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An Embodied Approach to Perception: By What Units Are Visual Perceptions Scaled?

Dennis R. Proffitt
University of Virginia

Abstract

When humans perceive the environment, angular units of visual information must be transformed into units appropriate for the specification of such parameters of surface layout as extent, size, and orientation. Our embodied approach to perception proposes that these scaling units derive from the body. For example, hand size is relevant for scaling the size of a strawberry, whereas an extent across a meadow is scaled by the amount of walking required to traverse it. In his article, Firestone (2013, this issue) argued that our approach is wrong; in fact, he argued that it must be wrong. This reply to Firestone's critique is organized into three parts, which address the following questions: (a) What is the fundamental question motivating our approach? (b) How does our approach answer this question? (c) How can we address Firestone's arguments against our approach? A point-by-point critique of Firestone's arguments is presented. Three conclusions are drawn: (a) Most of Firestone's arguments reflect a misunderstanding of our approach, (b) none of his arguments are the fatal flaws in our approach that he believes them to be, and (c) there are good reasons to believe that perception—just like any other biological function—is a phenotypic expression.

Keywords

embodied perception, perceptual scaling, spatial perception

In the study of perception, many of us are pursuing some aspect of Koffka's (1935) question, "Why do things look as they do?" My own research over the last 20 years has been an inquiry into how angular units of visual information are transformed into the semantics of human experience. I have concluded that the vehicle for this transformation is the human body. Perhaps this reflects my lack of imagination, but I cannot imagine how it could be otherwise.

Although he provided no alternatives for the fundamental question of how spatial perceptions are scaled, Firestone (2013, this issue) argued that our account is wrong. This reply is organized into three parts, which tackle the following questions: (a) What is the fundamental question motivating our research? (b) What is our account? (c) What are Firestone's arguments against our account, and how can they be addressed?

First, I need to put to rest the *paternalistic vision* moniker. Our embodied perception approach attempts to answer the following sorts of questions. How do you visually scale the size of a strawberry that you are about to pick up and eat? How do you visually scale the extent of a meadow over which you intend to walk? Our account proposes that you use your body in both of these cases, but different aspects of your body are used across these two occasions. In the case of picking up a strawberry, the size of your hand's precision grip is relevant, whereas in the case of walking across a meadow, the amount of walking required is relevant and perhaps scaled to the energy expenditure associated with walking. There is nothing paternalistic about scaling the size of a strawberry to the extent of one's precision grip or scaling long extents across the ground to the amount of walking required to traverse them. The term is simply not apt.

By What Units Are Visual Perceptions Scaled?

Visual information is composed of angular units, these being visual angles, changes in these angles, and oculomotor adjustments, which are scaled as angles as well. As Gibson (1979) repeatedly reminded us, we do not perceive information; rather, we perceive the environment

Corresponding Author:
Dennis Proffitt, Department of Psychology, University of Virginia, P.O. Box 400400, Charlottesville, VA 22904
E-mail: drp@virginia.edu

and our perspective on it. To derive spatial perceptions, the angular units of visual information must be transformed into spatial units. With respect to perceiving size and distance, for example, the angular units of visual information must be transformed into linear units. The length of an extent is defined by its magnitude on some unitized ruler. The question that has motivated our research is this: By what units are spatial perceptions scaled? Our answer is that the units derive from the body. Firestone proffered no alternative answer.

Figure 1, adapted from a drawing in Gibson's book (1979, pp. 195), shows an observer, first sitting in a chair and then standing a few steps in front of the chair. The lines drawn into his enlarged eye represent rays defining luminance contrasts at the edges of salient objects and textures in his environment. Animations of this figure can be viewed at http://www.faculty.virginia.edu/perlab/misc/bookanimations/

The most comprehensive discussion of our embodied scaling account is found in Proffitt and Linkenauger (2013). There we used eye-height scaling of size as an example of how the body can be used to scale spatial perceptions. In his essay, Firestone discussed eye-height scaling at some length and seems to believe that it is the general solution to the scaling problem. It is not; more will be written later about why eye-height scaling has limited utility. Consider another example, the scaling of binocular disparities by interocular distance. Binocular disparities are insufficient to scale the depth in an image beyond its affine structure. Interocular distance and viewing distance are required to recover depth (Proffitt & Caudek, 2013). Viewing distance can be recovered by relating the vergence angles to interocular distance; thus, depth can be scaled to this aspect of the body (Ono & Comerford, 1977).

In summary, visual information consists of angular units, whereas the units of perceived extent are linear. Thus, in all cases of perceiving size and distance, angular units must be transformed into linear ones. We propose that the requisite transformations relate angular magnitudes to bodily ones. In addition, we propose that no single aspect of the body can be used in all cases. Retinal disparities, for example, cannot be scaled with eye-height information, which is effective only for objects on the ground and not for objects held in the hand. Likewise, eye-height scaling is not composed of units of interocular separation.

Perception Viewed as a Phenotypic Expression

Background

Our account builds on two well supported ideas. The first is that people learn to interpret visual information by having agency in its creation. Whenever we move, there is a change in all of the visual angles arriving at the eye (i.e., optic flow), and it is represented in Figure 1 (and especially in the online animation). Learning how optic flow specifies the environment is a matter of discovering the relationship between our actions and the resulting flow. Discovering this relationship requires agency; optic flow must be self-produced as opposed to passively observed. Held et al.'s seminal "kitten carousel" experiment (Held & Bossom, 1961; Held & Hein, 1963) firmly established this role of agency in perceptual motor learning. In their experiments, pairs of kittens were given visual experience during the experimental phase of the study and were otherwise raised in the dark. In the experimental context, one kitten had control over locomotion, whereas the other was moved passively. After being raised in this manner, both kittens could see just fine—their visual systems had matured normally—but the kitten in the passive-movement condition behaved as if it could not understand the meaning of its visual experience. The passive-movement kitten had problems visually guiding its paws, it failed to discriminate the deep from the shallow side of a visual cliff, and it failed to make blink responses when something approached its eyes. This and many subsequent studies, including studies with humans, support the conclusion that we learn to interpret optic flow through the experience of producing it.

The second idea, upon which our approach builds, is Gibson's (1977) theory of affordances and the research literature that supports it. Gibson proposed that we perceive an environment in terms of the possibilities for action that it provides. These action possibilities are called *affordances*. They include whether an object is of a size that can be grasped; whether a surface is sufficiently substantial, smooth, and of an orientation that it can be walked upon; or whether an apple hanging on a tree is of a height that can be reached. As Adolph's research shows (cf. Adolph, Berger, & Leo, 2011), babies learn through experience those environmental affordances that are consistent with their current behavioral repertoire and continue to learn new affordances as their new action capabilities develop.

An embodied approach to visual perception

The conclusion to our recent chapter, "Perception Viewed as a Phenotypic Expression," stated the following (Proffitt & Linkenauger, 2013):

> Our account is quite simple. . . . In a given situation, we perceive the possibilities for action, and given our purposes, the world is scaled to that aspect of our body, which is relevant for the pursuit

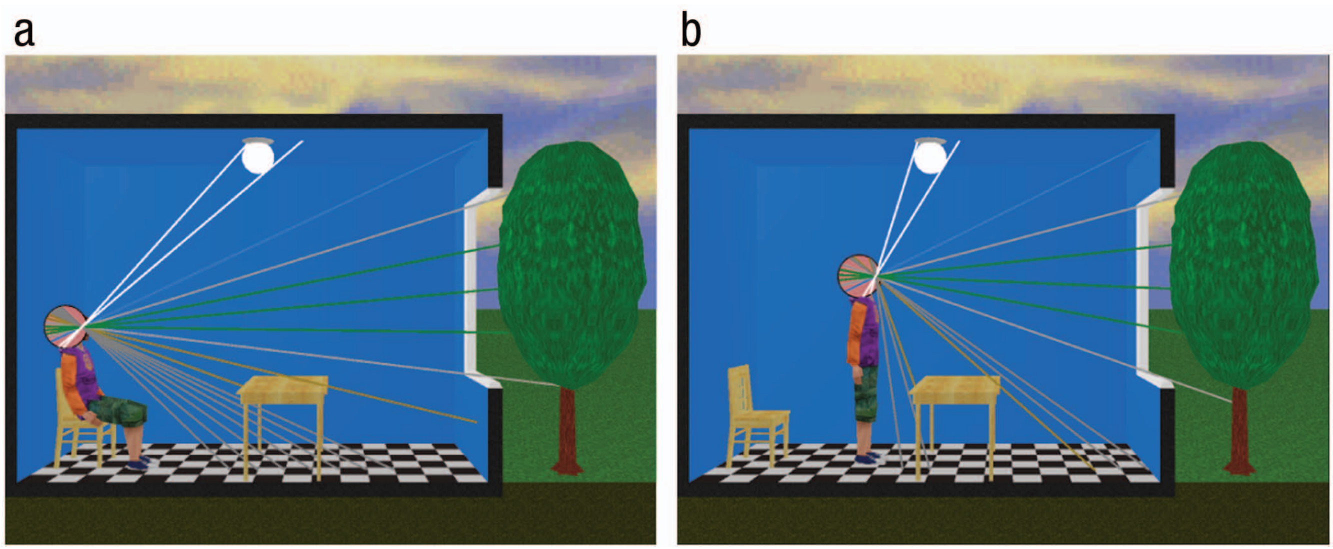

Fig. 1. The visual angles projecting to the eye from an illuminated surrounding. As the observer moves (b), these angles change, producing optic flow.

> of achievable aims. . . . Given current purposes, individuals organize their phenotypes to pursue their aims, and in so doing, transform themselves into action-specific phenotypes, such as "graspers," "reachers," "walkers," "throwers," "batters," and any of the indefinite other phenotypic organizations that we can achieve. Our purposes determine our phenotypic organization, which in turn, determines the aspect of our body that is appropriate for use as a perceptual ruler. For "graspers," hand size is relevant, for "reachers," arm length is relevant, and so forth. In essence, *our purposes determine what we become—our phenotypic organization—and what we become determines the relevant units of meaning for our spatial experience*. (p. 192, emphasis added)

Opposing this perspective, Firestone expressed a concern that the visual sciences have made substantial progress without appealing to embodied considerations. He wrote,

> Vision science has made real progress in understanding the cognitive processes underlying much of spatial perception, but the sophisticated and successful computational models of capacities such as the perception of depth and three-dimensional structure do not include terms for the weight on the perceiver's shoulders or the ability to hit a baseball. (p. 458)

He is correct; considerable progress has been made, but there is more to do. Formal models of perceiving structure from motion are useful; however, the ones that successfully derive accurate three-dimensional structure are unlikely to be candidate models for the human visual system (Todd & Bressan, 1990). A more serious problem is that structure-from-motion algorithms derive shape, not size and distance. Shape is size-invariant; a marble and the moon have the same spherical shape.

A distance is the linear extent between two locations. Defining the magnitude of a distance can be done only by relating one extent to another, typically by assigning one of the extents to the role of being a measurement ruler. The measurement ruler provides the semantic construct for a magnitude of extent. For example, the meaning of 10 cm is nothing other than an extent between two locations that subtends 10 cm on a metric ruler.

Transforming optical location information into linear units requires geometry and a ruler. We propose that the body provides a plethora of perceptual rulers, which are selected because they are relevant for intended actions. Without a ruler, the magnitude of a distance cannot be specified.

Our embodied approach is not necessarily at odds with computational approaches to vision. Rather, our account is tackling questions that have been given little attention in the computational literature. These questions include the following: What are the semantics of human visual experience? By what units are visual perceptions scaled?

Arguments Against Our Embodied Approach to Visual Perception

Argument 1: Embodied perceptual effects are the wrong size for the job

There are at least three problems with this argument.[1]

Our account predicts the occurrence and direction of these effects; no other account predicts either. When first reported, the finding that spatial perceptions are influenced by changes in people's action potential was surprising (Proffitt, Bhalla, Gossweiler, & Midgett, 1995). Currently, an embodied account continues to be the only perspective that predicts the presence and direction of phenotypic influences on spatial perception.

Learning new affordances takes experience and time. Firestone's reasoning is based on the false assumption that perceptual motor adaptation is instantaneous. As was briefly discussed in the previous section, learning new affordances requires agency, experience, and time. Babies, for example, are not sensitive to the size of a gap that they can step over when they first learn to walk (Adolph et al., 2011).

Treadmill walking—a perceptual motor adaptation that we have often used—evokes an adaptation to the atypical occurrence of walking in the absence of optic flow. Employing a design similar to that used by Anstis (1995), we had blindfolded participants attempt to walk in place for 20 s before and after walking on a treadmill for 30 s at 3 mph (Proffitt, Stefanucci, Banton, & Epstein, 2003). Similar to Anstis's findings, our participants drifted forward by approximately 1 m in the posttest compared with the pretest. Now, had our participants fully adapted to the new walking speed–optic flow pairing, they would have raced off in the posttest at 3 mph, thereby traversing 88 feet in the allotted 20 s. This, of course, never occurred.

In studies in which experimental manipulations were used to alter participants' action potential, we would not expect perceptual motor adaptation to be instantaneous. Adaptation takes agency, experience, and time.

Given sufficient experience, action boundaries and perceptions are well calibrated. We have data from participants with a lifetime of experience adapting to a changes in the action boundary for grasping (Linkenauger, Witt, & Proffitt, 2011). It turns out that right-handed people perceive the left hand to be smaller than the right, and as a consequence, they perceive that they can grasp larger objects with the right as opposed to the left hand (Linkenauger, Witt, Bakdash, Stefanucci, & Proffitt, 2009). Given this difference in perceived action boundaries for grasping, we predicted and found that the perceived sizes of objects were smaller when participants anticipated grasping with the right as opposed to the left hand. Moreover, participants perceived a 4% difference in the grasping ability of their left and right hands, and a 4% difference was found in the apparent size judgments across the left- versus right-hand grasping conditions.

Argument 2: Action-specific units are incommensurable

I completely agree with this statement; action-specific units are incommensurable. We do not measure strawberries with the same perceptual ruler as that with which we measure large extents across a meadow. Firestone views such incommensurability to be a problem because he incorrectly claimed that our approach proposes that people use minima in action units to make decisions about what actions to take in achieving goals, such as, for example, when choosing whether to reach for or walk to an object. This idea is Firestone's creation, not ours.

We have proposed that, in some circumstances, phenotypic scaling would promote efficiencies in behavior, but not in the manner that Firestone suggests. Consider, for example, our proposal that walkable extents are scaled by the bioenergetic costs of traversing them. Such scaling would cause distances up a steep hill to appear greater than equivalent extents on the flat ground, and this is what our research has found (Stefanucci, Proffitt, Banton, & Epstein, 2005).

Note that, in this example, efficient behavior is promoted within a specific type of action (i.e., walking). We have never claimed that the phenotypic scaling of space promotes efficiency in choosing between different actions not sharing a common scaling unit. In fact, most cases of phenotypic scaling do not promote efficiency at all. No efficiency is gained by scaling the size of a strawberry to the size of one's precision grip or by scaling the size of a target to the variability associated with one's ability to hit it. Grip size is determined by morphology and hitting a target is a matter of performance. Phenotypes consist of morphology, physiology, and behavior (see Zimmer & Emlen, 2013). Only in the case of physiology—bioenergetic scaling—have we claimed an efficiency advantage for phenotypic scaling.

An important finding across our studies is that the influence of an action unit—such as graspability—is evident only within its action boundary. For example, graspable objects appear smaller to people with large versus small hands; however, no size difference is apparent for objects too large to be grasped by either group (Linkenauger et al., 2011).

Argument 3: Ability-scaling is informationally ungrounded

Firestone argued that visual information cannot be scaled by action units in a manner analogous to the direct way in which size and distance can be scaled in units of eye height. If perceptual learning were impossible, then Firestone's claim would be true. Fortunately, we are not raised as the passive-movement kittens were in Held et al.'s (Held & Bossom, 1961; Held & Hein, 1963) kitten carousel experiments. We have the opportunity, agency, experience, and time needed to learn our action capabilities.

Consider, for example, learning to hit the bull's-eye of a target with a bow and arrow on a windy day. Where you should aim the arrow is not optically specified. You cannot simply point the arrow at the bull's-eye, because gravity will accelerate the arrow downward and wind will displace it laterally. So, you make your best guess about where to aim, you release the arrow, and you see what happens. Over time, your performance will improve; you can discover where to aim.

In like manner, people can learn the visual consequences of all of their actions. People simply need to behave and see what happens. Consider learning the extent of one's reach. People have many opportunities to learn the vergence angles, accommodative state, and optical information that coincide with their arm's reach. There is a large literature showing that people know the extent of their arm's reach; they overestimate a little bit, but they are reliable (see Rochat & Wraga, 1997). This and all other action boundaries are discoverable.

The scaling of target size with performance variability is necessarily a learned achievement. Golf putting holes, for example, look larger when people are putting well (Witt, Linkenauger, Bakdash, & Proffitt, 2008). People can see whether they sink their putts, and if they do not, they can see by how far they missed. We proposed that the frequency and magnitude of misses over time specifies a performance distribution that is used to scale the size of the putting hole. This distribution is discoverable.

What about scaling the extent across a meadow by how much walking is required to traverse it? Our visual motor system could easily relate the optically specified location of targets to the amount of walking required to arrive at their location. Amount of walking could be quantified as optic flow over time, number of steps taken, or energy expended. I have favored the latter, bioenergetic account, but I may be wrong.

Finally, Firestone's discussion of eye-height scaling requires brief comment. Like most depth and size cues, eye height has limited utility (Cutting & Vishton, 1995). It can be used only for objects and extents on a flat ground plane. People do not use eye height to scale the size of objects outside of the range of 0.2 to 2.5 eye heights (Wraga & Proffitt, 2000), and the degree change in visual angle of elevation per meter becomes negligible for targets beyond 20 m. Scaling via eye height will not suffice for either the strawberry or the meadow.

Argument 4: Embodied perceptual effects are not subjectively noticeable (and they should be)

When giving talks, I am often asked a question about phenomenology. For example, people will ask why they do not notice a change is spatial layout when they don a backpack. Once, after a talk, a friendly member of the audience got up, did a couple of deep knee bends (supposedly to induce fatigue), and then enquired as to why the appearance of the lecture hall had not changed for him. There are at least three answers to this question.

A goal of the visual system is to provide perceptions of a stationary environment having constant properties. Many aspects of perceptual processing are hidden from phenomenology. Consider a few examples. We make saccadic eye movements approximately 3 times a second. During the 30-ms duration of a saccade, a motion-blurred image is projected across the retina. You would think that we would notice this, and we would were it not for saccadic suppression, which blinds us during the saccade. Given that approximately 10% of our waking time consists of making saccades, we are blind for approximately 1.6 hr a day, which is surprising because it is not noticed. When making a saccade from one location to another, the location of every feature in the visual world moves to a new location. We do not notice these changes in location because, in programming eye movements, the visual system creates an efference copy and compares this model with the resulting sensory input. The visual system assumes a mostly fixed and stationary environment that does not move when we do. A goal of perceptual processing is to maintain this assumed constancy in our phenomenal experience.

Changing an action capability changes the perceptual ruler, not the location of the extent's endpoints. Imagine someone looking at a target on the ground. Now, suppose that this person dons a backpack or in some other manner increases the bioenergetic costs of walking. By our account, the distance to the target will now appear greater, a prediction borne out by our research (Proffitt et al., 2003). Does the person notice a change in the location of the target? Of course not; its location has not changed. The ruler used to measure the extent to the target has changed, not the target's location.

There is a deep issue here. Intuition suggests that we perceive the environment as it is, that distances simply are what they are. So, when we state that a relevant phenotypic change causes a change in perceived extent, people assume that the world should appear to shrink or expand. This would be true only if the locations being measured moved, not if the endpoints of the extent remained stationary and the measurement device shrank or expanded.

Research shows that even if the environment does shrink or expand as we walk, we do not notice it. The perceptual system's attempt to provide an awareness of a stationary world having constant properties is so strong that even large magnitudes of environmental contraction or expansion are not noticed. Glennerster, Tcheang, Gilson, Fitzgibbon, and Parker (2006) immersed participants in a large virtual room using a head-mounted display. As participants walked about, the room expanded or contracted by up to a fourfold magnitude. None of the participants noticed the change in room size, although some reported that they seemed to be changing their gait speed or stride length as they walked about.

Alternative accounts for our findings

Rather than propose an alternative account for how spatial perceptions are scaled, Firestone argued, instead, that our findings could be explained by alternative explanations, which I will briefly discuss.

Biased in judgment, not perception: Task demands. With respect to the backpack manipulation, it was I who first raised this alternative explanation:

> A very reasonable objection would be that these manipulations might have created a response bias, so that the results might not reflect an influence on perception itself. After all, if people are asked to wear a heavy backpack while making distance judgments, they might well suspect that the backpack is supposed to have an effect on their judgments—why else are they being asked to wear one? (Proffitt, 2006, p. 115)

Firestone's claim that our findings are due to task demands relies primarily on Durgin and colleagues' studies looking at the backpack manipulation's influence on perceived slant. In one study, participants viewed an incline while wearing a backpack under different cover stories (Durgin et al., 2009). In a reply to Durgin et al., I stated that their study may not generalize to ours because they used an incline consisting of a 2-m long ramp that abutted a closed door (Proffitt, 2009). The incline did not afford walking, and thus wearing a backpack was irrelevant to its perceptual scaling. More recently, Durgin, Klein, Spiegel, Strawser, and Williams (2012) published a study looking at the backpack manipulation's influence on slant judgments of an outdoor hill that could be ascended. In one condition, they told participants nothing about why they were wearing the backpack, and in the other condition, they told participants to ignore its possible influence on their slant judgments. In Durgin et al.'s words:

> To reduce the experimental demand of wearing a heavy backpack, we adopted an instructional manipulation in which, just before 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. (p. 1584)

This instructional manipulation was found to result in lower slant judgments relative to the no-instruction condition. From this finding, it was concluded that the no-instruction condition induced a demand characteristic, whereas the detailed instructions to ignore potential demand characteristics did not. I am unconvinced that this is so. Research in social psychology has convinced me that if you tell someone not to think about *X*, then they will surely think about *X* (see Wegner, 1989). Indeed, Orne's (1962) classic article on demand characteristics explicitly noted that it is impossible to design a study without demand characteristics, because participants will always have some expectations or intuitions about the research. I can think of no principled reason to accept Durgin et al.'s assertion that it is possible to eliminate presumed demand characteristics by introducing a completely new set of demand characteristics.

A way to eliminate demand characteristics is to study individual phenotypic differences in action capabilities. In these designs, there are no experimental manipulations; everyone is treated the same. Such studies of individual differences have been done in the domains of reach and grasp scaling of perception (Linkenauger, Witt, Stefanucci, Bakdash, & Proffitt, 2009), bioenergetic scaling of slant perception (Bhalla & Proffitt, 1999; Schnall, Zadra, & Proffitt, 2010, Study 2), and perceived target size as influenced by performance (Lee, Lee, Carello, & Turvey, 2012; Witt et al., 2008). (These citations are not an exhaustive list.) In these studies, individual differences in arm length, hand size, fitness, age, fatigue, and accuracy in hitting targets were found to influence spatial perceptions as predicted.

Judgment, not perception: Affordances and action-plans. We have tried to be responsive to arguments that some of our manipulations may have their influence on judgment rather than perception and have performed studies to evaluate this alternative. One of these studies made use of treadmill walking adaptation, a consequence of which is that distances to targets on the floor appear greater after adaptation then they did before (Proffitt et al., 2003). By our account, this result was due to a rescaling of the effort required to walk to the target, which would change the perceptual ruler for measuring the extent; however, others suggested that the effect was on the judgment process, instead. We conducted a study to address this concern in which the response measure, blind walking, was the same for all participants (Witt, Proffitt, & Epstein, 2010). Firestone suggested that while viewing the target, participants may have encoded different action plans into memory and these were responsible for the obtained results. This study, however, was a follow-up on an earlier one that used a similar design but used verbal distance estimates while viewing the targets (Witt, Proffitt, & Epstein, 2004). The assessment of perception in this study cannot be explained by Firestone's proposed memory encoding account. On the other hand, we agree with Firestone that action planning is important; it is the basis for selecting perceptual rulers. A recent study by Kirsch and Kunde (2012) nicely demonstrates how the anticipated effort associated with an action plan influences the perceptual scaling of apparent distances.

Evidence. Firestone cites two failures to replicate our findings, both of which failed to find an influence for wearing a backpack on perceived distance (Hutchison & Loomis, 2006;[2] Woods, Philbeck, & Danoff, 2009). It should be noted, however, that these null results are as problematic for Durgin et al.'s (2009) demand characteristic account as they are for our bioenergetic proposal. As summarized in the Appendix, there exists a far greater body of research—from labs with no connections to ours—that replicates and extends our findings.

Conclusion

Currently, Proffitt and Linkenauger (2013) is the best summary of our position. I finish this essay with excerpts from the final paragraphs of this chapter's conclusion:

> Is our account complete? Of course not. We have painted our approach with broad strokes, and most of the important questions pertaining to spatial perception remain unaddressed.
>
> Is our account right? For this question, our answer is yes and no. Our central claim must be true; in many situations, the body has to provide the fundamental scales for perceiving size and extent. The example of the differently scaled perceptual worlds of Gulliver and the Lilliputians makes this point obvious, and it is difficult to imagine how it could be otherwise. Have we got all of the details right? Of course not. We are happy to be shown where we are wrong so long as better alternative accounts are also advanced. Without the provision of alternatives, null findings provide few insights. Gibson (1979) often reminded his readers that we do not perceive information, we perceive the world. Visual information must be transformed from angles into extent-specifying units. *If these units do not derive from the body, then what is their source?*" (p. 192–193, emphasis added)

Appendix

Numerous studies have found changes in perceived distance within *near space* after relevant phenotypic changes: Alter and Balcetis (2011), Balcetis and Dunning (2010), Bloesch, Davoli, Roth, Brockmole, and Abrams (2012), Kirsch, Herbort, Butz, and Kunde (2012), Kirsch and Kunde (2012), Longo and Lourenco (2007), Morgado, Gentaz, Guinet, Osiurak, and Palluel-Germain (2012), Morgando, Muller, Gentaz, and Palluel-Germain (2011), Osiurak, Morgado, and Palluel-Germain (2012), and Valdés-Conroy, Román, Hinojosa, and Shorkey (2012).

For *far space*, including walkable distances, size, and height perception, the following studies replicate and extend our results: Balcetis and Dunning (2007); Chambon (2009); Cole, Balcetis, and Zhang (2013); Harber, Yeung, and Iacovelli (2011); Jackson and Cormack (2007); Jarraya, Chtourou, Souissi, and Charmari (2011); Schwebel, Pitts, and Stavrinos (2009); and van der Hoort, Guterstam, and Ehrsson (2011).

In the domain of *goal-directed action on targets*, the influence of performance on perceived target size has been found in the following studies: Canal-Bruland, Pijpers, and Oudejans (2010, 2012), Canal-Bruland and van der Kamp (2009, 2012), Canal-Bruland, Zhu, van der Kamp, and Masters (2011), den Daas, Haefner, and de Wit (2012), Gray (2012), Lee, Lee, Carello, and Turvey (2012), Masters, Poolton, and van der Kamp (2010), Vasey et al. (2012), and Wesp, Cichello, Gracia, and Davis (2004).

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Declaration of Conflicting Interests

The author declared no conflicts of interest with respect to the authorship or the publication of this article.

Notes

1. Firestone's account of the geographical slant overestimation found in our studies is misleading. Firestone claimed that

> . . . subjects who drank 250 ml of a juice beverage containing natural sugars and artificial sweeteners judged a hill to have a grade more than 50% steeper than did subjects who drank 250 ml of a sugar-sweetened version of the beverage (Schnall et al., 2010)—a difference in perceived slope equivalent to nearly twice the grade of San Francisco's steepest avenues. (p. 459)

In fact, in Schnall et al.'s Study 1, the hill was judged to be 14° steeper relative to 42° in the control condition, which is a difference of 33%; in Study 2, the hill was judged to be 6° steeper relative to 22°, which is 27%. (These differences are not twice the slant of San Francisco's steepest avenue, which is 18.5°.) Firestone's claim about a 50% increase in steepness is an artifact of his converting the dependent measure, degrees, into its tangential function, grade. Slant measured in degrees conforms to an interval scale ranging from 0 to 90°. Grade is not an interval scale—horizontal is 0 and vertical is ∞.

2. In a reply to Hutchison and Loomis, we pointed out that they used a very different dependent measure in their study, one for which we would not have predicted an influence of wearing a backpack on assessments of apparent distance (Proffitt, Stefanucci, Banton, & Epstein, 2007).

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