Reliance on constraints means detection of information

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Abstract: We argue four points. First, perception always relies on environmental constraints, not only in special cases. Second, constraints are taken advantage of by detecting information granted by the constraints rather than by internalizing them. Third, apparent motion phenomena reveal reliance on constraints that are irrelevant in everyday perception. Fourth, constraints are selected through individual learning as well as evolution. The "perceptual-concept-of-velocity" phenomenon is featured as a relevant case.

SHEPARD proposes internalized constraints as the vehicles by which perception achieves concordance with the environment. His prime examples are apparent motion phenomena in which participants perceive motion paths that, some would say, are not present in the stimuli. As pointed out by SHEPARD (p. 555, target article), and by KUBOVY & EPSTEIN (K&E) as well, these paths are noticeable only as visual defaults in severely impoverished vision conditions.

A motion perception phenomenon that occurs under normal conditions, yet entails large discrepancies with the physical motion, is the so-called "natural start" or "perceptual concept of velocity" phenomenon (Runeson 1974; 1975). Motions that start in an inertially natural way, that is, with a constant acceleration that gradually levels off to a constant velocity, appear to have constant velocity throughout. Motions with other velocity profiles appear accelerated or decelerated depending on how they differ from natural start motions.

In both apparent motion and the natural start phenomena, perception seems to "go beyond the given" in an adaptive way. By this, a role for environmental regularities in perception is indicated. We argue, however, that the phenomena do not prove internalization of these regularities.

Reliance on constraints: Indispensable or exceptional? The biological purpose of perception is to establish informational coupling between organisms and their environments. Information is the commodity perception deals in. Regularities, or constraints, are the "grantors of information" (Runeson 1985; 1999). If an organism uses a particular informational variable, it demonstrates dependence on the prevalence of the constraints that grant the usefulness of the variable. We do not disagree, therefore, with the claims in the target articles that perception takes advantage of constraints. To the contrary, even stronger claims should often be made. Constraints are necessities (e.g., Runeson 1985; 1994; Runeson et al. 2001). Since there can be no information without constraints, there can be no perception without constraints. Two examples illustrate that this stronger claim is not always appreciated.

First, reliance on constraints is often considered necessary only when the stimulus in itself does not specify the to-be-perceived property. For instance, in describing SHEPARD's position HECHT writes, "Whenever the stimulus is ambiguous or ill-defined, as in apparent motion, an internalized default influences the percept" (p. 609). Such claims seem to imply that some stimuli can be unambiguous by themselves, that they can be specific to properties in a supposedly unconstrained world. This, however, is not the case.

Second, reliance on constraints is also invoked as an explanation for perceptual deviations from the "objective stimulus." Proponents of different theoretical views would agree, we think, that the natural start phenomenon shows reliance on the constraint that material motions must start gradually. Imagine that the empirical situation had been the opposite, that is, that starting motions had been perceived in accordance with the physical-science concepts of velocity and acceleration. Would it be agreed that constraints are required to explain that too? Presumably not, but why not?

Runeson (1974; 1975) proposed that motion perception is couched in terms of a perceptual concept of velocity (PCV), which incorporates the characteristic way in which motions of material objects start. The PCV has superior descriptive power because the speediness of most pre-technological motions is describable with a single constant value. However, descriptions couched in physics-velocity terms are commonly considered real and objective, whereas PCV-based descriptions seem derived or subjective. The PCV phenomena thus may appear to require inferential conversion, which would necessitate constraints, while physics-velocity conformant percepts would not.

Such a distinction is not valid, however. Scientific concepts are invented and defined to provide convenient ways of handling various phenomena under study, hence they are on equal ontological footing. Whether or not additional processing is needed for physics-velocity or PCV-style perception is not deducible from basic physical laws but depends on which variable the measuring device is designed/developed for (Runeson 1977; 1994).

In sum, all perception depends on constraints – without regularities, stimuli are always ambiguous. Accordingly, as we have discussed elsewhere (Runeson et al. 1988; Runeson et al. 1991; HECHT; K&K; SHEPARD) as well, these paths are noticeable only as visual defaults in severely impoverished vision conditions. Relatively, HECHT draws attention to experiments in which perceivers appeared not to rely on a few presumably useful constraints and argues that this is problematic for internalization theory. We do not agree. Any theory that poses reliance on constraints should accommodate the fact that not all constraints are relied on. Perception always takes advantage of constraints, but this does not imply that all conceivable constraints are taken advantage of.

How to take advantage of constraints? Theories that describe how constraints are taken advantage of can crudely be classified as either "internal-entities theories," which hold that perception draws on knowledge or assumptions about the constraints, or "regularities-in-design theories," which hold that the design of organisms is compatible with the constraints. Both types of theories have their merits. Internal-entities theories are more useful if one considers cognitive processes. A physicist, for instance, can use knowledge of laws to make inferences about, say, the amount of kinetic energy of a system. The regularities-in-design alternative is better suited to describe, for instance, how lungs take advantage of the availability of oxygen in the air – without knowledge about that constraint.

Which analogy is better for perception? SHEPARD's internalization notion seems to be an internal-entities theory. However, in keeping with the ecological approach, and with K&K, we are skeptical about internal entities for the explanation of perception. A long explanatory story would have to be told, going from constraints, to informative variables, to organs that can register the variables. We see no way that such internalized constraints could be beneficial for the perceiver and, therefore, no way that evolution could have endowed us with them. Evolutionary changes in the constitution of visual systems must be on account of adaptive advantages gained from modifications in the pickup of optical variables and how these are used in action control. Thus, the evolution of perception is not a matter of constraints getting internalized. Rather, it is the ways of exploiting the external consequences of constraints – specificity of optical variables – that develop and thus upgrade perceptual skills.

The regularities-in-design alternative is to some extent implicit also in most internal-entities theories; realistically, there would be too many constraints for a perceiver to consider explicitly (Runeson 1988). This is evident, for instance, in the lens structure of the
eye, which takes advantage of the refraction properties of light, without knowledge about these properties. Thus, an additional burden for internal-entities theories is that they should explain why perceptual systems take advantage of some constraints by carrying assumptions about them, and of other constraints without such assumptions.

Our understanding of the role of constraints entails a different idea about the division of labor between perceivers and perception scientists (likewise, see K&E, p. 618, Abstract). Perceivers are just being selected or reinforced for the information they use. It is we, the scientists, who need to bring in constraints to explain perception—just as in explaining any other real-world phenomena.

**The importance of apparent motion.** The previous section argued that perceptual systems take advantage of constraints merely by relying on the information granted by them. We now consider implications of this view for SHEPARD’s interpretation of apparent motion phenomena. SHEPARD claims that apparent motion results reveal deeply internalized universal principles. Our view, in contrast, is that they reveal a reliance on constraints that are usually not relevant in more natural situations.

Many potentially useful constraints exist. The target articles consider, for instance, object constancy, theorems of kinematic geometry, gravitational acceleration, and so on. Previously considered constraints include the rectilinear propagation of light, conservation of momentum, and the regularity of surface texture. Such lists could be extended endlessly. Given the diversity of constraints, one might wonder whether all types of constraints are equally important for perception. Can constraints be classified in a way that enhances our understanding?

Classification can, for instance, be based on the extent to which there are exceptions to constraints (e.g., HECHT). If there are exceptions, then the constraint is not sufficient to grant full specificity of information. The general veridicality of everyday perception seems to show that perceivers use information granted by constraints which apply to a large extent in the relevant ecologies.

This is not the case, however, if the typical richness of information is artificially reduced. What happens if a visual system is deprived of its usual optical support? Does it give up and is nothing perceived? No. Pressed to function, the visual system reverts to other variables. Since few variables are available in the impoverished situation, the variables used might not be “information” in the specificational sense.

In apparent motion stimuli, typically used information is not available. Therefore, the perceptual system is forced to use other optical variables, which rely on other constraints. These might include theorems of kinematic geometry, as argued by SHEPARD. But, even if this were the case, we argue that these constraints are not relevant in regular motion perception. Participants are merely forced to rely on such constraints by the impoverished stimuli. It follows that apparent motion phenomena do not necessarily reveal fundamental characteristics of vision—the opposite might very well be the case.

**Universal principles of mind?** One of SHEPARD’s main goals is to reveal universal principles of mind. He argues that such principles can exist because many constraints are universal and that, consequently, evolution might have shaped the minds of all species to reflect the same universal constraints. In opposition, we argue that many more constraints prevail in the niches of particular species than in the universe. For an animal and its evolution it does not matter whether or not a constraint applies outside the niche. One could expect that animals often rely on local constraints that apply only in their niches or, in other words, that animals often use variables that are useful only there. Furthermore, perceivers can learn to take advantage of the particular constraints in different task situations (e.g., Jacobs et al. 2000; Michaels & de Vries 1998; Runeson et al. 2000).

In sum, constraints that are relied on depend on the particular ecology in which the species evolved as well as on the learning history of the individual. This indicates that the minds of individuals are just as likely to reflect local, as universal, constraints—a dis-couraging perspective if one searches for SHEPARD’s type of mental universals.

On a positive note, we suggest that although individuals might differ in the constraints they exploit, universal principles of mind might reside elsewhere. For instance, some principles of learning might hold very widely. One of these could be that the looser the exploited constraint, the faster perceivers learn not to rely on it. Or equivalently, the poorer the detected variable, the faster perceivers come to detect other, in the long run better, variables. We suspect that searching for principles at this level is more fruitful than trying to determine which regularities are reflected in the mind, the way suggested by SHEPARD.

**NOTE**

1. Kubovy & Epstein use the word “guarantors.” We consider the improvement subtle and retain the original term “guarantors of information” (Runeson 1988).

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**What is internalized?**

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**Abstract:** Hecht provides insights concerning the difficulty of empirically testing Shepard’s internalization hypothesis, but his argument for an externalization hypothesis suffers from similar sins.

**HECHT**

HECHT’s article does a fine job of focusing the reader on the two primary questions raised by SHEPARD’s internalization hypothesis. These are: (1) What is “internalized”? and (2) What is internalized? As for the definition of internalization, HECHT contrasts literal and abstract interpretations, but acknowledges that these are actually two ends of a continuous spectrum. Nonetheless, once one deviates from a literal interpretation, the hypothesis becomes more difficult to falsify.

This raises the question of whether falsification is as crucial a criterion for theoretical utility as HECHT assumes. The value of a psychological theory rests in its ability to describe and predict behavior. Yes, a theory must be testable, but ultimately, all that can ever be tested is a particular instantiation of a theory. The failure of these instantiations undermines the theory’s utility as a descriptive and predictive device.

In fact, no instantiation of the internalization hypothesis has proven robust to empirical testing. However, this reflects the flaw of the particular instantiation, not the underlying hypothesis. HECHT argues that the logical opposite of internalization is externalization (i.e., the observer’s imposition of his own body dynamics on an under-specified stimulus to create the perceived reality). Actually, the logical opposite of internalization (as well as externalization) is an unconstrained perceptual system—one that imposes no assumptions, and finds any under-specified stimuli ambiguous and uninterpretable.

Obviously, our visual system is not unconstrained. It both filters incoming stimuli (e.g., extracting zero- and first-order kinematics while virtually ignoring higher-order motions), and imposes assumptions, biases, and expectations. We can debate the extent to which these constraints are innate or acquired (and, consequently, absolute or tunable), but the unconstrained hypothesis is obviously a straw man.