Perceptual Learning Meets Philosophy: Cognitive Penetrability of Perception and its Philosophical Implications

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Abstract

The undermining of the cognitive impenetrability of perception has led to the abolition of the distinction between *seeing* and *seeing as*, clearing the way for the relativistic theories of science and meaning, since perception becomes theory-laden. Hence the existence of a theory-neutral basis, on which a rational choice among alternative theories could be based, is rejected and scientific theories become incommensurable. One of the arguments against the cognitive impenetrability of perception is based on evidence from neuroscientific studies that suggest the plasticity of the visual cortex, in the sense that there can be some local rewiring of the neural circuitry of the early visual system, as a result of experience. This is taken to constitute evidence that the early vision is cognitively penetrable. In this paper I argue that the evidence concerning perceptual learning does not entail the cognitive penetrability of perception. To that end I discuss the issue of perceptual learning and claim that this learning is task and data-driven and not theory-driven. The process is mediated by the allocation of attention, which though cognitively penetrable, allows only an indirect form of cognitive penetrability of perception. In the last part I elaborate on the significance of this indirect penetrability, as opposed to the direct penetrability by cognition, and discuss its implications for the issue of the incommensurability of scientific theories. My conclusion is that attention can be controlled across different theoretical backgrounds, and thus, that the indirect cognitive penetrability does not entail incommensurability.

Introduction

The undermining of the cognitive impenetrability of perception has led to the abolition of the distinction between *seeing* and *seeing as* (Gregory, 1974; Hanson, 1958; Kuhn, 1962), clearing the way for the relativistic theories of science and meaning, since perception becomes theory-laden (what we see depends on our expectations, beliefs, and so forth). Hence the existence of a theory-neutral basis, on which a rational choice among alternative theories could be based, is rejected and scientific theories become incommensurable. There can be no communication between scientists that belong to different scientific paradigms, because there is not a theory-neutral perceptual basis that could resolve matters of meaning. Instead, empirical evidence, becomes part of a paradigm or a theoretical research program, being modulated by its theoretical commitments. Thus, proponents of different paradigms or research programs either perceive different worlds (strong version of relativism; Kuhn, 1962), or cannot compare their theories on the basis of some neutral empirical evidence but must search for other criteria of theory evaluation (medium version of relativism; Churchland, 1989).

One of the arguments against the cognitive impenetrability of perception and in favor of its theory-ladenness is based on evidence from neuroscientific studies that suggest the plasticity of the visual cortex, and more specifically, on evidence that there can be some local rewiring of the neural circuitry of the early visual system, as a result of experience (the phenomenon of perceptual learning).

The plasticity of the brain and the possibility of rewiring of the neural circuitry of the perceptual systems, as a result of acquiring knowledge, goes against the view (Fodor, 1983; Pylyshyn, 1999) that some part of vision, the early vision, is cognitively impenetrable, and shows (Churchland, 1988) that perception is cognitively penetrable, in so far as learning, which is a cognitively driven process, affects even those circuits that are involved in early vision.

In this paper I argue that the evidence concerning perceptual learning does not entail the cognitive penetrability of perception. To that end I discuss the issue of perceptual learning and claim that this learning is task and data-driven and not theory-driven.

Being the former it allows only an indirect form of cognitive penetrability of perception. In the last part I elaborate on the significance of this indirect penetrability, as opposed to the direct penetrability by cognition, and discuss its implications for the issue of the incommensurability of scientific theories. My conclusion is that this indirect penetrability does not entail incommensurability.

I have spoken of perception. This term is not employed consistently in the literature. Sometimes "perception" purports to signify our phenomenological experience, and thus, "is seen as subserving the recognition and identification of objects and events" (Goodale 1995, 175). Since I do not use the terms the same way, I will introduce some terminology.

I call *sensation* all processes that lead to the formation of the retinal image (the retina's photoreceptors register about 120 million pointwise measurements of light intensity). This image, which initially is cognitively useless, is gradually transformed along the visual pathways in increasingly structured representations (such as, edges, boundaries, shapes, colors) that are more convenient for subsequent processing. I call these processes that transform sensation to a representation that can be processed by cognition *perception.* Perception includes both low-level and intermediate-level vision and, I claim, is bottom-up. In Marr's (1982) model of vision the *21/2D sketch* is the final product of perception. As I shall argue next perception is non-epistemic, that is, it is independent of specific-object knowledge. All subsequent visual processes fall within *cognition*, and include both the post-sensory/semantic interface at which the object recognition units intervene as well as purely semantic processes, that lead to the identification of the array (high-level vision). At this level we have observation (Marr's *3D model*), which is a cognitive activity.

Perceptual Learning

There is growing evidence for the diachronic penetrability of perceptual systems and for local rewiring of their neural circuits (Ahhisar and Hochstein, 1993; Antonini, Strycker, and Chapman, 1995; Karni and Sagi, 1995; Stiles, 1995). Is there a way to reconcile the notion of cognitive impenetrability of perceptual systems with this evidence? Fodor thought that there is not any, and that this issue would be resolved with the findings of empirical research. Should empirical research show perceptual learning to be possible, then the encapsulation of his input modules would have been proved false. The evidence suggests that perceptual systems are indeed diachronically, in the long run, open to some rewiring of the patterns of their neural connectivity, as a result of learning. These systems are to some extent plastic. But this does not mean that they are cognitively penetrable. Let us see why.

Research shows that changes can be induced in visual cortical neural patterns in response to learning. More specifically, visual processing at all levels may undergo long-term, experience-dependent changes. The most interesting form of learning is "slow learning", because it is the only type that causes structural changes in the cortex (formation of new patterns of connectivity). Such learning can result in significant performance improvement. For example, one may learn with practice to perform better at visual skills involving target and texture discrimination and target detection, and to learn to identify visual patterns in fragmented residues of whole patterns (priming). Performance in these tasks was thought to be determined by low-level, stimulus-dependent visual processing stages. The improvement in performance in these tasks, thus, suggests that practice may modify the adult visual system, even at the early levels of processing. As Karni and Sagi (1995, 95-6) remark "[L]earning (acquisition) and memory (retention) of visual skills would occur at the earliest level within the visual processing stream where the minimally sufficient neuronal computing capability is available for representing stimulus parameters that are relevant input for the performance of a specific task."

Karni and Sagi (1995) suggest that slow learning is independent of cortico-limbic processing, which is responsible for top-down processes and, through the interaction of the limbic system with the visual pathways, responsible for conscious object recognition. It is also independent of factors involving semantic associations. Yeo, Yonebayashi, and Allman (1995) suggest that priming facilitates the neural mechanisms for processing images and that the cortex can learn to see ambiguous patterns by means of experience-induced changes in functional connectivity of the relevant processing areas. Thus, priming involves a structural modification of basic perceptual modules. Practice with fragmented patterns leads to the formation of the "priming memory" which may be stored in the cortical visual areas. Long-term potentiation (*LTP*) may be the mechanism implementing these architectural changes by establishing experience-dependent chains of associations and dissociations.

Slow learning-induced architectural modifications are "experience dependent" (Greenough, et al., 1993), in that they are controlled by the "image" formed in the retina. But, although learning and its ensuing functional modifications occur in those neuronal assemblies that are activated by the retinal image, still some extra-retinal factor should provide the mechanism that will gate functional plasticity. Although many neuronal assemblies are activated by the retinal image, learning occurs only in those assemblies that are behaviorally relevant. This is called the "gating of neuronal plasticity".

The factor that modulates gating is the demands of the task. They determine which physical aspects of the retinal input are relevant, activating the appropriate neurons. Functional restructuring can occur only at these neuronal assemblies. The mechanism that accomplishes this is attention. Focusing attention ensures that the relevant aspects of the input are further processed. Attention intervenes before the perceptual processes; selective attentional shifts to specific parts of the visual field precede saccadic eye movements directed to these parts (Hoffman and Subramaniam, 1995). Attention seems to determine the location at which search will be conducted and/or the relevant features that will be picked-up, since focal attention may enhance the output of the salient feature detectors by lowering firing thresholds (Egeth, *et al.*, 1984; Kahneman and Treisman, 1992; McCleod *et. al.*, 1991). There is indeed ample evidence for the necessary role of attention in perceptual learning (Ahissar and Hochstein, 1995) and for the role of attention in learning to perceive ambiguous figures (Kawabata, 1986; Peterson and Gibson, 1991).

Recall that slow learning is independent of recognition and semantic associative memory. Most of the priming effects are associated with identification and discrimination of relative spatial relations and extraction of shapes. This brings to mind Hildreth and Ulmann's (1989) *intermediate level* of vision. The processes at this level (the extraction of shape and of spatial relations) are not bottom-up, but do not require the intervention of specific-object knowledge, since they require the spatial analysis of shape and spatial relations among objects. This analysis is task dependent but not theory-driven, that is, it is not directly penetrated by cognition.

I have spoken of "specific-object knowledge" and claimed that this kind of knowledge does not intervene in slow learning, and does not threaten cognitive impenetrability of perception. I would like to explain the qualification "knowledge about specific objects". Even if perception turns out to be bottom-up in character, still it is not insulated from knowledge. Knowledge intrudes on perception, since early vision is informed and constrained by some general world principles that reduce indeterminancies in information. They are general assumptions about the world constraining visual processing (Marr, 1982; Ulmann, 1979). These principles however are not the result of explicit knowledge acquisition about specific objects but are general reliable regularities about the optico-spatial properties of our world.

This knowledge is implicit, in that it is available only for the processing of visual information, whereas explicit knowledge is available for a wide range of cognitive applications. Implicit knowledge cannot be overridden. The general constraints hardwired in the visual system can be overridden only by other similar general constraints with which they happen to compete (although no one knows yet how the system "decides" which constraint to apply). Still, one cannot decide to substitute it with another body of knowledge, even if one knows that under certain conditions this implicit knowledge may lead to errors (as is the case with the visual illusions). This theoretical ladenness, therefore, cannot be used as an argument against the existence of a theory-neutral ground, because perception based on a shared theory is common ground.

Slow learning, thus, takes place under specific retinal input and attention-dependent conditions. Although the allocation of attention is clearly cognitively driven (that is, it is shaped by knowledge, beliefs, expectations, needs etc.), it operates before the onset of perceptual processing, and therefore, does not imply the cognitive penetrability of perception. One could say at most that cognition indirectly affects perception, in the sense that the modifications in perceptual circuitry are connected to cognitive factors mediated by attention. This is an indirect form of cognitive penetrability of perception, in that the contents of our cognitive stances do not affect the kind of the neural modifications but only determine, as it were, the conditions of learning by means of attentional mechanisms. As Pylyshyn (1999) remarks, to argue that this is a form of cognitive penetrability is like arguing that, because the decision to wear glasses is cognitively determined and because wearing glasses affects perception, perception is cognitively penetrable. We will discuss in the next section the philosophical implications of the distinction between direct and indirect cognitive penetrability.

So, the perceptual systems are to some extent plastic, as Churchland argues. But this plasticity is not the result of the penetration of the perceptual modules by higher cognitive states, but rather, the result of learning-induced changes that are modulated by the retinal input and task-demands. Fodor (1983), given his view that the perceptual modules have a fixed architecture, had to concede that if evidence is found for diachronic changes in the functional architectures of the modules, then the modularity of perception would collapse. But this is not necessarily so.

First the data-driven changes can be accommodated by the notion that the modules are semi-hardwired. All this view requires is that the functional changes reshape the microcircuitry and not the macrocircuitry of the modules. Bearing in mind that priming enhances performance, one cannot see how such learning could reshape their basic macrocircuitry. Second, even though the perceptual systems do not have a fixed architecture, the factor that modulates the rewiring is task-driven and not cognitively driven. This bars any movement from the possibility of rewiring of the perceptual systems to the cognitive penetrability of these systems, and thus, to the incommensurability of scientific theories.

Philosophical Implications

Let me now turn to the implications of the possibility of learning-induced changes in the visual system as these relate to the issue of the existence or not of a theory-neutral basis on which the issue of rational choice among scientific theories and scientific relativism rest. The question boils down to whether scientists with different experiences could form a different *perception* of the same retinal image. Suppose that, as a result of learning through repeated experience in her field, a scientist has somewhat shaped her perceptual sensitivity according to her specific professional needs and can recognize patterns that others cannot. She has learned which dimensions of visual analysis to attend to, and this process has reshaped her basic sensors by selecting the output of certain feature detectors. Suppose further that this learning has induced changes in the circuitry of her early vision, altering her visual perception (the part of vision, which is supposedly cognitively impenetrable). Hence, the answer is *yes*; some scientists who are trained in certain fragmented patterns and have stored them in the so-called "priming memory" may be able to recognize patterns that others could not. Suppose further that these changes affect her assessment of experiential evidence about theory evaluation.

Does this pose a threat to the possibility of creating a theory-neutral perceptual basis, and thus, does it constitute a basis on which the incommensurability of scientific theories could be established? I think that it does not, since as I have argued, this neural change is task or data-driven and not theory-driven. The difference is an important one for the following reasons:

First, all humans have roughly similar perceptual circuits (barring some damage or other). Thus, despite the fact that no two humans share identical brain circuits, we all cut the world in roughly similar ways. We all share, for instance, the same neural mechanisms for perceiving colors, and thus, we have the same conceptual representations of colors (Barsalou, 1999; Lakoff, 1987). Rosch's (Rosch, et. al., 1976) findings that there exists a "universal" basic-level categorization of objects in the world, which in the case of living things corresponds to the categorization into natural kinds, seem to confirm the contention that humans cut, at some level of analysis, the world roughly in the same way. The existence of universal natural kinds can be attributed to many causes, one of which is that the animals that belong to the same natural kind have roughly the same overall shape. Since shape is one of the attributes that matters the most with regard to the human-environment interaction, shape plays an important role categorization. The fact that we all cut the world into the same natural kinds supports the thesis that we all perceive shapes the same way, undoubtedly because we share (ceteris paribus) the same visual circuits.

Second, all scientists have had experiences of more or less the same objects; they share more or less the same scientific education, and work with roughly the same objects and instruments. Thus, their brains share a roughly similar basic microcircuitry, as far as this circuitry bears on the practice of their profession, since the circuitry is formed as a result of experience.

Third, even if some of them have acquired some particular priming memory, and as a result can *perceive* patterns that others cannot, nothing precludes the latter from undergoing the same training and reestablishing a common *perceptual* ground. Learning of this kind is data- and task-driven, which means that the same training will almost certainly produce the same "priming memory". It is at this point that the difference between the direct cognitive penetrability of perception by beliefs and expectations and the indirect penetrability through task-driven learning, which in its turn is shaped by cognitive is cashed out. In task-driven learning, cognition indirectly mediates the process through the allocation of attention. Attention, can be controlled though, since people can be instructed to focus their attention on such and such a location and scan for such and such a feature, despite the fact that these people may have entirely different intentional stances. Once this factor has been controlled, differences in beliefs etc., do not affect the course of the "priming" training, and thus, of perceptual learning. This implies that similar training will induce similar brain changes. Thus, experience-induced plasticity of the brain does not threaten the possibility of a theory-neutral perceptual basis.

The difference between data-driven and theory-driven learning in general is important. The task and what one should attend to can be specified intersubjectively in groups with varying theoretical commitments. Since the whole enterprise is data and task-driven, the same task is bound to induce similar changes. This allows scientists to perceive the same things after some training, even if initially one of them was more capable than the other to perceive certain patterns. This way a channel of communication is established, since now they perceive similar things, no matter how they interpret them, which importance they attribute them and so forth. This explains why scientists working within very different paradigms can test one the experiments of the other, compare their results etc., even though they may disagree as to their importance and confirmatory role, a finding that receives ample support from research in the history of science (Gooding, 1990; Nersessian, 1984). This finding shows that even though different theoretical frameworks shape the design of experiments and their interpretations still scientists within different paradigms can understand what others scientists are doing.

By introducing a distinction between a bottom-up and non-semantic perception and a semantic cognition I join a long tradition of similar distinctions. Jackendoff (1989) distinguishes "visual awareness" from "visual understanding". Similarly Dretske (1995) distinguishes a "phenomenal sense of see" from a "doxastic sense of see". To the extent that the first parts of the pairs clearly correspond to a non-epistemic sense of perception, and the second parts of the pairs to an epistemic sense of perception, these distinctions are coextensive with the "perception-observation" distinction that I introduced in the introduction.

I would like to close the discussion regarding the philosophical implications of perceptual learning with a remark on the dichotomy between perception and cognition. In the introduction I defined perception as the set of processes that transform sensations to cognitively usable structures, and distinguished between perception and cognition, by claiming that the former is bottom-up, whereas the latter is not. This dichotomy however, should not be taken to imply a functional and even a neural distinction between perception and cognition.

I have argued elsewhere (Raftopoulos, 2001a; 2001b) that many cognitive functions (e.g., imagery and spatial conceptualization) take place at the same neural areas that support early vision (see also Barsalou, 1999). In this sense, the mechanisms implementing perception and cognition cannot be divorced. Since the perceptual input systems are necessarily involved in higher cognitive tasks, our conceptual systems are severely constrained by the architecture of the perceptual modules. Perception does not serve only as the faculty that provides input to higher cognition and then comes on-line, after the cessation of the conceptual processing, in order to test empirically its outcome, but also constitutes an active participant of the conceptual processing itself.

This does not, mean, however, that perception and cognition function simultaneously, as Barsalou (1999) claims. There is ample neurospychological and neurophysical evidence suggesting that the perceptual processes precede cognitive processes of a scene, and that their outcomes differ. Thus, it makes sense to distinguish between perceptual and cognitive processes, even though cognition should be extended to include perception. But even if perceptual systems are cognitively penetrable, still a case cannot be made for incommensurability. For, according to Barsalou, the top-down information is overridden if in conflict with the bottom-up information coming from the perceptual modules. Thus, given some incoming information, different cognitive stances cannot cause different perceptions of a visual array.

Conclusion

I have argued in this paper that perceptual learning and the resulting rewiring of the early visual systems need not suggest the cognitive penetrability of early vision, since this form of learning is experience and task-driven and not theory-driven. This is so because perceptual learning, by being modulated by attention, is only indirectly affected by cognition. To the extent that attention can be controlled, the influence of cognition on early vision is neutralized.

We see the problem in the arguments against the cognitive encapsulation of perception. In attempting to demonstrate the cognitive penetrability of our perception and that the theoretical neutrality of observation is false, they confuse the plasticity of the brain and perceptual learning with cognitive penetrability. But the former does not entail the latter. The only way out is to argue that the experience-induced learning changes the way we observe the world, and this, in its turn, by means of some top-down flow of information which affects the way we perceive. Though it is true that our experiences shape our theories and the way we see the world, to say that these theories influence the way we *perceive* the world is question begging, since one must show that this top-down influences occur.

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