Perceptual Expertise

Bridging Brain and Behavior

Edited by

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Foreword

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Having observed the Perceptual Expertise Network (PEN) in action, I can attest to its importance and uniqueness. The PEN group has been a highly tight-knit and intellectually vibrant community, self organized in a grass-roots manner by researchers intrinsically interested in a common topic—the scientific understanding of perceptual learning leading to expert performance. Their efforts were jump-started by a McDonnell Foundation grant, and to my mind, the resulting workshops and research synergies are simply the best example that I know of for how to successfully foster true cross-laboratory collaboration. The PEN group is now a large community, not organized around a single individual, but rather around a core group of about 10 large research teams. The PEN group is itself integrated into other groups such as the National Science Foundation Science of Learning Center on Temporal Dynamics.

As to the topic itself, perceptual learning is important for two reasons—because it is perceptual and because it is learning. Changes to perception are particularly important because they affect all subsequent cognitive processes that occur downstream. There is good evidence, both neurophysiological and behavioral, that perceptual learning can involve early changes to the primary visual, auditory, and somatosensory cortices. One might feel that the early perceptual system ought to be hardwired—it is better not to mess with it if it is going to be depended upon by all processes later in the information processing stream. There is something right with this intuition, but it implicitly buys into a “stable foundations make strong foundations” assumption that it is appropriate for houses of cards, but probably not for flexible cognitive systems. For better models of cognition, we might turn to Birkenstock shoes and suspension bridges, which provide good foundations for their respective feet and cars by flexibly deforming to their charges. Just as a suspension bridge provides better support for cars by conforming to the weight loads, perception supports problem solving and reasoning by conforming to these tasks. Many of the chapters in this book attest to the advantage of having a flexible perceptual system that customizes itself to its needed tasks. Avoiding both the Scyllae of requiring all perceptual discriminations to be "preloaded" into the brain/mind, and the Charybdis of assuming that all sophisticated discriminations require the explicit concatenation of many elementary perceptual features, the contributions contained herein point to a third middle route. Namely, new perceptual representations can be constructed because of their diagnosticity for a personally relevant task. These representations do not have to be hardwired, and in fact, it is difficult to see how all personally relevant representations (e.g., cars for mechanics, pitches for umpires, birds for naturalists, or X-rays for radiologists) *could* be hardwired. These representations do not have to be processed as concatenations assembled from a set of generic elemental detectors. The chapters provide solid evidence that many pertinent perceptual representations functionally act as holistically registered, acquired detectors. Accordingly, the representations are genuinely perceptual, acting as the components for later cognitive representations.

If perceptual learning is crucially perceptual, it is also crucially learning. Consistent with the ripples of downstream influence that early perceptual changes exert, perceptual systems should generally be designed to change slowly and conservatively, so as not to disrupt their downstream consumers. For this reason, this book's focus on perceptual *expertise* is appropriate. Expertise typically requires at least 10 years to attain (Ericsson, Krampe, & Tesch-Römer, 1993), sufficient time to influence perception, not simply decision trees or explicitly memorized strategies. The protracted time course of acquiring new perceptual tools is certainly frustrating for those in the business of judging wines, rock samples, cell structures, dives, or manufacturing flaws. One of the reasons why wisdom can't be simply told (Bransford, Franks, Vye, & Sherwood, 1989) but rather must be lived is that wisdom is frequently perceptual and thus must be built into one's neurological wiring. Doctors with years of clinical experience frequently experience surprise that their verbal descriptions have little value to second-year residents. The lecturer knows what she means by "spiky" tumors or "aggravated" tissue, but these words are not transmittable in the same way that "isosceles" can be simply verbally communicated as "a triangle having two sides of equal length." The doctor's terminology is not easily communicated because the words are just the tip of the iceberg. The iceberg below the surface is the years of experience needed to connect perceptual information to the words. Understanding the words is largely a matter of acquiring perceptual skills of segmentation, highlighting, differentiation, and unitization. Although the doctor's terminology takes years to master because its perceptual basis must also be learned, the final product of this mastery is that the newly forged expert sees a new world. Thomas Kuhn (1962) described how scientists, when exposed to a particular theoretical paradigm, see physical phenomena in new ways: "Though the world does not change with a change of paradigm, the scientist afterward works in a different world." (p. 121). A similar transformative experience accompanies expertise and justifies the hard and long work necessary to establish this "see change" in perception.

One might suppose that perceptual learning and perceptual expertise have strictly limited spheres of application because evolution has already tuned our perceptual systems to be sensitive to the most important elements of the world in which we live (Olshausen & Field, 1996). Having an adaptive perceptual system is advantageous when the world is variable. However, at least at a first pass, isn't the world fairly stable? We are all exposed to the same wavelengths of light thanks to the sun's spectral class. The gravitational constant is . . . constant. However, I would reply that there is an important sense in which different people face different environments. Namely, to a large extent, a person's environment consists of animals, people, and things made by people. All of these things have been designed by evolution or people to show local and regional variation. We *might* have been built by evolutionary R&D to be adept at processing faces (but see Chapters 1, 2, and 3 for persuasive arguments against strong forms of even this claim), but we could never have been prebuilt to be expert at processing particular faces such as Barack Obama's and John McCain's because there are simply too many possible faces. If we develop the need to identify a face or discriminate among faces, then these perceptual skills need to be acquirable. It is vital that perceptual systems be tunable because differences between faces are critical for the social animals that we are. Furthermore, our very identities are connected with the objects for which we become experts. Our vocations, avocations, and values are revealed by whether we become experts at distinguishing wines, words, or warplanes.

Although certain aspects of our world are shared by all of us, many of the most important identifications that we make cannot be universal and hardwired. When a domain becomes important to us, differences among the objects in that domain necessarily become important to us. To be a bird expert is to cease treating all birds alike, and to make distinctions between them (Tanaka & Taylor, 1991). The same is true for expertise with food, disease, art, music, or sport. One of the most striking regularities of learning is that the expert cannot help but make distinctions that they could not originally make at all as novices. Cognitive psychologists have rightly emphasized the cognitive equipment that all people share, but a powerful piece of this equipment is the ability to differentiate ourselves so that we are each unique. We can employ domain-general processes to become specialized for domains and particular instances within the domains.

A corollary of this ironically universal tendency to become unique is that what becomes highly specialized processing need not have started that way. As the chapters in this book demonstrate, the presence of neuroanatomically compact regions with distinct functional specializations does not sanction the inference that these regions were innately wired to perform those functions. The functional specializations of brain regions adapt over an organisms' lifetime and often span multiple object domains. Cognitive scientists have traditionally linked domain specificity and constraints. To learn, we must have constraints. Gold (1967) and Chomsky (1965) showed that there are too many possible grammars to learn a language in a finite amount of time, let alone 2 years, if there were no constraints on what those grammars look like. Psychologists applied these formal results to development and learning, concluding that different domains (including language, but also physics, biology, quantitative reasoning, social relations, and face perception perhaps) have their own special structures which should be exploited for learning. To efficiently exploit these kinds of structures entails having different kinds of constraints for different domains.

An exciting possibility pursued by the contributions to this book is that some constraints may be acquired rather than built in. Computational modeling suggests that the eventual specialization of a neural module often belies its rather general origins (Jacobs, Jordan, & Barto, 1991). Very general neural differences, such as whether a set of neurons has a little or a lot of overlap in their receptive fields, can cause the two populations of neurons to spontaneously specialize for handling either categorical or continuous judgment tasks, or snowball small initial differences into "what" versus "where" visual systems (Jacobs & Jordan, 1992). Empirical evidence from these pages, as well as developmental psychology (Sloutsky & Fisher, in press; Smith, Jones, & Landau, 1996), has begun to support this modeling work, showing that we do not need to start with domain-specific constraints. The specific domains can emerge from more domain-general principles of association, contingency detection, statistical learning, and clustering.

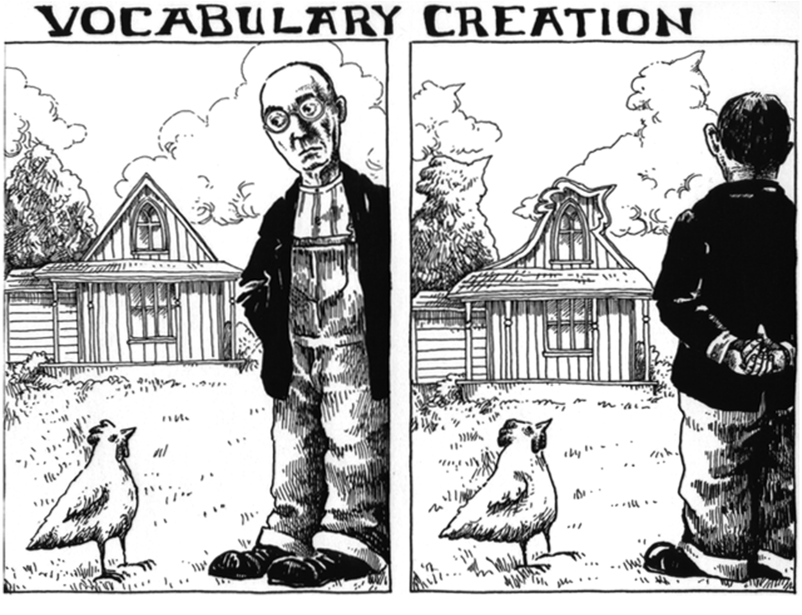

Figure F.1An illustrated allegory of the human bias to see the world filtered through a perceptual system that has been tuned to the same world. [Conceived by Robert Goldstone and Joe Lee, illustrated by Joe Lee.]

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This computational and developmental work fits well with this book's leitmotif that particular domains, such as faces and letters, are indeed special for people, but that the process by which they became special may in large part be general. We learn about faces, and this learning changes how we learn about new faces. We develop constrained expectations about what faces should look like by being exposed to faces. Constraints both shape learning, and are shaped by learning. The promise of this work is that it will elaborate on how an intelligent system can create at least some of its own constraints—constraints that were not originally there before the brain organized itself to reflect important domains. The classic work on formal language learning is still correct. A system that aspires to learn needs to have constraints on what it can learn. There is no such thing as a system that is good at learning absolutely anything that it is presented. Efficient learning depends on making good assumptions about the kinds of things that will be presented. However, it still may be the case that many of these assumptions can be acquired by exposure to what the world has to offer. The functional and neurophysiological specializations explored in the following papers attest to the power of acquired constraints. Our perceptual systems enforce strong constraints on what we extract from the world, but they are also adapted to what we extract (see Figure F.1). If we must be constrained in order to learn, there is nonetheless substantial consolation in having those constraints themselves be flexibly tuned.

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