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Reading Commentary 2

Isomorphistic and Nonisomorphistic Approaches in Vision: Issues

Madhu Shashanka

shashanka@cns.bu.edu

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Abstract

This essay deals with isomorphistic and nonisomorphistic approaches of theories which try to explain visual perceptual phenomena. We discuss the main ideas involved - the concepts of bridge locus and isomorphism. We clarify what it actually means for a theory to "explain" a particular phenomenon and discuss Teller's notion of linking propositions. We then discuss various philosophical arguments and other evidence both in favor of and against each of the approaches and finally conclude that neither of the approaches is entirely sound. Neither of these approaches really "explain" what they set out to explain.

Isomorphistic and Nonisomorphistic Approaches in Vision

Visual perception can be defined [Palmer, 1999] as "the process of acquiring knowledge about environmental objects and events by extracting information from the light they emit or reflect." Sometimes, it so happens that this knowledge we acquire is different from actual reality. Such instances are known as illusions. The Craik-O'Brein-Cornsweet Effect (COCE) is an example. In this essay we discuss the concept of analytic isomorphism [Thompson et al., 1999], which forms the basis of many theories that explain perceptual phenomena like the COCE.

We provide some basic definitions first (as given in [Adelson, 2000]). Luminance is the amount of visible light that comes to the eye from a surface. Illuminance is the amount of light incident on the surface. Reflectance is the proportion of incident light that is reflected from the surface. These are physical quantities that can be measured by physical devices. There are two subjective variables, lightness and brightness, which are defined as follows: Lightness is the perceived reflectance of a surface and brightness is the perceived intensity of light coming from the image. In the COCE, regions having identical luminances (and reflectances) are perceived to be differentially bright.

Consider two different luminance distributions as follows: distribution A, with two homogeneous regions of identical luminances except for two relatively narrow luminance gradients flanking the common border of the regions, and distribution B, with two homogeneous regions of different luminances. Both these luminance distributions give rise to the same percept, that of two homogeneous regions with different luminances. See [Todorović, 1987] for a detailed explanation of the phenomenon.

Many theories have been proposed to explain the COCE and brightness perception in general. Based on the concept of isomorphism, these theories can be categorized into two categories which we shall refer to as *isomorphistic* and *nonisomorphistic* approaches. The underlying idea of the isomorphistic approach is that spatial variations of brightness in the visual field should be accounted for by analogous variations of neural activity. In other words, the neural distribution should "look like" the percept. A theory based on this approach would explain how the two different luminance distributions A and B transform into identical neural distributions (which is identical to the brightness percept). According to the nonisomorphistic approach, similarity of the neural distribution is sufficient to explain the similarity of the percepts; it is not necessary for the neural activities to "look like" the brightness percept.

Notice that there are many issues implicit in the descriptions presented above. It is assumed that activity of a particular type in a specific set of neurons is necessary and sufficient for the occurrence of the percept. The idea, in other words, is that percepts are represented neurally in the brain and there is some "final stage" composed of a set of neurons, whose activities correspond to the percept. We try to disentangle these issues one by one in the rest of the essay and see if either of the two approaches qualify as real "explanations" of what is going on.

That gets us to the first question – what do we mean when we say a theory "explains" certain perceptual phenomenon? According to Teller, acceptable explanations within

visual science have the following form – "If the question is, what is it about the neural substrate of vision that makes us see as we do, the only acceptable kind of answer is, we see X because elements of the substrate Y have the property Z or are in the state S" ([Teller, 1990], p. 12 as quoted in [Thompson et al., 1999]). But what is the relation between the form of a given neural response and the form of the corresponding visual percept? To answer this, [Teller, 1984], by analyzing how visual scientists reason, formulates families of what are called *linking propositions* – propositions that relate neural states to perceptual states. The analogy family, which is the one that concerns us, is as follows:

$$F \text{ "looks like" } Y \rightarrow F \text{ explains } Y,$$

where F stands for physiological terms and Y stands for perceptual terms. The formulation reads: "If the physiological processes (events, states) look like the perceptual processes (events, states), then the physiological processes explain the perceptual process." However, [Thompson et al., 1999] point out that the $\rightarrow$ is only a heuristic meant to guide one to the major causal factors involved in a given perceptual phenomenon, and the term "explains" on the right hand side would be too strong. To quote Teller - "...if psychophysical and physiological data can be manipulated in such a way that they can be plotted on meaningfully similar axes, such that the two graphs have similar shapes, then that physiological phenomenon is a major causal factor in producing the psychophysical phenomenon" ([Teller, 1984], p. 1240 as quoted in [Thompson et al., 1999]).

Before we can proceed further, we have to discuss in some detail the isomorphistic and nonisomorphistic approaches and examine the kind of criticisms each one faces from the followers of the other approach.

- **Nonisomorphistic approach**: It is claimed that the nonisomorphistic approach is conceptually parsimonious since it does not require any additional stages (e.g.

filling-in), involves no logical contradiction, and is consistent with empirical data. However, the main criticism is that the claimed parsimony is spurious and that there is no clear explanation of how the neural representation maps to the percept. Consider the COCE example where we mentioned that two different luminance distributions give rise to identical percepts. According to [Todorović, 1987], this approach explains why they look alike but does not explain what they look like. He points out that there is a need for an explicit general transformational principle to provide a unified set of appearance predictions for a variety of neural distributions. In the isomorphistic approach, the solution to the corresponding problem is trivial because the map is just the identity function. These approaches, although seemingly contradictory, are similar in certain respects. The nonisomorphistic approach assumes an isomorphic mapping from early to final neural representations, followed by a nonisomorphic mapping from the final neural representation to the percept. In the isomorphistic approach, it is the other way around: the initial mapping is nonisomorphic and the neural-perceptual mapping is isomorphic. Both approaches assume the same two types of maps, executed in a different order. The challenge for both approaches is to account for the nonisomorphic map and according to Todorović, the nonisomorphistic approach gets into problems because the nonisomorphic mapping does not belong to the neural domain but is related to the "notorious mind-body problem". The isomorphistic approach cannot avoid this problem either but according to Todorović, "the idea of an isomorphism between certain aspects of neural activity and certain aspects of percepts may be more acceptable, at least within a general reductive stance that assumes that, at some level of description, perceptual states *are* neural states" ([Todorović, 1987] p. 550). This is a tall claim to make and we shall return to this later.

- **Isomorphistic approach**: We have discussed the isomorphistic approach partly

in the previous paragraph itself. Let us now consider the kind of criticisms that it faces. According to Dennett, there need be no isomorphisms between perceptual contents and neural representations, for some perceptual contents might correspond to neural processes that ignore the absence of neural representations, or they might correspond to symbolic representations. He takes the example of a person viewing a colored region and argues against the possibility of "filling-in". Most isomorphistic approaches would require such a process to occur. According to him, "The brain's job is not "filling in". The brain's job is finding out" ([Dennett, 1992] as quoted in [Thompson et al., 1999]). Whether Dennett thinks that the brain accomplishes this by ignoring the absence of a representation or by providing a label ("color by number"), he clearly thinks that filling in the color of each sub-area ("color by bit map") is not the thriftiest way to do it. (It has to be pointed out here that ruling out isomorphism does not imply that filling-in has to be ruled out. See [Thompson et al., 1999] for such a perspective.) Dennett makes a few other claims which are questionable but we shall not deal with them here since they are not relevant to the present discussion.

Both approaches presented above assume that neurons of a particular type are responsible for the percept. The term *bridge locus* is often used to describe such neurons - a particular set of neurons having a particular pattern of activity that is necessary and sufficient for a particular perceptual stage. However, this notion of bridge locus is not a desirable one. Why should there have to be one particular neural stage whose activity forms the immediate substrate of visual perception? Neurophysiological evidence does not favor this concept. Brain regions are not independent stages or modules: they interact reciprocally due to dense forward and backward connections. There is ample evidence of the highly interactive, context-dependent nature of visual processing. As

Todorović rightly observes, the concept of bridge locus is "probably oversimplified" and "there is no compelling reason to believe that the bridge locus is confined to neurons of a single type within a single cortical visual area" ([Todorović, 1987], p. 550). Taking into consideration all these factors, [Thompson et al., 1999] argue that the concept of bridge locus should be abandoned. Hence, the two approaches as described above, also will have to be abandoned.

We now return to the concept of isomorphism. This principle has its roots in the writings of Ernst Mach (1865), Ewald Hering (1878), G. E. Müller (1896), Max Wertheimer (1912), Wolfgang Köhler (1920, 1947) and others (See [Thompson et al., 1999] for more details). According to Köhler, "The principle of isomorphism demands that in a given case the organization of experience and the underlying physiological facts have the same structure" ([Köhler, 1947], p. 301 as quoted in [Thompson et al., 1999]). As pointed out in [Thompson et al., 1999], "Köhler did not hypothesize that neural-perceptual isomorphism obtained for all properties of perceptual experience. In particular, he did not extend the principle of isomorphism to sensory qualities, such as brightness and color... The principle was restricted to structural properties of the perceptual field,..." However, they also point out that in vision science today, this idea is often taken to mean a spatial correspondence, so that, for example, spatial variations of brightness in the visual field are explained by analogous spatial variations of neural activity ([Todorović, 1987]).

As we have already mentioned, the isomorphistic approach is the idea that one must arrive at a "final stage" in the brain - a bridge locus - where there is an isomorphism between neural activity and the percept as experienced by the subject. [Thompson et al., 1999] refer to this idea as *analytic isomorphism.* To quote them - "The doctrine is that it is a condition on the adequacy of an explanation that there be a bridge locus where an isomorphism obtains between neural activity and the subject's experience. Furthermore, the isomorphism is typically taken to hold for spatial or

topographic properties, thus suggesting that vision involves representations having the form of an "internal screen" or "scale model" that preserves the metric properties of the external world." According to Dennett, analytic isomorphism depends on a fundamentally mistaken conception of consciousness which he calls as *Cartesian materialism.* According to this, there is a place in the brain - a *Cartesian theater* - where contents become conscious as a result of being presented to an inner audience or homunculus. Everybody agrees that this idea is wrong but Dennett says most of them are not clear exactly why this is wrong. According to him, the mistake is to assume that consciousness is a property of individual contents in the way that truth can be considered a property of individual sentences.

We finally return to the statement by Todorović where he talks about a general reductive stance which assumes that at some level, perceptual states are neural states. This is contentious. [Thompson et al., 1999] disagree with this and point out that the thesis of neural perceptual isomorphism does not logically entail mind-brain identity. Even if one does assume that perceptual states are neural states at some level, the isomorphism would be plausible only if perceptual states are strictly identical to neural states. The isomorphism would fail if the identity is weak, i.e., if perceptual states are multiply realizable with respect to neural states.

All the arguments presented so far force us to reject the notion of analytic isomorphism. This implies that we will have to reject isomorphistic approaches. We have already presented reasons to reject nonisomorphistic approaches.

In conclusion, conceptual clarity is very important in the study of visual perception, especially so since we often stray close to philosophical issues like the "notorious mind-body problem". One should not shy away from trying to analyze the philosophical aspects of the problem, they are as important as say, giving a mechanistic account of transformations of input distributions to neural activities. When somebody claims

that his/her theory "explains" a particular phenomenon, they should clearly state what they exactly mean by the term "explains". More often than not, the theory will just be pointing to one of the major causal factors involved in the phenomenon. According to [Thompson et al., 1999], it is important to understand the relation between the personal and the sub-personal. "Although brain processes play the main causal role in enabling perception, they are not the proper bearers of perceptual content; the bearer is the animal as a whole interacting in its environment... In short, personal-level perceptual content has a rational bearing on thought and action, whereas the content of sub-personal states does not: brain states have contents that outstrip the conceptual skills of the person, and they have only a causal bearing on thought and action, not a rational/normative one."

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