling me back, I think they were looking to see if I would overestimate more (think the hill was steeper).
- When wearing a backpack, the hill looks steeper
- Maybe it gave me a sense that the hill was steeper? But again, there wasn't a control…so I don't really know.
- Maybe to make me think, at some level, that the hill was steeper than it actually was, as wearing a relatively heavy backpack would put me in the mindset of thinking how hard it would be to climb a hill with weight on my back, so I would exaggerate in my head how steep the hill actually was.
- The backpack weighted me down and made me feel lower, so I might have overestimated the steepness of the angle.
- so that id feel more tired and say it was steeper
- to make the incline seem steeper, because I had a heavy load that would stink to carry up it.

Purpose was to alter perceived or judged slant (N = 7)

- Maybe to see how the heavy weight affected my perception of space?
- I think I was asked to wear the backpack to see if the effort of supporting it would affect my visual perception of the angle of the path.
- Maybe to put some sort of stress on the body. Maybe people in the past were getting it easier and you needed a different set of data.

- To change my center of gravity, so i get a different perspective on the incline of the hill.
- I think it was to throw off my judgment of the slope of the hill.
- It threw off my equilibrium so that I couldn't use that to determine the angle of the path.
- To affect how I was able to balance myself while trying to make this judgement

Purpose was to reduce perceived or judged slant (N = 1)

- Perhaps the weight of the backpack makes you feel heavier, hence you are likely to underestimate the angle of the slope?

Other (N = 6)

- Maybe to recreate the feeling I have when I go up the hill with my backpack? So maybe because of the weight bringing my body down a bit, I can imagine the incline my body will go on if I went up the hill better.
- I have no idea.
- to simulate how an average student feels during a given point during the academic day.
- To simulate a student walking to class.
- I think it was to simulate a typical condition of a college student (since college students usually walk around with their backpacks).
- it could diverted my whole attention

Low demand condition (told to ignore backpack)

Purpose was to increase perceived or judged slant (N = 7)

- to change my reaction to the hill. A backpack would make the hill more daunting and thus steeper
- I think I was asked to wear the backpack because when a person judges the slope of a hill their judgement can be skewed based on how difficult they think climbing the hill will be. Therefore, with the heavy backpack on, I may have seen the hill as steeper than it is in reality.
- Does it make the hill look steeper?
- I would assume it was to see if i would overestimate the slope of the hill. Maybe it was full of sugar.
- to see if i thought the hill to be steeper than it actually was because i had all that weight on my back
- To simulate me having to walk up the hill which would presumably make me think the hill was steeper
- It probably throws off balance, brings you back so you overestimate the slope

Purpose was to alter perceived or judged slant (N = 6)

- To see if the backpack had any effect on the way I perceived the slope of the hill

- I think the weight of the backpack can change a person's opinion about distances and depths
- Maybe estimating slope changes depending on you much you are carrying/ how much you weigh
- To simulate as if I was going to be walking up the slope. Maybe having a heavier weight on would change my perception of the hill.
- To see if I would let it affect my perception
- To see if it affected my hand estimate versus my visual estimate.

Purpose was to reduce perceived or judged slant (N = 1)

- I think we were asked to wear the backpack because it tilts our body backwards and so we would estimate a lesser slope than the actual slope.

Other (N = 2)

- So that there was a distraction present - the physical pressure of the backpack took my mind off concentrating only on the slope
- I was explicitly told during the test that the wearing of the backpack is supposed to emulate a social environment, and thus they seemed to be trying to infer the behavioral implications (spatial judgment included) of making judgments in such an atmosphere.

References

Adair JG, Spinner B. Subjects' access to cognitive processes: Demand characteristics and verbal report. Journal for the Theory of Social Behaviour. 1981; 11:31–52.

Balcetis E, Dunning D. Wishful seeing: More desired objects are seen as closer. Psychological Science. 2010; 21:147–152. [PubMed: 20424036]

Bhalla M, Proffitt DR. Visual-motor recalibration in geographical slant perception. Journal of Experimental Psychology: Human Perception & Performance. 1999; 25:1076–1096. [PubMed: 10464946]

Creem SH, Proffitt DR. Two memories for geographical slant: Separation and interdependence of action and awareness. Psychonomic Bulletin & Review. 1998; 5:22–36. [PubMed: 11543314]

Durgin FH, Baird JA, Greenburg M, Russell R, Shaughnessy K, Waymouth S. Who is being deceived? The experimental demands of wearing a backpack. Psychonomic Bulletin & Review. 2009; 16:964–969. [PubMed: 19815806]

Durgin FH, DeWald D, Lechich S, Li Z, Ontiveros Z. Action and motivation: Measuring perception or strategies? Psychonomic Bulletin & Review. 2011:1077–1082. [PubMed: 21912998]

Durgin FH, Hajnal A, Li Z, Tonge N, Stigliani A. Palm boards are not action measures: An alternative to the two-systems theory of geographical slant perception. Acta Psychologica. 2010; 134:182–197. [PubMed: 20176342]

Durgin FH, Hajnal A, Li Z, Tonge N, Stigliani A. An imputed dissociation might be an artifact: Further evidence for the generalizability of the observations of Durgin et al. 2010. Acta Psychologica. 2011; 138:281–284. [PubMed: 20889135]

Durgin FH, Li Z. Perceptual scale expansion: An efficient angular coding strategy for locomotor space. Attention, Perception & Psychophysics. 2011; 73:1856–1870.

Durgin FH, Li Z, Hajnal A. Slant perception in near space is categorically biased: Evidence for a vertical tendency. Attention, Perception & Psychophysics. 2010; 72:1875–1889.

Durgin, FH.; Ruff, A.; Russell, R. Constant enough: On the kinds of perceptual constancy worth having. In: Hatfield, G.; Allred, S., editors. Visual Experience. Oxford University Press; (in press).

Gailliot MT, Baumeister RF, DeWall CN, Maner JK, Plant EA, Tice DM, Brewer LE, Schmeichel BJ. Self-control relies on glucose as a limited energy source: Willpower is more than a metaphor. Journal of Personality and Social Psychology. 2007; 92:325–336. [PubMed: 17279852]

de Grave DDJ, Brenner E, Smeets JBJ. Using a stick does not necessarily alter judged distances or reachability. PLoS ONE. 2011; 6(2):e16697. [PubMed: 21390215]

Hajnal A, Abdul-Malak DT, Durgin FH. The perceptual experience of slope by foot and by finger. Journal of Experimental Psychology: Human Perception and Performance. 2011; 37:709–719. [PubMed: 20731518]

Higashiyama A, Ueyama E. The perception of vertical and horizontal distances in outdoor settings. Perception & Psychophysics. 1988; 44:151–156. [PubMed: 3405741]

Hutchison JJ, Loomis JM. Does energy expenditure affect the perception of egocentric distance? A failure to replicate Experiment 1 of Proffitt, Stefanucci, Banton, and Epstein (2003). Spanish Journal of Psychology. 2006:332–339. [PubMed: 17120712]

Jacoby LL. A process dissociation framework: Separating automatic from intentional uses of memory. Journal of Memory and Language. 1991; 30:513–541.

Knill DC, Saunders JA. Do humans optimally integrate stereo and texture information for judgments of surface slant? Vision Research. 2003:2539–2558. [PubMed: 13129541]

Li Z, Durgin FH. Perceived slant of binocularly viewed large-scale surfaces: A common model from explicit and implicit measures. Journal of Vision. 2010; 10(14):1–16. 13 http://journalofvision.org/content/10/14/13. [PubMed: 20465327]

Li Z, Durgin FH. Design, data and theory regarding a digital hand inclinometer: A portable device for studying slant perception. Behavior Research Methods. 2011a; 43:363–371. [PubMed: 21298570]

Li Z, Durgin FH. Manual matching of perceived surface orientation is affected by arm posture: Evidence of calibration between proprioception and visual experience in near space. Experimental Brain Research. 2011b

Li Z, Phillips J, Durgin FH. The underestimation of egocentric distance: Evidence from frontal matching tasks. Attention, Perception & Psychophysics. 2011; 73:2205–2217.

Loomis JM, Da Silva JA, Fujita N, Fukusima SS. Visual space perception and visually guided action. Journal of Experimental Psychology: Human Perception and Performance. 1992; 18:906–921. [PubMed: 1431754]

Loomis JM, Philbeck JW. Is the anisotropy of perceived 3-D shape invariant across scale? Perception & Psychophysics. 1999:397–402. [PubMed: 10334089]

Loomis JM, Philbeck JW, Zahorik P. Dissociation between location and shape in visual space. Journal of Experimental Psychology: Human Perception and Performance. 2002; 28:1202–1212. [PubMed: 12421065]

Mook DG. In defense of external invalidity. American Psychologist. 1983; 38:379–387.

Ooi TL, He ZJ. A distance judgment function based on space perception mechanisms: Revisiting Gilinsky's (1951) equation. Psychological Review. 2007; 114:441–454. [PubMed: 17500634]

Orne MT. On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. American Psychologist. 1962; 17:776–783.

Palmisano S, Gillam B, Govan DG, Allison RS, Harris JM. Stereoscopic perception of real depths at large distances. Journal of Vision. 2010; 10(6):19. [PubMed: 20884568]

Philbeck JW, Loomis JM, Beall AC. Visually perceived location is an invariant in the control of action. Perception and Psychophysics. 1997; 59:601–612. [PubMed: 9158334]

Proffitt DR. Affordances matter in geographical slant perception: Reply to Durgin, Baird, Greenburg, Russell, Shaughnessy, and Waymouth. Psychonomic Bulletin & Review. 2009; 16:970–972. [PubMed: 19815807]

Proffitt DR, Bhalla M, Gossweiler R, Midgett J. Perceiving geographical slant. Psychonomic Bulletin and Review. 1995; 2:409–428.

Proffitt DR, Stefanucci J, Banton T, Epstein W. The role of effort in perceived distance. Psychological Science. 2003; 14:106–112. [PubMed: 12661670]

Ross, HE. Behavior and perception in strange environments. London: George Allen & Unwin; 1974.

Russell R, Durgin FH. Demand characteristics, not effort: The role of backpacks in judging distance. Journal of Vision. 2008; 8(6):755a. [Abstract].

Schnall S, Harber KD, Stefanucci J, Proffitt DR. Social support and the perception of geographical slant. Journal of Experimental Social Psychology. 2008; 44:1246–1255. [PubMed: 22389520]

Schnall S, Zadra JR, Proffitt DR. Direct evidence for the economy of action: Glucose and the perception of geographical slant. Perception. 2010; 39:464–482. [PubMed: 20514996]

Shaffer DM, Flint M. Escalating slant: Increasing physiological potential does not reduce slant overestimates. Psychological Science. 2011; 22:209–211. [PubMed: 21169523]

Shebilske WL. Baseball batters support an ecological efference mediation theory of natural event perception. Acta Psychologica. 1986; 63:117–131. [PubMed: 3591429]

Stein KD, Jacobsen PB, Blanchard CM, Thors CT. Further validation of the Multidimensional Fatigue Symptom Inventory-Short Form (MFSI-SF). Journal of Pain and Symptom Management. 2004; 27:14–23. [PubMed: 14711465]

Stigliani A, Durgin FH, Li Z. How accurate is memory for familiar slope? Journal of Vision. 2010; 10(7):1245.

Weber SJ, Cook TD. Subject effects in laboratory research: An examination of subject roles, demand characteristics, and valid inference. Psychological Bulletin. 1972; 77:273–295.

Woods AJ, Philbeck JW, Danoff JV. The various perceptions of distance: An alternative view of how effort affects distance judgments. Journal of Experimental Psychology: Human Perception & Performance. 2009; 35:1104–1117. [PubMed: 19653752]

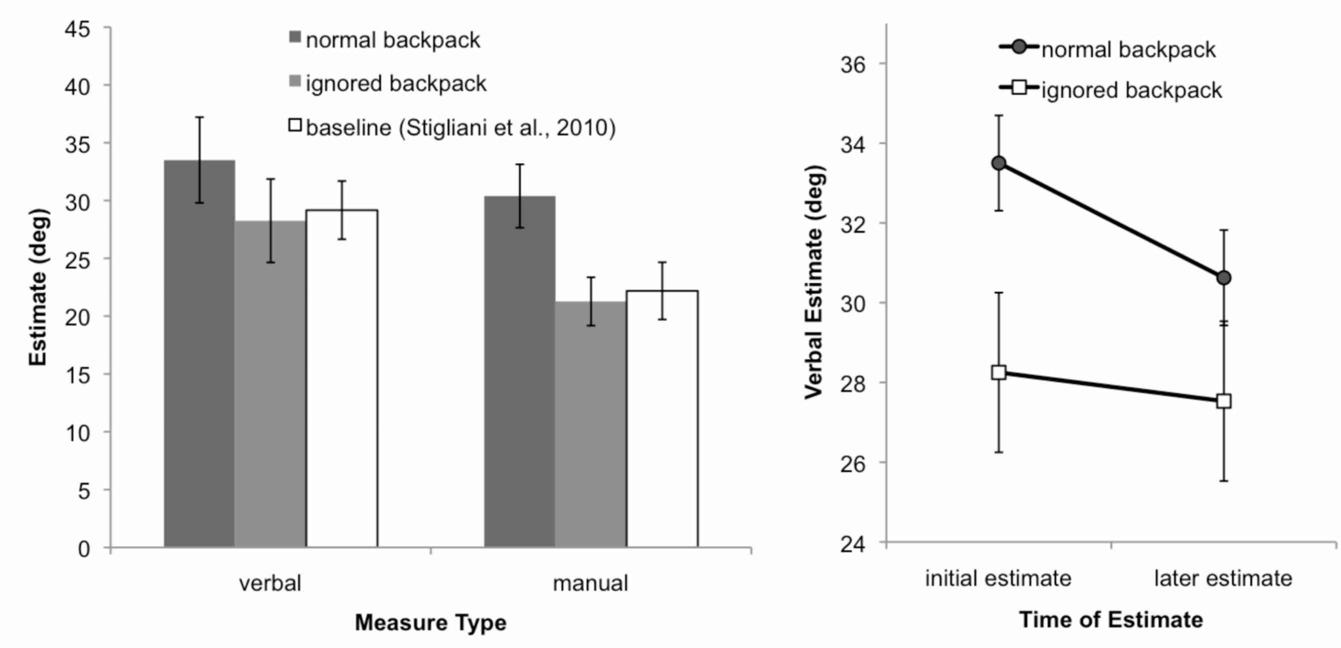

Figure 1.

Average slant estimates as a function of experimental demand and the type (left) and time (right) of measurement. The left plot shows that if participants are asked to ignore the heavy backpack, their slant estimates are not elevated relative to baseline data collected without a backpack. Standard errors of the means are shown for the left plot. The right plot shows that participants in the normal backpack condition revise their estimates downward when later asked how steep the hill actually is. Standard error bars for the right plot are computed with respect to within-subject differences.

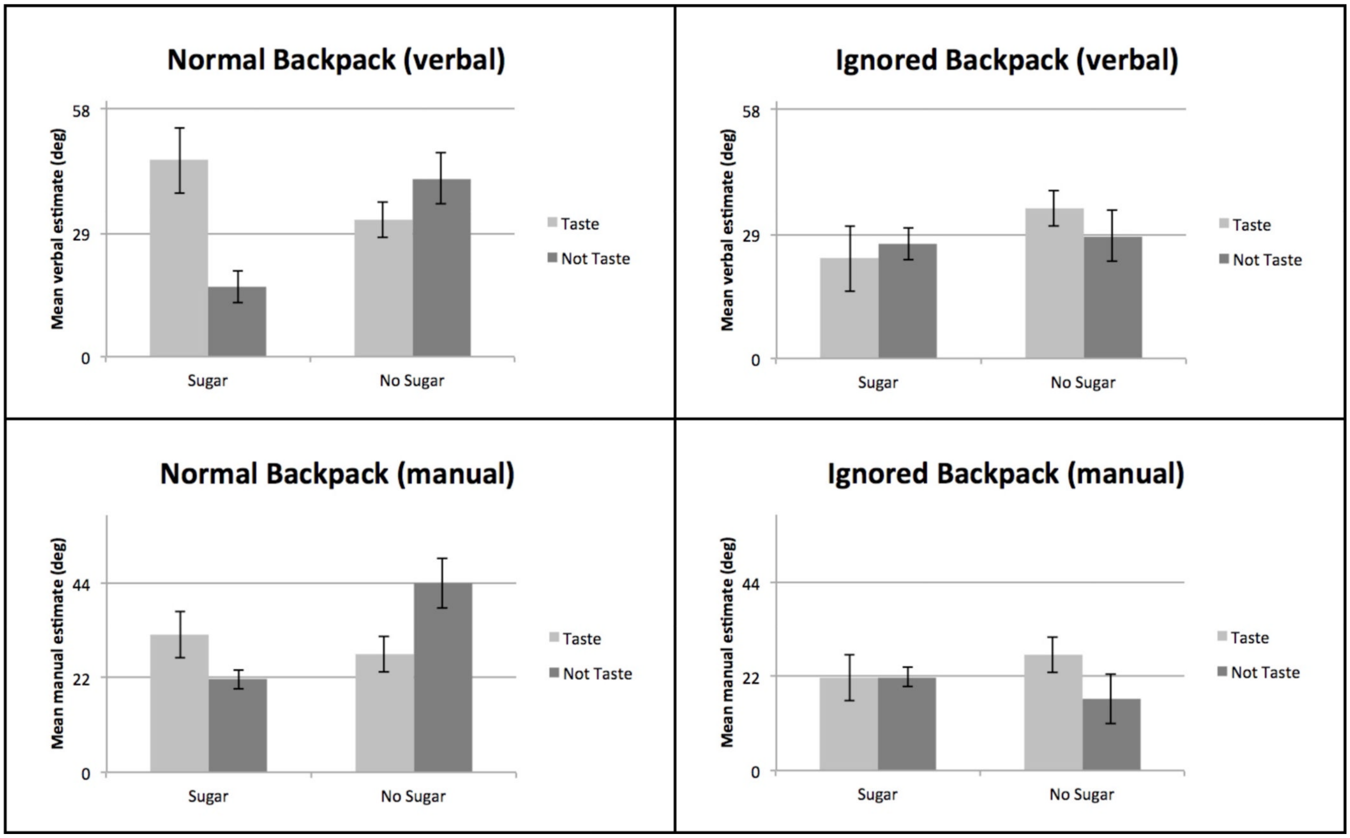

Figure 2.

Estimation data split by Demand (High Demand, left; Low Demand, right) and Measure (Verbal, above; Manual, below) and plotted as a function of both Sugar condition and self-reported sensory knowledge (Taste) of the condition. Gridlines (29° verbal; 22° manual) represent baseline estimates for this hill for the two measures. Standard errors of the means are shown.

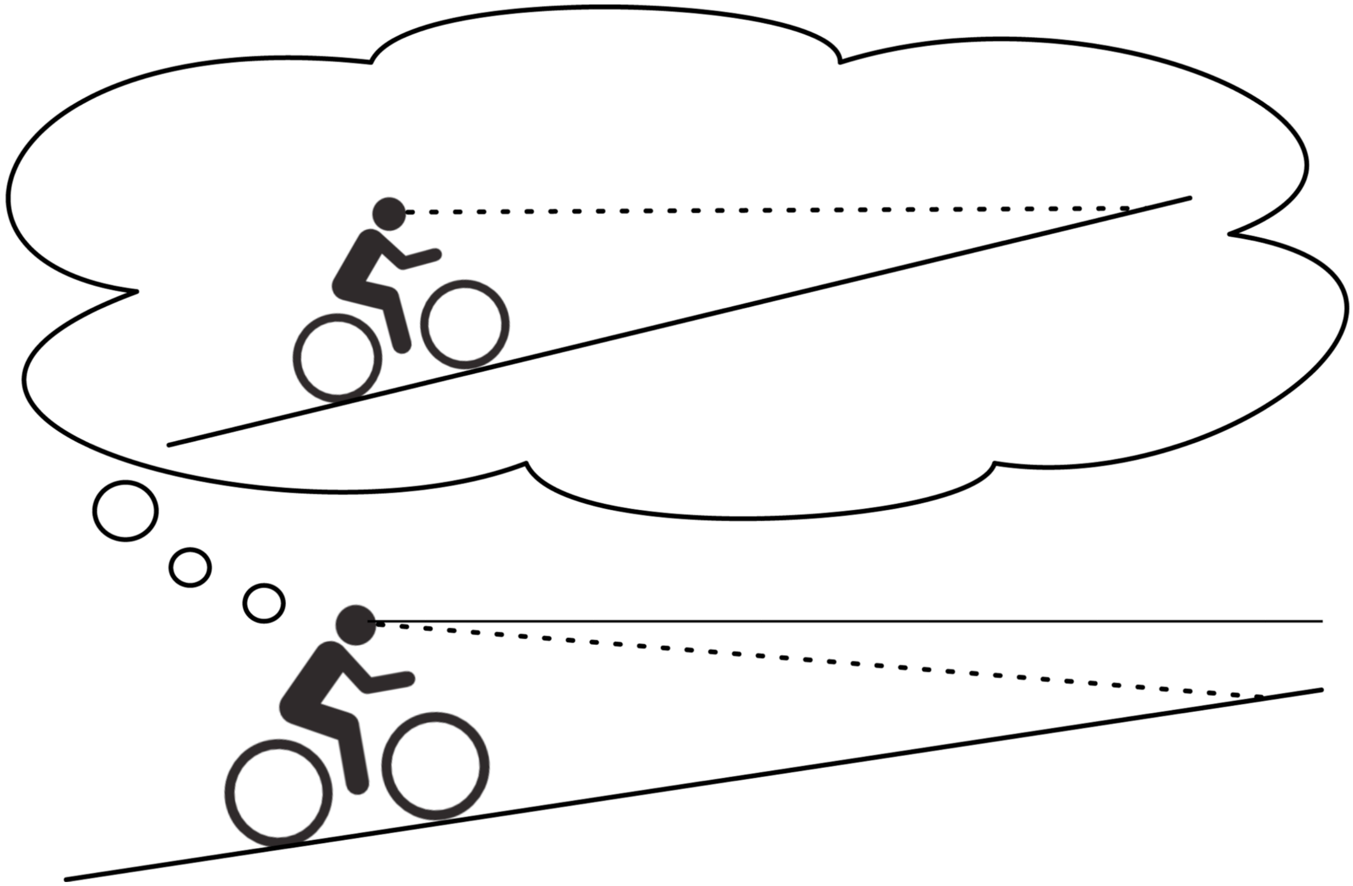

Figure 3.
Illustration of an alternative account of bicyclist hill misperception based on postural adaptation after extended riding: If one adapts to a lowered head or gaze posture while biking (or hiking), one may misperceive slightly downward gaze as being forward gaze. The image in the bubble represents the perceptual error in geographical slant (increased overestimation) predicted based on a misperception of gaze direction (dashed line) relative to the true straight ahead.

Table 1

Frequencies of beliefs about the experimental intent of the backpack manipulation

Demand Condition	belief about intent of backpack on estimates/perception			
	alter (increase)	alter (unspecified)	alter (reduce)	other
High Demand	7	7	1	6
Low Demand	7	6	1	2