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How "Paternalistic" Is Spatial Perception? Why Wearing a Heavy Backpack Doesn't—and *Couldn't*—Make Hills Look Steeper

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Abstract

A chief goal of perception is to help us navigate our environment. According to a rich and ambitious theory of spatial perception, the visual system achieves this goal not by aiming to accurately depict the external world, but instead by actively distorting the environment's perceived spatial layout to bias action selection toward favorable outcomes. Scores of experimental results have supported this view—including, famously, a report that wearing a heavy backpack makes hills look steeper. This perspective portrays the visual system as unapologetically *paternalistic*: Backpacks make hills harder to climb, so vision steepens them to discourage ascent. The "paternalistic" theory of spatial perception has, understandably, attracted controversy; if true, it would radically revise our understanding of how and why we see. Here, this view is subjected to a kind and degree of scrutiny it has yet to face. After characterizing and motivating the case for paternalistic vision, I expose several unexplored defects in its theoretical framework, arguing that extant accounts of how and why spatial perception is ability-sensitive are deeply problematic and that perceptual phenomenology belies the view's claims. The paternalistic account of spatial perception not only isn't true—it couldn't be true, even if its empirical findings were accepted at face value.

Keywords

perception, action/performance, philosophy, embodiment

In a popular cinematographer's trick, a character's physical abilities and psychological states are conveyed to viewers by distorting the world as seen through the character's eyes. When a detective climbs a belltower's stairway in Alfred Hitchcock's *Vertigo*, his environment stretches in depth as he peers down in terror at how far he could fall. When all-star basketball player Michael Jordan leaps from half-court to make an heroic, game-winning slam dunk in *Space Jam*, the hoop creeps closer to him.

Mounting empirical and theoretical evidence spanning nearly two decades of research appears to suggest a striking perceptual reality to this cinematographic technique. According to a rich and influential theory I will call the *paternalistic vision hypothesis*, perception of the environment's spatial layout is systematically sensitive to the perceiver's abilities and purposes. Hills, it is claimed, look steeper to observers burdened by heavy backpacks (Bhalla & Proffitt, 1999), objects look closer to actors whose reach is augmented by a tool (Witt, Proffitt, & Epstein, 2005), and heights look higher to those who fear them (Teachman, Stefanucci, Clerkin, Cody, & Proffitt, 2008), just like *Vertigo*'s detective. Such effects are said to facilitate the selection of safe, efficient, successful actions: Heavy backpacks make hills harder to climb, so vision steepens them to discourage ascent.

If true, the paternalistic vision hypothesis bears deep and far-reaching consequences for several issues in perceptual, social, and philosophical psychology. Chief among these, it threatens to revise a long-held understanding of how—and even why—the visual system computes the three-dimensional structure of the world, according to which visual processing operates on little more than the stimulus information reaching the eyes and is stubbornly insulated against states such as the perceiver's goals, beliefs, or action capabilities (e.g., Fodor, 1983; Pylyshyn, 1999). If vision is paternalistic in the way

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suggested, then a new and exciting understanding of what perception *is*—and what it is for—is in order.

Moreover, although it is a virtue of much experimental vision research that empirical disputes can often be settled by demonstrations in which the relevant phenomena are experienced directly (e.g., illusory contours, change-blindness, apparent motion), it is widely agreed that this route has proven fruitless in the present case. As anyone can freely discover, no changes in landscape topography are subjectively apparent as one dons and removes a backpack—and certainly not to the seismic degree frequently reported (e.g., changes in perceived slant and distance of 25%–30%; Bhalla & Proffitt, 1999; Proffitt, Stefanucci, Banton, & Epstein, 2003). It is precisely because "Everyday experience suggests that the perceptual world reflects the constant geometric properties of the environment" (Proffitt, 2006b, p. 120) that it would be all the more earthshaking to discover that the perceptual world is ever bending and warping before our eyes.

These considerations offer strong reasons to interrogate the paternalistic account of spatial perception. This article's aim is thus to characterize, evaluate, and ultimately reject the paternalistic vision hypothesis on the basis of several insurmountable difficulties facing it. In particular, despite some initial plausibility, extant accounts of how and why spatial perception is sensitive to the perceiver's action capabilities fail, and there is no satisfactory solution to the challenge from perceptual phenomenology. I conclude that the motivation and explanatory framework for paternalistic vision are deeply flawed and that the existing empirical results can be satisfactorily explained by other factors.

The Paternalistic Vision Hypothesis

In a well-known study that has sparked a vibrant research program, observers stood at the base of a hill and estimated its slant by adjusting a handheld cross-sectional representation of the hill to visually match the real hill before them. One group estimated while wearing heavy backpacks, and another group viewed the hill without backpacks. Remarkably, those observers burdened by backpacks judged the hill to be approximately 5° steeper than did the unencumbered observers (Bhalla & Proffitt, 1999).

Various manipulations and dependent measures have since yielded similarly striking results. Wearing a heavy backpack inflates estimates of egocentric distance to objects (Proffitt et al., 2003), as does throwing a heavy ball before estimating (Witt, Proffitt, & Epstein, 2004). Fatigued or physically unfit individuals overestimate slant and distance relative to rested or fit individuals (Bhalla & Proffitt, 1999; Proffitt, Bhalla, Gossweiler, & Midgett, 1995; Sugovic & Witt, 2011; see also Witt et al., 2009), fixing weights to subjects' ankles increases size estimates of a jumpable gap (Lessard, Linkenauger, & Proffitt, 2009), holding one's arms out to one's sides decreases width estimates of doorway-like apertures (Stefanucci & Geuss, 2009), and standing on a wobbly balancing board reduces width estimates of a walkable beam (Geuss, Stefanucci, de Benedictis-Kessner, & Stevens, 2010). Conversely, subjects who wield reach-extending conductor's batons judge targets to be closer (Witt et al., 2005), and subjects who drink a sugary beverage such as Coca-Cola (rather than no-calorie Coke Zero) estimate hills to be shallower (Schnall, Zadra, & Proffitt, 2010). Hot-hitting batters report bigger softballs (Gray, in press; Witt & Proffitt, 2005), successful field-goal kickers report wider football uprights (Witt & Dorsch, 2009), shot-making tennis players report lower nets (Witt & Sugovic, 2010), accurate dart-throwers report larger targets (Cañal-Bruland, Pijpers, & Oudejans, 2010; Wesp, Cichello, Gracia, & Davis, 2004), and golfers who have had a favorable day on the green report larger golf holes (Witt, Linkenauger, Bakdash, & Proffitt, 2008). Swimmers judge underwater targets to be closer when wearing speedy flippers than when barefoot (Witt, Schuck, & Taylor, 2011), and individuals trained in the urban acrobatic sport *parkour* give shorter estimates of a wall's height than do untrained individuals (Taylor, Witt, & Sugovic, 2011).

These and many more results have inspired the proposal that visual perception distorts the world according to the perceiver's abilities and purposes—what I will call the *paternalistic vision hypothesis* (for reviews, see Proffitt, 2006b, 2008; Proffitt & Linkenauger, 2013; Witt, 2011a). The modifier *paternalistic* is for this theory's picture of the visual system as a teller of well-intentioned white lies about the world, so as to bias perceivers toward favorable actions. As vividly put by Proffitt (2006b), "A principal function of perception is to defend people from having to think" (p. 119).[1]

This imputed function of paternalistic visual systems—to assist their owners in selecting actions—itself plays a central role in supporting the broader hypothesis. Embedding information about ability into the perceived spatial world supposedly confers "adaptive advantages" (Proffitt, 2006b, p. 119; Witt, 2011a, p. 204) on perceivers by taking on some of the cognitive heavy lifting in selecting actions. For example, a prospective hill-climber blessed with paternalistic vision could choose to climb only those hills appearing shallower than, say, 20° and then leave the rest to the visual system: If the backpack is prohibitively heavy or if sugar stores are prohibitively low, vision will intervene and steepen the hill to exceed an invariant climbability-specifying critical grade, ensuring that the perceiver "does not have to relate perception to potential for action because this has already been achieved in perception" (Proffitt, 2008, p. 181). In this way, it is suggested, there is good reason for perception to operate paternalistically.

The "ability-scaling" account

So far, I have very briefly sketched what paternalistic vision is supposed to do, and why it might be supposed to do it. In recent years, the theoretical picture has been rounded out by an account of how paternalistic vision is actually achieved by the visual system. The central premise of this account, which will be revisited in much greater detail, is that the body provides the visual system with a bounty of so-called "perceptual rulers" with which to measure up the world and that changes in ability, performance, intention, and arousal can expand and contract the rulers and thereby alter the perceived spatial properties of the environment (Lessard et al., 2009; Linkenauger, Ramenzoni, & Proffitt, 2010; Linkenauger, Witt, & Proffitt, 2011; Linkenauger, Witt, Stefanucci, Bakdash, & Proffitt, 2009; Proffitt & Linkenauger, 2013; Stefanucci & Geuss, 2009, 2010; Stefanucci & Storbeck, 2009; Witt, 2011b; Witt, Proffitt, & Epstein, 2010; Witt et al., 2011). The proposal is explicitly modeled on prominent accounts of body-based *scaling* in size and distance perception—for example, scaling by eye height (e.g., Mark, 1987; Ooi, Wu, & He, 2001; Sedgwick, 1986; Warren & Whang, 1987; Wraga, 1999; Wu, Ooi, & He, 2004). Eye-height scaling accounts hold that the visual system measures the sizes and distances of viewed objects against the altitude of the observer's eyes, yielding values for spatial properties in *eye-level units*. (A nearby tree, for example, could be 3 eye-heights high and 10 eye-heights away.) One strength of eye-height scaling accounts is the explanation they offer for some intuitive phenomenological data relating to size and distance experience. To borrow Bennett's (2011) insightful examples, consider the common observation that childhood haunts seem smaller when revisited later in life, or the intuitively plausible portrayal of spatial experience in films such as *Honey, I Shrunk the Kids*, in which characters zapped by "shrink rays" experience football-field-sized backyards and gargantuan family pets. Eye-height scaling offers a ready explanation of such phenomena: Now that we are, say, twice as tall, the childhood jungle gym is half as many eye-heights high; and for the newly diminutive movie characters, the backyard is hundreds of eye-heights long. These perceiver-environment relations are then reflected in visuospatial experience of size and distance: The jungle gym looks smaller now than it did years ago because it looks fewer "copies-of-me" in size.

The innovative proposal of the paternalistic vision hypothesis is that there exists a multitude of "perceptual rulers" like eye-height, furnished by the body and applied to the world to "transform the manifest angles of visual information into proportions of a particular aspect of one's phenotype" (Proffitt & Linkenauger, 2013, p. 179). The additional rulers, however, are based on abilities ("phenotype" is construed rather broadly, as we will see). Whereas eye height may be relevant "when intending to walk under a low branch" (p. 180), different actions would call for different rulers. For example, "when a perceiver intends to reach, optical information is scaled by the perceiver's ability to reach" (Witt, 2011b, p. 1154). And such *reach-length scaling* would yield distance in units of arm's reach, so that if the reach-length perceptual ruler were lengthened (e.g., by grasping a baton)—as if pulling apart its "tick marks"—extents in depth would register smaller values in reach-length units and would thereby look closer.

> If the action capabilities of the body are expanded, then the perceptual ruler is expanded as well. Consequently, the object at the same physical distance will appear to be closer because the distance to the target measures as shorter on the expanded ruler (Linkenauger, Witt, et al., 2011, p. 1433).

The proposal is less an analogy with eye-height scaling than an elaboration and extension of such accounts. The claim is that the same kinds of principles at work making objects look smaller as we grow taller are also operative in, for example, making objects look closer as our reach grows longer.

Importantly, these additional perceptual rulers are not meant to be restricted to literal parts of the body. Reach-length is offered as an example of an *action boundary* (following Fajen, 2005), the maximum extent at which an action is possible. Another action boundary could be *maximum jump length*. If the maximum extent of one's standing broad jump is used to "scale" a potentially jumpable gap, then when a perceiver's maximum jump length decreases (e.g., by wearing ankle weights; Lessard et al., 2009), the gap would register more units on the jump-length ruler—and so, the story goes, look farther away. It is also suggested that scaling metrics need not be extents at all, so that even the amount of effort required to perform some action, such as walking across a field to an object, could be used to scale the object's distance, as if a metabolic "fuel gauge" (Schnall et al., 2010; p. 467) measured the energetic costs of walking to the object and returned the distance in units of required energy expenditure (perhaps as a proportion of total available energy). Finally, it is proposed that space can be scaled by behavior, as in the case of athletic skill. For example, consistently successful golfers who have a high probability of making a putt (and low variability in their shots' directions) are said to report bigger holes because "The variance of probability distributions can act as a scaling metric for the apparent sizes of goal-directed targets"; for better golfers, "the hole measures as larger on the more compact distribution" and so looks bigger (Proffitt & Linkenauger, 2013, p. 189; Witt et al., 2008). For tidiness, these various proposed scaling operations will collectively be referred to here as *ability scaling*.

Making the case against paternalistic vision

Revolutions in our understanding of the visual system have become increasingly rare with time; but the paternalistic vision hypothesis uniquely and boldly threatens several pillars of contemporary perceptual psychology. 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. Moreover, there are deep empirical and theoretical reasons to think that vision does not submit to coercion from extraperceptual influences such as a perceiver's wall-climbing ability or her fear of heights (e.g., Fodor, 1983; Pylyshyn, 1999), a notion directly challenged by the paternalistic vision hypothesis. Similar reverberations have been felt in social and philosophical psychology, where the notion that perception itself may be "embodied" has become an exciting possibility for similar theories of cognition at large (e.g., Balcetis & Dunning, 2010; Cole, Balcetis, & Zhang, 2013; Goldman, 2012; Meier, Schnall, Schwarz, & Bargh, 2012; Stefanucci, Gagnon, & Lessard, 2011; Veltkamp, Aarts, & Custers, 2008). These implications make the paternalistic vision hypothesis interesting, important, and profoundly consequential. However, they also call for a type and degree of scrutiny that has yet to be applied.

The paternalistic vision hypothesis holds that perceived spatial layout is systematically sensitive to the perceiver's action capabilities, that such sensitivity is achieved by scaling operations of a kind with eye-height scaling of space, and that paternalistic perceptual effects simplify action planning, relieving perceivers of having to reason about their abilities and steering them toward advisable behavior. In what follows, I will argue (in reverse order) that each of these claims—the what, how, and why of paternalistic vision—is false; indeed, at least some of them *must* be false.

"Why": Insufficiently Paternalistic Vision

Paternalistic vision's imputed, "highly adaptive" (Schnall et al., 2010; p. 466) function is to inform perceivers of their action capabilities by distorting spatial experience of the environment, updating the perceptual world to match the perceiver's ability to act on it. But a first strike against such purported usefulness is that, as an empirical matter, paternalistic vision seems to carry out this duty rather ineptly.

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

Most of the focus on the paternalistic vision program's findings has been on their *direction*. Wearing a backpack increases slant estimates, wielding a baton decreases distance estimates, etc., and this seems to suggest that vision distorts the environment according to the perceiver's abilities. However, to support the paternalistic vision hypothesis in particular, the magnitude of these effects is just as important. For to successfully "defend people from having to think" about their abilities, the visual system should distort the perceived environment in a manner proportionate with changes in the perceiver's ability—to convey, with at least some degree of accuracy, how much the perceiver's ability has changed, over and above the mere sign of the change. However, in the actual empirical cases on record, paternalistic vision has turned in an underwhelming performance.

To take one example of many, it has been reported that positioning one's hands 115 cm apart reduces width estimates of a potentially passable aperture (Stefanucci & Geuss, 2009). This effect supposedly serves to inform newly widened perceivers that the apertures have become less passable and thereby to discourage attempts at passage. But the data themselves tell this story far less compellingly. For all but the broadest-shouldered among us, 115 cm constitutes a doubling or tripling of our bodies' widest dimension and renders impassable nearly every doorway we would ever encounter. One might expect, then, that any changes in perceived aperture width following this manipulation would be commensurate with its drastic and consequential reduction in aperture-passing ability. However, the observed compression in perceived aperture width was only 3%! Although in the appropriate direction, an effect of this magnitude is much too modest to assist anyone actually interested in walking through an aperture. Consider even the subjects in the aperture-width study itself (Stefanucci & Geuss, 2009), who viewed apertures ranging from 76 cm in width (roughly that of a typical interior door) up to 152 cm. Any of these apertures would have been easily passable for the average person; however, upon repositioning subjects' arms 115 cm apart, more than half of the presented apertures became impassable. A mere 3% reduction in perceived width simply does not communicate this fact to the perceiver: An aperture that looks

100 cm wide also looks (and is) just as passable as one that looks 97 cm wide. But in fact, most of the presented apertures went from being easily passable to being decidedly impassable when subjects' hand positions were widened.

Such severe miscalibration carries immediate practical consequences. Paternalistic vision supposedly allows organisms to base action decisions on constant values of perceived spatial extents, working behind the scenes to ensure that the perceived environment literally bends to maintain the viability of a particular action-decision strategy (e.g., Proffitt, 2008). For example, perceivers endowed with paternalistic vision can supposedly choose to attempt passage only through doorways appearing, say, 60 cm or more in width, relying on their visual systems to appropriately distort the aperture when their effective body width changes. But the actual empirical results suggest that anyone who dares to take this counsel will collide with their fair share of doorways.

This is one case of many in service of the same point. Another is the finding that increasing reaching extent by more than 50% (by means of a 39-cm baton) reportedly caused only a 5% reduction in perceived distance to potentially reachable targets (Witt et al., 2005). In another, multiplying "apparent grasping ability" by a factor of 3.5—a 250% increase—reportedly decreased the perceived size of graspable objects by only 5% (Linkenauger, Witt, et al., 2011). And in other cases, the effects may even be too large. For example, 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.[2] If, as advertised, these effects are genuinely perceptual, then paternalistic vision radically (and often treacherously) misleads perceivers about their abilities.

Note that this is not meant as an empirical worry; that is, the concern is not that the effects fail to meet some particular experimental prediction of, for example, a "scaling" approach. There are, after all, many cues to visual size and distance, not all of which need be sensitive to ability (see Witt et al., 2005, who make this point as well). Instead, the present worry is that paternalistic vision is not paternalistic enough to do its intended job. If "simplified action planning is an adaptive consequence of seeing the world in terms of costs and benefits" because "seeing these costs in the world eliminates or reduces the need to explicitly deduce their influence" (Proffitt, 2006b, p. 119), then it is incumbent on paternalistic vision to represent the extent of these costs—and to do so on at least the appropriate order of magnitude. That paternalistic visual systems of the kind evidenced by the empirical literature rather spectacularly fail to accomplish this, and even mislead perceivers about what they can and cannot do, directly undermines the primary motivation for engaging in such spatial distortions in the first place.

Argument 2: Action-specific units are incommensurable

Despite inadequately advising perceivers about whether to perform a particular action, paternalistic vision could still be thought useful elsewhere. Indeed, it is often claimed that paternalistic vision can facilitate selection between actions that could fulfill some goal, by revealing the most advisable action through perceptual distortions (e.g., Proffitt, 2006b). However, this proposal, too, is untenable; in fact, it is undermined precisely by other assumptions of the paternalistic vision hypothesis.

As reviewed earlier, the paternalistic vision hypothesis holds that the perceived sizes, distances, and slants of objects and surfaces derive from the ability-based perceptual rulers that measure them, yielding values for those spatial properties in intrinsic, ability-based units: arm lengths, jump extents, calories, and the rest of the perceptual-ruler panoply. The idea is, roughly, that the content of one's spatial-perceptual experiences—say, the perceptual experience of distance—is something like "that object is 10 times as far away as I am tall" or ". . . as my reach is long" or ". . . as I can walk at a cost of 5 calories." As ability-scaling theorists perspicuously put it, "The meaning of an extent is grounded in the metric to which it is scaled" (Linkenauger, Witt, et al., 2011, p. 1433).

However, this formulation raises a worry about paternalistic vision's ability to inform decisions between prospective actions: If spatial extents are experienced in the proprietary units of each action's perceptual ruler (arm-lengths, calories, etc.), then there would seem to be an in-principle difficulty in comparing the values returned by each ruler's measurement, so as to decide between actions.

To illustrate, suppose a perceiver wishes to retrieve a nearby object and can either reach for the object or walk to the object. A straightforward-seeming question for the paternalistic vision hypothesis is as follows: How should this perceiver settle on one action rather than the other? At first, the answer seems equally straightforward: The perceiver should simply compare the output of each scaling operation (reaching and walking), and then choose the action for which the corresponding perceptual ruler returns the smaller value. The action for which the object is represented as closer would seem to be the appropriate choice.

But the situation is not so simple. The insight of ability scaling is supposed to be that the various "action-specific" perceptual rulers return the environment's spatial properties in different units: The perceptual ruler for reaching returns distance in units "specific" to reaching (e.g., reach lengths), whereas the perceptual ruler for walking returns distance in units specific to walking (e.g., footsteps, required walking effort). But if that's right, then each action-specific perceptual ruler's proprietary units would be incommensurable with one another; one could say there is no "conversion rate" from one unit type to another. In that case, it would turn out that neither ruler represented the object as closer, because each ruler would represent distance in different, intrinsic, action-specific units.

Proponents of paternalistic vision themselves appeal to the incommensurability of action-specific perceptual units, albeit in a different context. In repelling a version of the objection that perceptual phenomenology fails to reveal paternalistic perceptual effects, it is often contended that we should never have expected to see the world bend every which way as our intended actions change, because no comparison can be made between the values returned by different perceptual rulers. A reacher, it is suggested, experiences the world just plain differently than a walker does, and the two experiences (distance in arm lengths vs. distance in walking effort) simply are not comparable (see also Proffitt, 2008; Proffitt & Linkenauger, 2013; Witt, Proffitt, et al., 2010). Setting aside the success of this reply, it does seem right to assert this kind of unit incommensurability. But if action-specific units cannot be compared in introspective searches for paternalistic perceptual effects, then neither can they be compared in selecting among potential actions.

One might object here that, at bottom, only one kind of perceptual unit is relevant to paternalistic vision: energy expenditure. Why not think that the visual system always represents spatial extents according to the caloric cost of acting on them, which would allow perceivers to choose the action that makes the target look "fewer calories away"? The answer is that this response underestimates the impressive breadth of results generated by the paternalistic vision research program; it simply is not true that all (or even most) of the relevant empirical findings concern energetic costs. One class of particularly clear counterexamples involves the effects of otherwise-unrelated mental states on spatial judgments. For example, imagining a close friend decreases slant estimates just as consuming a sugary beverage does, supposedly because of increased social support (Schnall, Harber, Stefanucci, & Proffitt, 2008); fear, perceived danger, arousal, and mood influence estimates of altitude, size, and slant (Geuss et al., 2010; Riener, Stefanucci, Proffitt, & Clore, 2011; Stefanucci, Gagnon, Tompkins, & Bullock, 2012; Stefanucci & Proffitt, 2009; Stefanucci, Proffitt, Clore, & Parekh, 2008; Stefanucci & Storbeck, 2009; Teachman et al., 2008); and even witnessing another person successfully intercept a virtual ball in the computer game Pong decreases estimates of the ball's speed (Witt, Sugovic, & Taylor, 2012). Energy considerations are neither here nor there in these cases. Likewise, when athletes who are "in the zone" supposedly experience bigger softballs (Witt & Proffitt, 2005), wider football uprights (Witt & Dorsch, 2009), and larger golf holes (Witt et al., 2008), the assumption is not that less energy is required at that moment to, for example, boot the football between the uprights; it is that the kicker is more accurate. This may apply to even the most basic ability manipulations (e.g., Stefanucci & Geuss, 2009; Witt et al., 2005), which seem to be less about the energy required for an action than the likelihood of that action's success. An approach based exclusively on required energy expenditure would thus be too crude a characterization of such heterogeneous empirical results, and so it fails to solve the incommensurability problem.[3]

Choices between actions that could each fulfill a goal are commonplace, and paternalistic vision might have assisted in such situations (Proffitt, 2006b). However, to successfully defend people from having to think about the best course of action available to them, paternalistic visual systems must be equipped to compare available options. If action-specific units are incommensurable, then they cannot fulfill this essential purpose.

"How": The Lawlessness of Ability Scaling

Even if paternalistic visual systems do not serve their owners very well, compelling empirical evidence with appropriate theoretical backing could nevertheless convincingly support the broader hypothesis (although it would remain unclear why spatial perception should work that way in the first place). To that end, the ability-scaling approach marks a leap forward in accounting for how the visual system carries out the perceptual resizing of space so extensively catalogued over nearly two decades. Advertised as the theoretical synthesis that will integrate and explain the collection of otherwise-disparate findings reviewed thus far, the ability-scaling perspective has been especially well articulated in recent years (Lessard et al., 2009; Linkenauger et al., 2009; Linkenauger et al., 2010; Linkenauger, Witt, et al., 2011; Proffitt & Linkenauger, 2013; Stefanucci & Geuss, 2009, 2010; Stefanucci & Storbeck, 2009; Witt, 2011b; Witt, Proffitt, et al., 2010; Witt et al., 2011) and has already influenced the broader research community, directly motivating several new studies and analyses (e.g., Cañal-Bruland, Pijpers, & Oudejans, 2012; de Grave, Brenner, & Smeets, 2011; Kirsch, Herbort, Butz, & Kunde, 2012; Kirsch & Kunde, in press; Lee, Lee, Carello, & Turvey, 2012; Osiurak, Morgado, & Palluel-Germain, 2012). The central thesis is succinctly summarized by Witt (2011b): "perception is a function of scaling optical information to the perceiver's abilities" (p. 1155).

However, the appeal to perceptual scaling is a red herring. Lurking behind discussions of scaling space by ability is a deep and fatal disanalogy between the ability-scaling account and its claimed theoretical precursors. In particular, this section argues that the ability-scaling account critically lacks an *informational basis* of the sort that grounds successful scaling accounts in size and distance perception and that several of the proposed scaling metrics are inappropriate candidates in principle for the units of spatial perception. These difficulties irreparably undermine the only mechanism so far put forward as an explanation of paternalistic vision.

Eye-height scaling of size and distance

It will sharpen this issue to briefly review work on eye-height scaling of size and distance (the paradigmatic perceptual ruler), which the paternalistic vision hypothesis elaborates and extends to flesh out its ability-scaling approach. Some familiarity with these ideas should highlight the necessary ingredients of a successful scaling account, so that it is exceedingly clear just what is missing from accounts of scaling space by abilities.

Consider first scaling perceived size by the so-called horizon ratio, the original theoretical development of eye-height scaling (see Sedgwick, 1986). The simple, central insight of this account is that the horizon appears to each observer at eye level, thereby marking the observer's own eye height on any object she sees, irrespective of viewing distance. This convenient fact of optical geometry allows the visual system to use simple angular relations to determine an object's size in eye-level units, as illustrated in Figure 1 (A and B). Because α is the angular extent of the portion of the object above the horizon (A), and β is the angular extent of the portion of the object below the horizon (B), many relations between α and β also hold between A and B. For instance, the ratio of the full object's angular extent ($\alpha + \beta$) to the angular extent of the object's below-horizon portion (β) is equal to the ratio of the full object's size ($A + B$) to the size of the object's below-horizon portion (B). Expressed as an equation,[4] this relationship is

$$(A + B)/B = (\alpha + \beta)/\beta \qquad (1)$$

However, because the horizon (whether directly visible or instead implied, e.g., by a bifurcation in optic flow) cuts objects at eye level, the object's below-horizon portion (B) is equal in size to the observer's own eye height (H). This allows us to substitute H for B, so that the ratio of object size to eye height is given by $(\alpha + \beta)/\beta$ (the so-called horizon ratio):

$$(A + B)/H = (\alpha + \beta)/\beta \qquad (2)$$

or

$$\text{Size}/H = \text{the horizon ratio} \qquad (3)$$

By definition, $H = 1$ eye-level unit for any observer, leaving us with a simple expression of visual size in eye-level units, based on prevailing optical information: Size, in eye-level units, is given by the horizon ratio. All the visual system must do is detect the angles of inclination (α) and declination (β) from the horizon to the object's top and bottom, and eye-height-scaled size can be easily determined.

Eye-height-scaled distance is even simpler. In Figure 1c, distance to a target (D) is the base of a right triangle, and eye height (H) is the triangle's height. Note also the declination angle from the horizon to the target's base, and its complementary angle (θ). By a basic trigonometric relation:

$$D/H = \tan(\theta) \qquad (4)$$

As before, $H = 1$ by definition, so the distance to the target, in eye-level units, is given simply by $\tan(\theta)$. Thus, given only the declination angle to a target, the visual system can determine the distance to that target in eye-level units.

It now becomes clear why, for example, shorter observers might perceive objects to be larger and taller observers might perceive objects to be closer. For shorter observers, the horizon cuts objects lower to the ground (Fig. 1B), increasing the horizon ratio by increasing α and decreasing β. Because the horizon ratio just is size in eye-level units, Eq. 3 returns a larger value for size. Conversely, taller observers have a steeper declination angle and therefore a smaller θ and $\tan(\theta)$. $\text{Tan}(\theta)$ just is distance in eye-level units, so for taller observers, a smaller value is returned for eye-height-scaled distance. (And observers indeed underestimate distance when wearing prism goggles that deflect the apparent declination angle further below the horizon; Ooi et al., 2001.)

All of this exposition is to make clear the following moral: Growing taller does not by itself make objects look smaller or closer. Rather, growing taller changes the point at which the horizon cuts objects (for size) and the declination angle to targets (for distance). Growing taller, of course, entails that objects are in fact fewer eye-heights away and tall, but the visual system can discover this only because growing taller has the right kind of

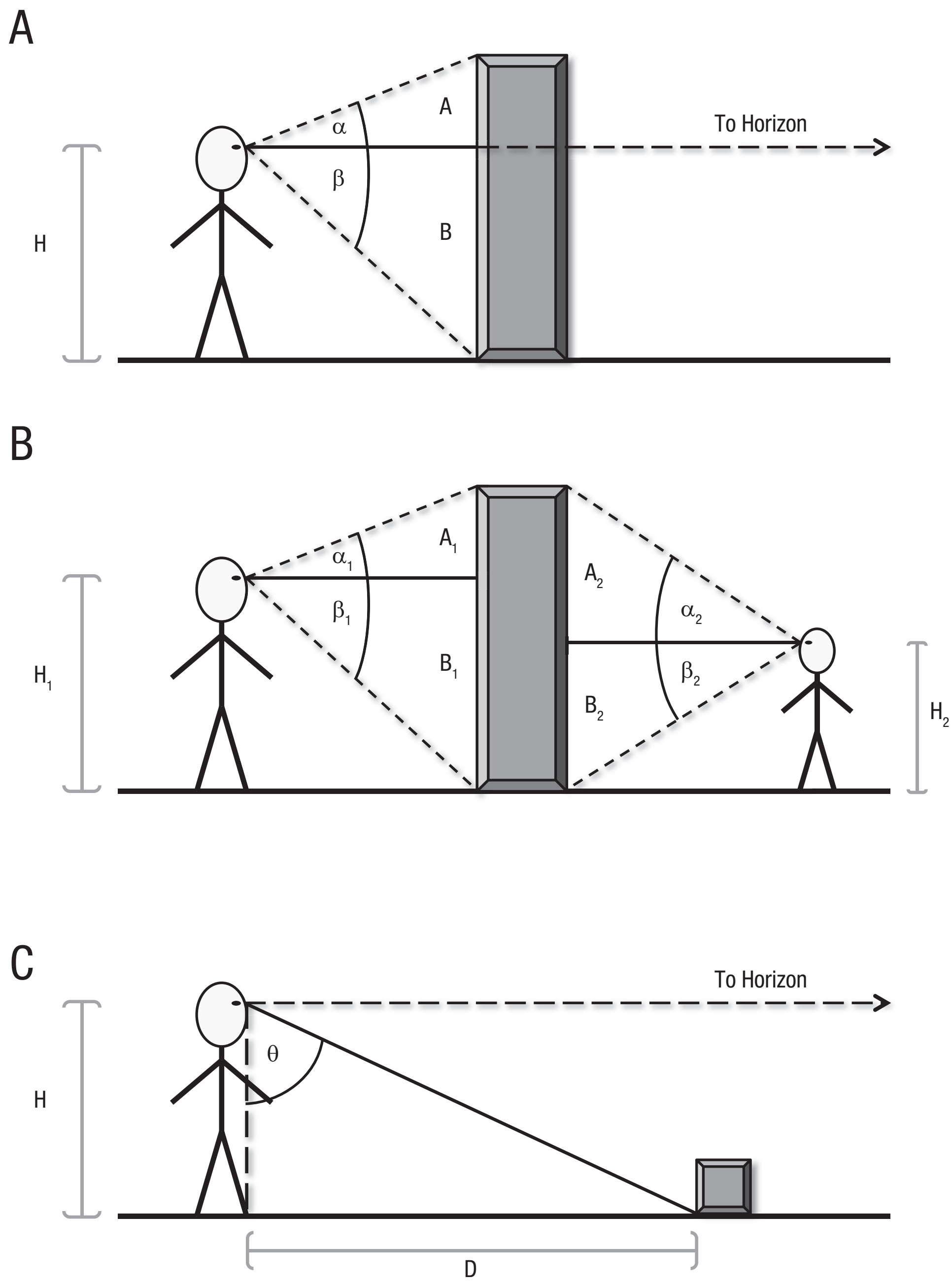

Fig. 1. Eye-height scaling. Eye-height scaling of size is grounded by the horizon ratio (A). For observers of different eye heights, the horizon cuts objects at different points, changing the value of the horizon ratio (B). The declination angle to a target (or its complementary angle, θ) can be used to scale distance in eye-level units (C).

optical consequences. And not just any optical consequences will do: To support perceptual scaling, changes in the scaling metric must leave the kind of informational traces that allow the to-be-scaled spatial property to be expressed in units of the scaling metric and determined by the visual system. Most precisely, what enables the visual system to scale size and distance by eye-height is the existence of lawful supporting relations between, on the one hand, optic-array structures (angles and ratios of angles, optical velocities, etc.), and, on the other hand, eye-height-scaled size or distance. The possibility of constructing equations such as 3 and 4, which articulate these relations between space in body-scaled units and the prevailing visual information, forms the bedrock of any account of the visual scaling of space.

Argument 3: Ability scaling is informationally ungrounded

The paternalistic vision hypothesis contends that we have vastly underestimated the stock of perceptual rulers used to scale spatial layout and that the overlooked rulers are based on effort, energy level, action boundaries, athletic skill, and even arousal. This seems to be a wise and forward-thinking insight: If the sound principles supporting eye-height scaling predict perceptual consequences for size and distance experience, then perhaps those same principles could figure in accounts of jump-height scaling, reach-length scaling, golf-skill scaling, and height-fear scaling and thereby offer similar explanations for the effects observed in the paternalistic vision studies. However, this apparent insight is illusory. As emphasized, there are (at least) two essential ingredients to a successful account of spatial-perceptual scaling: a proposed scaling metric, and a way to relate that scaling metric to the information specifying the to-be-scaled spatial property—a way to express the spatial property in units of the scaling metric through transformations on the information available to vision. The ability-scaling account has the former in spades—but in no case does it appear to have (or pursue) the latter.

The most straightforward reason, then, to think that the visual system does not scale space by ability in the way required for paternalistic vision is simply that there do not appear to be any appropriate relations between, on the one hand, the stimulus information reaching the visual system and, on the other hand, size, distance, height, or slant in ability-based units. In other words, there are no analogs to Eqs. 3 and 4 for size or distance in walking-effort units, glucose-level units, baseball-skill units, reaching-ability units, height-fear units, and so forth.

To illustrate, return to Figure 1, but now suppose the depicted observers wish to jump over (or toward) the objects before them (Lessard et al., 2009; Taylor et al., 2011). Linkenauger, Witt, et al. (2011) explicitly consider such a scenario: For a trekker approaching a crevasse, "the width of the crevasse would be perceived as a proportion of the maximum extent over which one can jump" (p. 1433). Ability-scaling theorists hold that "the visually perceived environment is fully specified by visual information" and that "the 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" (Proffitt & Linkenauger, 2013, p. 171–172). And they very clearly take the function of perceptual rulers to be carrying out these transformations: "Perceptual rulers transform visual angles into extent-appropriate units" (p. 179). By all accounts, then, the job of the jumping-ability ruler is to "transform" units of angular extent into units of jumping ability, just as the eye-height ruler transformed units of angular extent into units of eye-height.

But how will the visual system pull this off? We know how the angular size of viewed objects ($\alpha + \beta$) can be converted into eye-height units (just divide by β), and we know the same for ground-surface extents (apply the tangent relation). But what is the nature of the transformation from a viewed object's angular size to its size in units of jumping ability? An answer is not forthcoming in any discussion of paternalistic vision, and neither is it clear in its own right. There are simply no appropriate relations holding between size and distance in jumping-ability units and the visual angles subtended by objects and extents. Fixing weights to subjects' ankles does, of course, affect jumping ability, but not in a way that makes the right kind of imprint (if any) on the visual information specifying size or distance. But if that is the case, then it cannot be true that "the action capabilities of the body can provide perceptual rulers with which to transform manifest visual angles into extent-appropriate units" (Linkenauger, Witt, et al., 2011, p. 1433), whether for jumping ability or for any other of the myriad proposed ability-based scaling metrics.

Instances of spatial-perceptual scaling are solutions to problems—for example, problems of perceptual indeterminacy. They help observers determine how far away or how big environmental objects are from otherwise-ambiguous visual information such as angular extent. This is what makes so puzzling the persistent contention that "individuals perceive sizes and distances as a proportion of the *action-relevant* aspect of their phenotype" (Linkenauger, Witt, et al., 2011, p. 1433, emphasis added; see also Proffitt & Linkenauger, 2013; Witt, 2011a, 2011b; Witt et al., 2004, 2005; Witt, Proffitt, et al., 2010), such that eye-height scaling, for example, is useful only in circumstances such as "intending to walk under a low branch" (Proffitt & Linkenauger, 2013, p. 180). Eye-height scaling is a general solution to the problem of determining size and distance, and it could have evolved in a branch-less world. Note, for example, that the lack of overhead obstacles or any other action-relevant uses for eye-height in Figure 1C hardly detracts from the declination-angle account's applicability. No action requires expressing the distance to a far-off object in units of copies-of-myself-arranged-head-to-toe-along-the-ground—and yet apparently we use such eye-height-based distance cues (e.g., Ooi et al., 2001). This is certainly no suggestion that ability-scaling theorists are unaware of these aspects of scaling accounts (see especially Dixon, Wraga, Proffitt, & Williams, 2000; Proffitt, 2006a; Wraga & Proffitt, 2000); however, such accounts do seem mishandled for the present purposes. No information about visual size in ability-scaled units is out there to be detected in the first place.[5]

The difficulties with ungroundedness only intensify from here. Although the informational basis for scaling size or distance by these metrics is unknown at best, cases such as reach-length scaling and jumping-ability scaling should be among the easiest cases for the ability-scaling approach to handle. We should at least expect to recognize a successful jump-length scaling account if presented with one. But how will space come to be scaled by metrics such as walking energy, golfing variability, or emotional arousal? (The very suggestion is something of a category error: "Perceptual" or otherwise, unit rulers have the physical quantities they measure.) And what of metrics that uncontroversially leave no informational traces whatsoever? It has been reported that merely imagining reaching with a baton compresses perceived distance just as well as actually picking one up and reaching with it (Witt & Proffitt, 2008; see also Davoli, Brockmole, & Witt, 2012). Such findings alone should sufficiently refute the ability-scaling account as an explanation of the paternalistic vision findings: Needless to say, imagined batons do not impinge on the retina, perturb optic flow, or correlate with other scalable body units; therefore, they are of no use as perceptual rulers.[6]

The challenge to the ability-scaling approach is straightforward. If we are to take seriously the contention that "optical and ocular-motor information is scaled and transformed by action-specific influences into perceptions of spatial layout" (Witt, Proffitt, et al., 2010, p. 1159), then we need relations similar to Eqs. 3 and 4, with optical information on one side and a given spatial property expressed in units of a given action capability on the other. What is the nature of that transformation for the myriad proposed ability-based scaling metrics, from jump-length scaling to golfing-variability scaling to arousal-based scaling? Without an answer, the appeal to perceptual scaling is a distraction that fails to account for paternalistic vision.[7]

"What": Paternalistic Vision and Perceptual Phenomenology

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

Adventurous readers may have noted that several experiments reviewed thus far can easily be tried out at home. Anyone unimpressed by theoretical wrangling can take matters into their own hands and settle any dispute over paternalistic vision for at least their own case: Simply grab the nearest backpack, drink some Coca-Cola, or just raise your arms out to your sides, and look around. Such an undertaking is made easier by reports that mere imagined tool-augmented reaching elicits distance-compression effects similar to actual tool-augmented reaching (e.g., Witt & Proffitt, 2008). So take a moment to try some of these tasks for yourself; do such exercises deliver the expected phenomenology?[8]

These do-it-yourself experiments never seem to work on me, and I suspect that others will have similar luck. But one need not submit to extraordinary manipulations to find support for the claim that perceptual phenomenology fails to corroborate paternalistic vision—the view's proponents themselves implicitly concede the point, by framing the relevant findings to be at odds with introspection. In motivating the novelty of the paternalistic vision results, for example, it is often pointed out that "Everyday experience suggests that the perceptual world reflects the constant geometric properties of the environment" (Proffitt, 2006b, p. 120; see also Schnall et al., 2010). But while such statements indeed highlight the surprisingness of the findings, they also expose a problem for the broader view: If the perceptual world is always warping before our eyes, then why don't we notice it?

To be sure, perceptual experiences can be different without being discernibly different. But the putative effects of paternalistic vision possess several telltale characteristics of otherwise noticeable perceptual phenomena: They are often quite large (25%–50%; Bhalla & Proffitt, 1999; Davoli et al., 2012; Proffitt et al., 2003; Riener et al., 2011; Schnall et al., 2010; Stefanucci et al., 2008), they occur precisely where subjects are attending in space, they affect precisely the features to which subjects are attending, and the objects supposedly undergoing such changes can be studied for as long as one wishes. Such considerations undermine a common response that everyday obliviousness to a warping perceptual world could be explained by a phenomenon like change blindness, wherein substantial changes to visual scenes can go undetected in certain circumstances (Rensink, O'Regan, & Clark, 1997; Simons, Franconeri, & Reimer, 2000; Simons & Levin, 1998). The central lesson of change blindness is that attention is its antidote: If you know what to look for and where to look for it, you can attend accordingly and see the change every time. The paternalistic vision hypothesis assumes, plausibly, that perceivers considering an action (e.g., climbing a hill) attend to the very property (slant) of the very item (the hill) supposedly undergoing substantial perceptual change. So, although some account of our ignorance to the constant and considerable resizing of the perceptual world is indeed needed for paternalistic vision to remain phenomenologically plausible, change blindness is not it.

Interestingly, there is one—and only one—reported case of a subjectively noticeable paternalistic perceptual effect. While viewing an object through magnifying goggles, subjects who placed their hands next to the object so that they were visible through the goggles spontaneously reported that the object appeared to shrink before their eyes (supposedly because the object's size had been "rescaled" to the subject's "grasping ability"; Linkenauger et al., 2010). This so-called "illusory shrinkage" is an important finding worthy of closer empirical and theoretical attention.[9] However, if the result's interpretation is serious, then this finding vitiates, not vindicates, the scores of effects reported before it. No paternalistic vision study before or since has reported this kind of noticeable, dynamic change in apparent size, slant, or distance. This invites a straightforward question: Why not? Why do the other manipulations fail to induce subjectively appreciable, dynamic perceptual changes? And why do we ourselves not notice objects creeping closer when we imagine reaching them or drink Coca-Cola? Before the illusory shrinkage study, such questions might have seemed somewhat inane, because there might have been hope left for an account of why we *don't* notice paternalistic perceptual effects. But this finding purports to demonstrate that the putative perceptual changes *are* noticeable—so noticeable, in fact, that observers say so without being asked. This directly undermines previous reports of (unnoticed) paternalistic perceptual effects, and it makes decisive our own failure to notice putatively frequent, substantial, paternalistic visual changes in everyday perceptual experience.

Accounting for the Findings

The foregoing discussion sought to engage the paternalistic vision hypothesis on its own terms, taking the relevant empirical research at face value and identifying theoretical and nonexperimental difficulties facing the supporting theory. If these arguments have succeeded, then the dozens of studies reviewed thus far cannot be explained by paternalistic vision. What, then, accounts for them? This section offers a positive account of the findings typically cited in favor of the paternalistic vision hypothesis: Such effects actually reflect systematic biases in judgment rather than in perception.

Several empirical case studies will fuel this alternative account; however, it must first be acknowledged that a number of prominent findings reviewed earlier—including effects of backpacks, heavy balls, and tools on distance estimates—have not been replicable in other research laboratories. One such study sought to further investigate tool-use effects (Witt et al., 2005) with a new condition and task but instead failed to find the original effect of baton-holding on distance estimates (de Grave et al., 2011). Another examined whether size judgments and triangulated walking measures would corroborate backpack-induced compressions in verbal distance estimates (Proffitt et al., 2003) but instead found no distance-compression effects for any measure (including verbal estimates; Hutchison & Loomis, 2006a, 2006b; Proffitt, Stefanucci, Banton, & Epstein, 2006a, 2006b). Others have scrutinized more recent "indirect" findings (Ontiveros, Mejia, Liebenson, Lagos, & Durgin, 2011; Witt, 2011b). And in an especially comprehensive replication attempt, Woods, Philbeck, and Danoff (2009) ran one replication of Proffitt et al. (2003) and three replications of Witt et al. (2004), failing to find the predicted effect in all cases. Such investigations unavoidably bear on any positive assessment of the paternalistic vision findings; wrestling over theoretical details is of little use if the findings fail to survive empirical scrutiny. However, the paternalistic vision hypothesis wears thick empirical armor and has scores of findings to its name (several of which have indeed been replicated[10]). It is for this reason that a comprehensive, generalizable, alternative account is needed. Fortunately, further empirical evidence points directly to such an account.

Judgment, not perception: Task demands

In perhaps the single most important finding pertaining to the dispute over paternalistic vision, Durgin et al. (2009) ran a version of the classic backpack/slant experiment (Bhalla & Proffitt, 1999), adding to the two usual conditions (backpack and no backpack) a third condition in which subjects wore a backpack accompanied by a deceptive "cover story" about the backpack's purpose. (The backpack allegedly contained electromyographic equipment to monitor ankle-flexion signals, and even included a whirring fan for effect.) Tellingly, merely providing this plausible alternative explanation for the backpack's presence eliminated the effect of wearing a backpack on slant estimation. Subjects wearing unexplained backpacks indeed gave greater slant estimates than did those without backpacks, but subjects who wore a backpack accompanied by the deceptive cover story gave estimates indistinguishable from those of unencumbered subjects. The researchers concluded that subjects with unexplained backpacks sought—and found—a connection between backpacks and perceived slant (nearly all subjects said so themselves in debriefing) and then complied with the demand to inflate their slant estimates. Subjects in the cover-story condition, however, were satisfied with the reason offered for the backpack's presence and so pursued no such link. This suggests that backpack effects and related findings could be products of demand characteristics—the implicit cueing of experimental predictions to subjects, by experimenters or by the task itself—rather than effects of effort or ability on spatial perception.

It has been protested (Proffitt, 2009; Witt, 2011a; also Goldman, 2012) that Durgin et al.'s (2009) use of a 2-m wooden ramp rather than an expansive hill invalidates any general conclusions inferable from the study, because "the relative difference in the amount of energy required to walk 1 m [i.e., halfway] up a ramp with and without the backpack is probably not enough to produce a reliable change in perception" (Witt, 2011a, p. 203). However, this line of criticism is misplaced. Durgin et al. were not attempting to replicate the original backpack study; they were simply trying to show that offering subjects unexplained backpacks and asking for slant estimates bears substantial experimental demand that can bias those estimates and is therefore a burden-shifting confound that must be controlled for (see also Russell & Durgin, 2008; at any rate, subjects in real-hill experiments also say they believe the backpack is supposed to inflate slant estimates; Durgin, Klein, Spiegel, Strawser, & Williams, 2012). And at this they surely succeeded, first by successfully finding a backpack effect on slant judgments—with a measly ramp, no less!—and then eliminating that effect using their clever demand-reduction manipulation. Whether climbing the ramp would have been taxing enough to elicit a paternalistic perceptual effect is beside the point, which is that unexplained backpacks bias slant estimates.[11]

Demand has since been shown to make the difference in several additional cases. For example, explicitly informing backpack-wearing subjects about compliance effects eliminates the backpack's influence on slant estimates, even for real-world hills (Durgin et al., 2012). And when climbing effort is manipulated but demand is not—by having subjects estimate the slant of either a staircase or an escalator—no effect of required effort is found (Shaffer & Flint, 2011). Conversely, manipulating belief but not ability affects spatial judgments in just the way one would expect if demand explained the results. For example, falsely informing subjects that a recently ingested diet soda was in fact sugary decreases slant estimates (Williams, Ciborowski, & Durgin, 2012), telling subjects that a golf club once belonged to a famous golfer increases estimates of golf-hole size in a putting task (C. Lee, Linkenauger, Bakdash, Joy-Gaba, & Proffitt, 2011), and telling subjects that some darts to be thrown at a target are actually defective eliminates the correlation between throwing accuracy and size estimation (Wesp & Gasper, 2012). The demand account earns even further support from a more unlikely source. When backpack-wearing subjects were found to give shallower slant estimates with close friends nearby than when alone, the preferred interpretation was an effect of "psychosocial resources" on perceived slant (Schnall et al., 2008). Although this was already a somewhat incongruous explanation (psychosocial resources, of course, do not actually improve hill-climbing ability), Durgin et al. (2009) note that this finding may more parsimoniously favor the demand account: The social support of a friend may have simply reduced the pressure to go along with the experimental demand of wearing a backpack (see Asch, 1956).

Most paternalistic vision studies give ample reason to worry about this alternative account's reach. Consider, for example, the investigations of athletic skill and size judgments of sporting equipment. These experiments had no manipulations to speak of—each subject performed the same task and made the same judgment. Moreover, the observed effects show what Witt (2011a) calls "functional specificity," in that "the direction of the effect is specific to the goal of the task" (p. 204). For example, softballs look bigger to hot-hitting batters, but tennis nets look smaller to successful tennis players (although see Cañal-Bruland & van der Kamp, 2009). Could even these findings be explained by demand and response bias? As noted in these articles' introductions, these experiments—and, crucially, their hypotheses—were inspired by the relevant sport's respective folklore. For example, Witt and Proffitt (2005) quote a hall-of-fame baseball player who remarked that a cold streak at the plate feels like "swinging at aspirins." But such quotes (although not unambiguously about spatial perception in the first place) actually favor the demand account: If a piece of sport legend is popular enough to motivate experimental hypotheses, then surely the experimental subjects themselves (who actually play the sport) can generate such hypotheses, too. There is every reason to think, then, that demand should be equally "functionally specific" in these studies and could bias responses accordingly.

Indeed, it is difficult to find a paternalistic vision study not susceptible to this alternative account, including even those that explicitly defend against it. Consider, for example, that wielding a baton reduced distance estimates only if subjects actually used the baton to reach, which prompted the conclusion that "tool-use affects perceived distance, but only when you intend to use it" (Witt et al., 2005, p. 880). Witt (2011a) asserts that "It is difficult to account for these results with a nonperceptual explanation. For example, why would subjects have adjusted their distance judgments when holding and reaching [with] the tool but not when just holding the tool?" (p. 204). But a demand-based account of these findings could be quite straightforward. For example, confounded with subjects' intentions to reach were the experimenter's instructions to reach—subjects who simply held the baton and made distance estimates were never told what the baton was for. Once subjects were told to use the baton for reaching, however, the hypothesized connection between the two became clear, and the demand took effect.[12]

To be sure, the possibility that demand could contaminate spatial judgments has been acknowledged for some time (e.g., Proffitt et al., 2003), and several steps have since been taken to control for such factors. One promising defense against demand, as Witt (2011a) rightly suggests, is the use of "opaque manipulations" (p. 204) that do not telegraph the subject's experimental condition or the experimenters' hypotheses about that condition. Unfortunately, this strategy has foundered in practice. Witt cites the study of sugar consumption and slant judgment as such an opaque manipulation: Subjects drank either a sugary beverage or an artificially sweetened beverage, and there were between-group differences in slant estimates despite evidence that subjects could not identify their drink condition (Schnall et al., 2010). However, omitted from later discussions of these findings (e.g., Proffitt & Linkenauger, 2013; Witt, 2011a) is that subjects in the sugar experiments wore heavy backpacks during slant estimation. We know that this creates demand to inflate slant estimates; perhaps, then, sugar-depleted subjects were just more likely to feebly go along with such demand or at least were more likely to judge the backpack as more burdensome and so more severely inflate their estimates. Conveniently, exactly this hypothesis was recently confirmed. Although drinking a sugary beverage indeed lowers backpack-wearers' slant estimates, instructing subjects to ignore the backpack eliminates the effect of sugar consumption on slant judgments (Durgin et al., 2012)—just as predicted by an alternative account appealing to compliance with backpack-induced demand. Even when steps were taken to control for demand and response bias, they crept in and undermined what might otherwise have been compelling findings (see also Ontiveros et al., 2011, and Witt, 2011b, on indirect measures).

Judgment, not perception: Affordances and action-plans

Spatial judgments may also be biased by factors more subtle than the unintentional communication of an experimental hypothesis. One empirical study that speaks to the influence of such factors could extend a judgment account to nearly every paternalistic vision finding reviewed so far. In a fifth experiment, Woods et al. (2009) deviated from exact replication of the ball-throwing experiments by giving three groups of subjects different criteria upon which to base their distance judgments: (a) "Objective distance" ("Base your response on how far away you think the object really is"), (b) "Apparent distance" ("Base your response on how far away the object visually appears"), and (c) "Nonvisual factors" ("Base your response on how far away you *feel* the object is, taking all nonvisual factors into account"). At last, an effect of heavy-ball-throwing on distance judgments was observed—but only in the nonvisual factors condition.

It is not quite clear what it should mean for an object to "feel" some distance away (although it is clear enough what this does not mean, given the null findings for objective and apparent distance). However, one intuitive way to interpret "felt distance" could be through Gibson's (1979) theory of affordances (see also Chemero, 2001, 2003). Affordances are opportunities for action in the environment, and they include the climbability of hills, the walkability of ground-surface extents, and even the "throw-to-ability" of targets; crucially, however, affordances are distinct from lower-level visual properties such as size, distance, slant, or location. This should be fairly intuitive: A hill can seem less climbable without actually looking any steeper (i.e., without appearing to rise more degrees from horizontal). One way to interpret the nonvisual factors finding, then, is that heavy balls and backpacks did indeed change subjects' impressions of their environments—but only of their environments' affordances, not their spatial layout. These subjects were then eager to give voice to their changed impressions and so used the spatial estimation task to express them (because that task was all they were offered; see Loomis & Philbeck, 2008). In that case, subjects in nearly every one of the paternalistic vision studies could have been responding similarly, basing their estimates on felt slant, felt size, felt height, etc., rather than on the perceived spatial layout of their environments.

Indeed, it is possible along similar lines to concede that action considerations contribute to some paternalistic vision effects without at all conceding that such effects are perceptual. For example, consider a recent empirical claim that effort-based distance-compression effects *must* be effects on perception rather than on judgment, response, or other postperceptual processes. Adapting subjects to reduced optic flow on a treadmill has been shown previously to increase verbal estimates of distance (supposedly by increasing anticipated walking effort; Proffitt et al., 2003). In a follow-up study (Witt, Proffitt, et al., 2010), two groups of subjects underwent the treadmill adaptation, but each was given different instructions: One group was told they would look at a target, close their eyes, and then "blind-walk" to wherever they remembered the target to be; the other group was told they would look at the same target, close their eyes, and then "blind-throw" a ball to wherever they remembered the target to be. The trick was that although the first group was in fact asked to walk after closing their eyes, the second group (the ostensible throwers) was told after they closed their eyes that there had been a mistake and that they too would actually blind-walk to the target. In other words, although both groups underwent the treadmill adaptation and then walked to the target, only one group viewed the target while expecting to walk, whereas the other group viewed the target expecting to throw. The results showed that the walker group walked farthest, suggesting that the treadmill manipulation affected only them. It was then concluded that

> This result demonstrates that effort and intention affect perception directly. If effort and intention had exerted their effects during postperceptual processes, both groups would have walked equally far because both groups experienced the same effort manipulation and both groups intended to walk at the time that their response was generated. (Witt, Proffitt, et al., 2010, p. 1158; see also Goldman, 2012)

But the result demonstrates no such thing. Perhaps it shows that the estimation bias was introduced while the subjects' eyes were open, and not afterward—but that does not at all entail that the bias was perceptual in nature. First, note that to complete a blind-walking task is just to walk some remembered distance; this result, then, could simply be an effect on remembered distance, rather than on perceived distance (see especially Cooper, Sterling, Bacon, & Bridgeman, 2012). But second, note also that subjects in Witt, Proffitt, et al.'s (2010) experiment did not know they were estimating distance—all they knew about was their task to blind-walk or blind-throw to a target. Although this is often an experimental advantage (see Loomis & Philbeck, 2008), here it introduces a plain route toward explaining this effect through factors other than perception—in particular, as an effect on action planning rather than on distance perception. Suppose that, while looking at the target, the expectant walkers prepared for their upcoming task in the most natural way: They imagined how long it would take to walk to the target, so that they could subsequently walk for as long as they had imagined walking. However, their imagined walks—not their perceptions of distance—were affected by the treadmill adaptation, so that when they completed the walking task, they ended up walking farther. Meanwhile, the throwers imagined how hard they would have to throw, but their imagined throws were unaffected by the treadmill adaptation, and so their subsequent walks (which they had not imagined) remained similarly unaffected, and they did not walk as far. Such an account allows action-based factors to play a role in generating the effect but does not at all require that the target ever actually looked farther away. Instead, the locus of the effect is in *preparing an action* on the basis of an (unchanged) perceptual experience of distance, and then responding on the basis of that prepared action.

Other paternalistic vision findings may of course admit of more particular alternative interpretations having to do with specific methodological details, but accounts such as those reviewed earlier are easily generated for nearly all the paternalistic vision findings. Until future experiments definitively rule out accounts such as those articulated here, it will remain eminently plausible that judgment, memory, and response—not perception—explain the paternalistic vision findings. For in every case so far that such alternative interpretations have been tested (e.g., Cooper et al., 2012; Durgin et al., 2009; Durgin, Hajnal, Li, Tonge, & Stigliani, 2010; Durgin et al., 2012; Shaffer & Flint, 2011; Woods et al., 2009), they have been vindicated.

Conclusion

"I know it works in practice," goes a new spin on an old saw, "but will it work in theory?" Although the paternalistic vision hypothesis may seem to unify and explain an impressively broad collection of findings, I have argued that it cannot be the right theory of the results typically adduced in its favor. Any sufficiently ungrounded theory can seem to parsimoniously account for a large and otherwise-disparate set of empirical data. But although there do exist compelling, generalizable, empirically supported alternative accounts of those data—indeed, every time such an alternative account has been sought, it has been found—the deepest shortcoming of the paternalistic vision hypothesis is not that the weight of the empirical evidence is against it (though this may indeed be the case). Rather, it never could have been the right account of the relevant results in the first place. It is just the wrong kind of theory for the job.

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Notes

1. This well-known view has for too long gone without an appropriately memorable name. Though sometimes called *embodied perception* (Proffitt, 2006b), *action-specific perception* (Proffitt, 2008; Witt, 2011a), or *perception as a phenotypic expression* (Proffitt & Linkenauger, 2013), these labels conflate several nonidentical perspectives and may also mischaracterize the breadth of the relevant empirical findings, not all of which pertain to bodies, actions, or phenotypes. Thanks to Susanna

Siegel for first using the adjective "paternalistic" to artfully capture the suite of findings and views discussed here.

2. The comparison is given here in terms of grade (rise/run) rather than angle (degrees) because Schnall, Zadra, and Proffitt (2010) used an extraordinarily steep hill: At 29° (a 55% grade), it was steeper on average than a typical route up Mount Everest (e.g., Hamill, 2012). The challenge imposed by each additional degree varies with a surface's steepness, so comparisons in degrees may mislead for such slants.

3. Alternatively, the incommensurability problem could be one horn of a dilemma. If action-specific perceptual units are incommensurable, then the problem goes through as described; if not, a new problem arises. For reasons skipped over earlier, it has been claimed that motor simulations mediate paternalistic perceptual effects, such that, for example, simulating reaching an object with a baton is necessary and sufficient to make the object look closer (Witt & Proffitt, 2008). Most discussions of motor simulations (including Witt, Kemmerer, Linkenauger, & Culham, 2010) assume that (a) multiple simulations can run in parallel and (b) such simulations are often irresistibly triggered by apparent opportunities for action. (A nice illustration of each is the finding that people use a wider grip-aperture to grasp a small cherry if a larger apple is also in view; Castiello, 1996.) These features of motor simulations conspire against paternalistic vision. Consider someone in the circumstances given by Proffitt (2006b, p. 114), deliberating over whether to run, jog, walk, or saunter to some destination while minimizing energy expenditure. Given points a and b, this person will run parallel simulations of each action; how, then, should the world look once the various parallel motor simulations (running, jogging, walking, sauntering) have run to completion? Suppose the perceiver puts on footwear that makes walking easier and running harder. Should the destination look closer (walking) or farther (running)? Somewhere in between? If different perceptual rulers use different perceptual units, then perhaps it is no contradiction to represent a spatial extent as some number of walking-units long and some other number of running-units long. But if perceptual rulers share units (e.g., required energy expenditure), then there is no way the world could look that would communicate one action's advantage over another; spatial perception just cannot work that way. (Note that Zadra et al.'s 2011 investigation of serially ordered actions is orthogonal to this issue.)

4. More precisely, $(A + B)/B = (\tan(\alpha) + \tan(\beta))/\tan(\beta)$, but when size is small relative to viewing distance, Eq. 1 is approximately correct (and is the standard presentation of horizon-ratio scaling).

5. It is sometimes hinted that ability scaling could be made possible by learning to relate optical information to one's abilities—for example, associating patterns of optic flow with walking costs (Linkenauger, Witt, et al., 2011; Proffitt & Linkenauger, 2013; Proffitt, Stefanucci, Banton, & Epstein, 2003; Witt, Proffitt, et al., 2010). Although the details of how such associations are structured or how they will actually enable ability scaling are never elaborated, *any* account founded on such learning is preemptively ruled out by the success of manipulations for which such learning would have been impossible or unlikely. On the one hand, if learning refers to recalibration to manipulated abilities, then even the classic backpack/slant study is a counterexample: Despite the fact that "all subjects arrived at the hill without the backpack and were given no opportunity to walk while wearing it" (Bhalla & Proffitt, 1999, p. 1081), the manipulation successfully influenced slant judgments. On the other hand, if the relevant learning involves developing such perception-ability mappings in the first place (e.g., learning to associate optical information with effort or ability) and occurs over a considerable time period (as suggested by Proffitt & Linkenauger's brief review of infant perceptual-motor development), then counterexamples exist in the many studies of unfamiliar actions that would not have been sufficiently learned or practiced. Such actions include dart dropping (Wesp, Cichello, Gracia, & Davis, 2004), Pong playing (most subjects reported no experience with the game; Witt & Sugovic, 2010; see also Witt & Sugovic, 2012), and field-goal kicking (22 of 23 subjects reported having never kicked a field goal before, and steps were taken to ensure that all subjects "would not receive any visual feedback on their ability to kick successfully" during a short warm-up phase; Witt & Dorsch, 2009, p. 1331), among others. Evidently, the relevant actions had rarely (if ever) been performed, and yet the manipulations succeeded. And of course, learning to pair actions with optical information could never explain, for example, influences of social support and fear on judgments of slant and height—or, especially, results of a study in which subjects aimed a nonfunctional laser pointer at a distant object and imagined that it was functional, which involves no actions, no optical changes, and no ability manipulations, and yet still affected distance estimates (Davoli, Brockmole, & Witt, 2012).

6. Effects of imagination also intensify earlier worries about paternalistic vision's purported adaptive advantages. Perceivers cannot actually wield imagined batons; but barring some as-yet-unspecified mechanism to distinguish the perceptual effects of real action capabilities from wished ones, what is to stop someone from acting on his or her imagined baton-augmented reach?

7. The outlook for ability scaling is worse still—it may be disconfirmed by the paternalistic vision data themselves. It has been reported that individual differences in age and fitness correlate with verbal estimates of slant and distance, such that when asked a question like "How far away, in feet and inches, does that cone look?", obese or older individuals give greater estimates than fit or younger individuals do (Sugovic & Witt, 2011, 2013; *mutatis mutandis* for slant and degrees—Bhalla & Proffitt, 1999; see also Witt, Schuck, & Taylor, 2011). But such results should perplex any "scaling" theorist. Consider eye-height scaling: Even if two people, one short and one tall, experience objects as different amounts of eye-level units in size, they should still verbally agree about an object's size in feet, because the word "foot" should pick out a correspondingly different amount of body-scaled units for each of them. (How else could we all manage to get just what we expect when ordering foot-long hot dogs or sandwiches, our differently sized perceptual rulers notwithstanding?) But then the same logic should apply to, for example, fitness level: Even if obese individuals experience a target as "more calories away" than fitter people do, all parties should still verbally agree about the target's distance in feet—against these empirical findings. (See Firestone,

in press, and Firestone & Scholl, in press, for more detailed expositions of this objection's logic, which is related to the "El Greco fallacy.")

8. Note that it will not vindicate a theory of paternalistic spatial perception if, for example, drinking Coca-Cola merely makes hills look more climbable or otherwise affects their perceived affordances. To corroborate paternalistic vision, hills must genuinely appear to rise fewer degrees from horizontal and look shallower.

9. My suspicion is that this is not a paternalistic effect to begin with, regardless of whether it turns out to be perceptual (see also Linkenauger, Mohler, & Proffitt, 2011). The illusory shrinkage study diverges from most other paternalistic vision studies in that its effect requires actually viewing one's manipulated body. This diminishes the finding's force as a case study of paternalistic vision, in part because visual effects of visual manipulations are much more easily accommodated by a modular view of perception.

10. See, for example, Firestone and Scholl (in press), who twice replicate effects of rod-holding on width estimates (Stefanucci & Geuss, 2009)—albeit in circumstances that demonstrate that this effect must not be perceptual.

11. More on-target is Proffitt's (2009) response that, in the earlier effort and fatigue studies (Bhalla & Proffitt, 1999; Proffitt, Bhalla, Gossweiler, & Midgett, 1995), a third, haptic measure of perceived slant—in which a waist-high, unseen palm board is manually adjusted to haptically match the hill's visually perceived slant—was unaffected by backpack-wearing or exercise (see also Creem-Regehr, Gooch, Sahm, & Thompson, 2004; Witt & Proffitt, 2007). If backpacks bias slant estimates, that response goes, then why weren't palm-board estimates biased as well? However, Durgin, Hajnal, Li, Tonge, and Stigliani (2010) meticulously and compellingly dismantle this objection, demonstrating (among many relevant findings) that palm-board estimates are unusually variable and noise-susceptible, but that when palm-board estimates from the two fatigue experiments are analyzed together, the combined data do indicate a statistically reliable fatigue effect (see also Durgin, Hajnal, Li, Tonge, & Stigliani, 2011; Proffitt & Zadra, 2011).

12. Ontiveros, Mejia, Liebenson, Lagos, and Durgin (2011) also ask whether distance-compression effects of tool use could be explained by biases in the hand-only control conditions. Reach is systematically overestimated (Fischer, 2005); perhaps, then, attempting (and failing) to reach a target with only a hand increased distance estimates in that condition, giving the appearance of a tool-use compression effect only because the tool conditions (real, anticipated, and imagined) were compared to an inflated baseline.

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