

Spatial Representation: Posers and Paradigms

Spatial Representation

Edited by Naomi Eilan, Rosaleen McCarthy, and Bill Brewer. Oxford, England: Blackwell, 1993. 409 pp. Cloth, \$59.95.

Spatial Representation attempts to pull together two very different ways of thinking about how people represent external objects and events. To psychologists, the title suggests topics such as frames of reference, cognitive maps, and computation of spatial coordinates. To their surprise, the domain is shown to involve the more fundamental issues of what our senses tell us about the existence of distal objects. The inclusion of such philosophical issues is very much needed to guide empirical work on topics of spatial representation. The book is a collection of articles resulting from an interdisciplinary workshop by the Spatial Representation Project at King's College Research Center in Cambridge, England. The contributions are grouped into five major sections: "Frames of Reference," "Intuitive Physics," "Spatial Representation in the Sensory Modalities," "Action," and "What and Where." Thus, rather than attempt to review the book as a cohesive whole, we will briefly summarize and critique the individual contributions.

The "Frames of Reference" section is concerned with how we establish environment-centered object coordinates (allocentric frames of reference). Herbert L. Pick, Jr., proposes the following sequence in the development of spatial knowledge. First, children acquire the capacity to associate egocentric vectors with salient landmarks; next, the ability develops to add and subtract these vectors, resulting in routelike knowledge. Finally, the egocentric system is transcended, and allocentric spatial knowledge develops. This model is supported by studies in which parents lead their toddler on a more-or-less direct path to a location in a room. The toddler then has to

go back to the parent. Whereas 16-month-olds retrace the path, 24-month-olds find the shortest route. Infants' behavior can be explained without having to assume any kind of spatial representation. At older ages shortcuts and procedural knowledge may be used instead of configurational spatial knowledge.

John O'Keefe believes that the crucial tests for models of spatial representation are physiological. He presents evidence that single cells responsive to environmental coordinates have been found in the hippocampus, and argues that Kant's transcendental speculations about allocentric categories of space are rooted in neurophysiology. This is a provocative thesis, but lacks strong evidence at this time. O'Keefe takes a neo-Kantian nativist position that "at least one neural space, the hippocampal allocentric cognitive map, is built primarily on the basis of genetic and epigenetic rules" (p. 44). This sentence conveys all the terminological problems that surface in this chapter. How can a neural substrate be a cognitive map? Such an equating would only be tenable from the point of view of an identity theory holding that thoughts and brain activity are one and the same. Although such a view is possible, it contradicts Kantian idealism to which O'Keefe seems to subscribe. The claim that the Kantian "synthetic a priori" reside in the hippocampus of the human brain is very intriguing, but it is not clear what neurophilosophy has to say about spatial representation. Also, it is difficult (if not impossible) to follow the author's argument that a lack of congruence between physical and mental space can be taken as support for a nativist position.

John Campbell argues that neither the distinction between egocentric and allocentric nor the interdependence of object recognition and familiarity of space is sufficient to describe object recognition in space. Recognition of objects and places also depends on the causal context of action, or what Campbell terms *internal causal connectedness*. We perceive objects as close or far, as behind or in front, etc., as a function of our actions. Campbell calls these the *causal index of terms*. A purely allocentric frame of reference is taken only when objects are causally nonindexical, that is, passively observed. The extension of the notion of indexicality to causal properties is well taken. Typically, philosophers think of objects as being spatially and temporally indexed, that is, they cannot be thought of or represented without spatial and temporal coordinates. Thinking of spatial representation as a function of causal indexicality is a very powerful concept. Unfortunately, the author does not seem to be familiar with the work of Gibson, who would certainly agree with the idea of actor-centered units in perception, such as an individual's eye height, arm length, or strength. The concept of causal indexicality reeks of "affordance," albeit without any claims that spatial perception has to be direct.

The section "Intuitive Physics" deals with a body of research that has gained popularity among cognitive psychologists and is starting to be considered by philosophers. The domain of intuitive physics is concerned with the question of how laws of classical mechanics are represented by the human cognitive system. Typically, large discrepancies are found between repre-

sentational understanding and visually guided performance, suggesting that the two systems exist quite separately. Among psychologists, two vastly different approaches to intuitive physics have been taken. Direct perceptionists (e.g., Runeson & Frykholm, 1983) believe that most, if not all, of what we admire as intuitive knowledge about mechanics can be described by perceptual processes that do not require the representation of objects or physical laws. Representationalists (e.g., Shepard, 1984) believe that people have more-or-less simplified representations that are based on geometric, kinematic relationships. This section, as the whole book, presents only the second position, and should not be misinterpreted as representing all of intuitive physics research.

Lynn Cooper and Margaret P. Munger cover an interesting, but noncentral phenomenon of intuitive physics: the extrapolation of motion trajectories in the absence of stimulation. Cooper and Munger are able to describe the good performance that human observers show in these cases in kinematic and geometric terms. That is, dynamic concepts such as force, mass, and friction are not needed to explain performance. The discussant (Eilan) is at a loss when she points out the blatant contradiction of these findings with Peacocke's well-reasoned claim that intuitive mechanics must employ the concept of force. The Gibsonian perspective on intuitive physics (Runeson & Frykholm, 1983) offers an alternative that explains the data found by Cooper and Munger and nevertheless allows dynamic concepts. Moreover, Cooper and Munger's data are based on static object renditions, where mass or other dynamic variables are meaningless, or on rotations, which we know observers generally underestimate in the absence of reference cues (Hecht, 1993). Thus, their results, as fascinating as they are, should not be generalized to represent all classes of mechanical events.

Elizabeth Spelke and Gretchen A. Van de Walle take a much broader view on intuitive physics that encompasses the general principles by which infants discover the concept of physical objects. Their view is rooted between the direct perception and the representational positions mentioned earlier. The authors' research indicates that infants need to explore objects perceptually. Yet, at the same time, infants relate these explorations to their cognitive knowledge of physical principles to understand what a physical object is. They find evidence for various principles that define the boundaries and connectedness of parts of an object (cohesion) as opposed to occlusion of parts, a principle of contact (what moves together on impact is one object), and a principle of continuity (objects trace one path over space and time). These principles are reminiscent of gestalt principles of grouping. They can be extended to object understanding in adults. But why do the authors think that reasoning in infants has to be assumed at all? Perhaps their use of a surprise reaction paradigm primes them to assume that surprise is a sign of reasoning. For example, the infant looks at complete objects being lifted upward repeatedly until boredom (habituation) sets in. Then if only the top portion of the object is lifted upward, the infant keeps looking at this new event. This dishabituation is interpreted as evidence for interest, surprise,

and the reasoning that the object is incomplete. Likewise, once habituated to colliding objects, infants dishabituate when spatial (i.e., a gap between the two objects) and temporal anomalies are introduced. This is interpreted as an inference about the causal link between the two objects. It is not surprising, then, that the authors find commonalities between reasoning and perceiving in infants.

Christopher Peacocke tackles two issues that have received attention mainly by direct perceptionists. First, he posits that our perceptual representations of physical quantities have to be unit free, unlike our conceptual representations. This problem, however, is only associated with the visual system if it is thought to represent visual object and space properties. Gibson (1979) argues that the gap between unit-based concepts like force and their unit-free visual analogs does not exist and is based on misunderstandings that every representationalist runs into. The visual system has an intrinsic metric that is relative to the person. We judge distances in terms of our own eye-height above the ground, and we judge the weight of objects based on how heavy an object we can maximally lift up. Another of Peacocke's claims is also addressed by the Gibsonian view: For objects to change their state of movement, forces have to be exerted, and vice versa, if a force is applied, some movement change has to occur. The correctness of this metaphysical argument is, unbeknown to Peacocke, supported empirically by studies demonstrating that observers have direct access to dynamic quantities such as weight and force.

The section "Spatial Representation in the Sensory Modalities" offers a diverse variety of stances on and evidence for both integration and specificity of the different modalities in the process of object identification.

Roberta L. Klatzky and Susan J. Lederman argue that the cognitive representation of objects is to a large degree modality specific. What matters in one modality is often irrelevant or less important in another. For example, temperature and weight are crucial in haptic object exploration, but they are secondary on visual inspection, where color and shape can be used to identify the object.

Michael Martin addresses the puzzling question of how we distinguish our own body as different from other objects, and finds that the boundaries of our body are by no means constant. A tool that we use becomes part of ourselves. This does not hold only for artificial limbs, but also for larger tools we can easily cast aside. Although our awareness of external objects is mostly defined by visual impressions, our body awareness seems more dependent on haptic and visceral perceptions.

Andrew N. Meltzoff provides a large collection of empirical evidence suggesting that infants are able to match information from different modalities in the absence of any prior association between them. The most impressive piece of evidence is probably a study with 12 to 21-day-old infants who were able to imitate facial expressions of an adult actor. Even though they had never seen their own faces, they could translate an observed gesture into their own facial expression. The author concludes that there is an inborn amodal link between the modalities.

Eilan explores the question of whether object representation is amodal, a question that was popularized by Locke. If a person who is congenitally blind learns to distinguish spheres from cubes by touch only, would that person after miraculously gaining eyesight, be able to tell which is the sphere and which the cube? Eilan argues that a negative answer, involving modality-specific systems for object representation (including spatial aspects), is possible. However, she argues that evolutionary theory makes this approach unlikely, because it is much more parsimonious to have one representation that is commensurable with several modalities. The question of whether the unity of objects in our consciousness argues for amodal representation remains open. Eilan seems to assume that dynamic and kinematic properties of physical objects are initially confined to haptic and visual perception, respectively. Thus, we can feel the mass of an object, but we cannot see it. Then, to explain why we have concepts of dynamic variables that are modality-nonspecific, amodal categories must be assumed. However, a much simpler solution to the problem should be considered: Within the visual modality, dynamic properties of objects can be sufficiently specified by the kinematics of events. As Runeson and Frykholm (1983) argue, dynamics may be directly accessible within the visual modality without the need to assume amodality or involvement of conceptual thinking.

Ruth Garrett Millikan raises two theoretical problems or errors that are often made when talking about object representations. One error is projecting the content of a perceptual state onto its vehicle (the representation), such as assuming that the representation of succession has to be of a successive nature. This is the error of *content internalization*. The opposite error (*content externalization*) occurs when, for example, successive representations are taken as evidence for a representation of succession. The conclusion is that we may know much less about representation than we claim. The warning against these two errors seems well justified. However, these errors appear to be nothing other than the stimulus error and the experience error that Gestalt psychologists have been tireless in warning against.

The section "Action" contains only two chapters. The first strives for a psychological definition of action (as distinguished from a response to a stimulus). The second discusses the issue of separate versus common coding schemes for spatial perception and action. Anthony Dickinson and Bernard Balleine propose psychological criteria that define an action in contrast to a response to a stimulus. An activity, so they suggest, deserves to be called an action only if the actor can detect a contingency of an outcome on his behavior. A rat who knows to press a lever to trigger a food dispenser should stop its pressing behavior as soon as the device fails to work. That action requires the detection of omission of contingencies. The second and more traditional criterion is goal directedness. The rat, if trained to hate the food pellets produced by the dispenser in a different context, should stop triggering the dispenser even if it works perfectly. According to these criteria, rats are capable of goal-directed actions that go beyond stimulus-response (S-R) association. It escapes our appreciation how this chapter relates to the rest of the book and what its implications are for spatial representation.

Bill Brewer does a commendable job of relating the issue of separate versus common coding to spatial representation. He argues that separate coding accounts of visual afferences and motor efferences are fraught with problems, and favors the common coding approach suggested by Prinz (1990). He then proceeds to posit that common coding requires distal spatial representation. That is, spatial representations of limb or body movements have to be coded in terms of distal world coordinates rather than proximal body-centered coordinates. The second part of Brewer's article raises a completely different question. He attempts to find a plausible mechanism that explains the correlation between personal and subpersonal aspects of a spatial action. The personal, willed action of grasping an object, he argues, belongs to folk psychology and cannot be part of the common code. Now, if one rejects the identity of the personal and the subpersonal (e.g., neural representations) explanation of an action, the relationship between the two becomes problematic. Not surprisingly, Brewer fails to solve this variant of the mind-body problem.

Despite McCarthy's effort to relate the final section ("What and Where") to the rest of the book, it stands apart. In sum, the chapters in this section posit different memory and recognition systems for object features and their spatial location. These differences can be found on a neural level as well as in higher order vision. Given the rudimentary state of the what/where research, we do not find any answers to the interesting psychological questions about spatial representation that were brought up in the first chapters of the book. Taken on their own merits, however, these chapters offer a useful overview of two-system research and models.

Janette Atkinson introduces three biologically based theoretical approaches to define the mechanisms underlying "what" and "where" processing from a neurophysiological point of view. These models are primarily differentiated by the lowest level of visual processing at which such parsing occurs. The remainder of the chapter reviews the empirical studies on the development of different attributes required for determining "what" and "where" (e.g., form, orientation, motion), with an attempt to relate the findings to the three models. Although this mapping is difficult for readers not well versed in visual physiology to follow, even naive readers can absorb several critical "take home" lessons. To wit: The where and what systems of object recognition develop at different rates—the parvocellular system, representing color and form, develops earlier than the magnocellular system for relative position, motion, and depth.

Oliver Braddick tells us that spatial location and object recognition are processed separately, as demonstrated by visual-search experiments such as those by Treisman and Gelade (1980). However, depending on the experimental paradigm, one obtains very different results concerning object localization. Arguing against the existence of one homogeneous mechanism underlying visual localization, Braddick shows that within the where-system one can distinguish multiple mechanisms. He argues that any successful theory has to be able to account for top-down processing.

Michael Tye uses the indeterminacy of image interpretation to demonstrate a bifurcation of "what" and "where" information in higher level vision. He analyzes imagery theories put forth by Kosslyn and Pylyshyn to show that separate where and what systems can also be found in higher level cognitive processes. Tye argues that a picture theory of imagery is able to accommodate these what and where processes.

Finally, Rosaleen McCarthy points out that the dichotomy of what and where is too coarse to be compatible with the growing body of neurophysiological evidence. Especially in the neural processing that occurs further upstream (e.g., in temporal and parietal areas), the what/where categorization becomes less meaningful. Cortical damage in these areas seems to result in general deficiencies in information assembly rather than damage to the "what" system, as often suggested.

In sum, the editors have succeeded in assembling a well-organized body of questions that are associated with spatial representation, although the topics are diverse and the stylistic gap between the participating psychologists and philosophers is significant. The book does not (and does not claim to) outline a workable theory of spatial representation. Rather, it raises a vast number of issues that should be in the back of the mind of everybody who seriously works on the topic, whether from a psychologist's or a philosopher's perspective. The book can be recommended as an incomplete source of inspiration, but not as a textbook. Also, as a necessary sacrifice to its interdisciplinary nature, the book will not satisfy the need for detail that one could expect from a narrower focus on either empirical or theoretical topics.

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