Does *The Sensory Order* Have a Useful Economic Future?

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Abstract

F.A. Hayek's theoretical psychology was developed in his 1952 book, *The Sensory Order*. Because economists have increasingly become interested in cognition and psychology, this work has valuable implications for economic science. Nevertheless, these implications have sometimes been obscured by bogus interpretations of the book. We address down such interpretations of Hayek and suggest some ways in which the message of *The Sensory Order* matters for economic research today.

I. Introduction

Cognition and psychology have become central issues in economics. While this interest represents a radical change in economic theory, it does have a useful history that we believe is only partially recognized by contemporary economists. Although it is customary to cite Herbert Simon's important work in this regard,[1] we suggest Hayek's earlier work *The Sensory Order* (1952) should enjoy similar billing.

The nexus of economics, cognition, and psychology has become a matter of interest to many contemporary researchers.[2] We think this current high level of interest in such areas should induce a similarly high interest in Hayek's theoretical psychology. The level of interest has, in fact, been rising; yet, it is not always clear what value Hayek's very abstract notions might have for economists. We will offer some answers that we hope will increase the interest and understanding of economists in Hayek's psychology.

The next section is yet another summary of *The Sensory Order*. Logic seemed to demand that we include this section, although we have tried to be brief. Readers who are familiar with the work should probably read the section anyway so that they know what we make of Hayek's book. The subsequent section articulates some errors of interpretation that have made their way into the economics literature. We try to show why each of the supposed errors is, in fact, a false reading of Hayek. In the section following that we give our reasons why economists should read *The Sensory Order* and build on it in their own work. Some of these reasons concern methodology; others concern economic theory. A short conclusion recapitulates our main points and gives a brief exhortation to the effect that economists should let *The Sensory Order* inform their thinking.

II. Yet Another Summary of *The Sensory Order*[3]

The Sensory Order presents Hayek's solution to the mind-body problem. Hayek tried to show "how the physiological impulses proceeding in the different parts of the

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[1] Simon (1955). Also see Sections VII & VIII in Simon (1982).
[2] This growing group of scholars includes Daniel Kahneman & Amos Tversky, Gerd Girgenzer & Reinhard Selten, Brian Arthur, Brian Loasby, Douglas North, and Vernon Smith. Also see note 14 below.
[3] Several parts of this section borrow from Butos and Koppl (1993), Koppl (1999), and Koppl (2002). Also see McQuade and Butos (2004).

central nervous system can become in such a manner differentiated from each other in their functional significance that their effects will differ from each other in the same way in which we know the effects of the different sensory qualities to differ from each other" (1952a, p. 1). The object of inquiry, then, is "the sensory order," which tells us that this is green and that is blue, this is warm, that is cold, and so on. He claims that higher mental processes "may be interpreted as being determined by the operation of the same general principle which we have employed to explain the formation of the system of basic sensory qualities" (p. 146).

For Hayek "psychology must start from stimuli defined in physical terms and proceed to show why and how the senses classify similar physical stimuli sometimes as alike and sometimes as different, and why different physical stimuli will sometimes appear as similar and sometimes as different" (pp. 7-8). The senses give us a natural and naive picture of how the world works. Science replaces this picture with another one, less likely to disappoint our expectations. Theoretical psychology has the job of explaining how the world described by science could generate organisms possessed of the more naive picture from which this same scientific view departs.

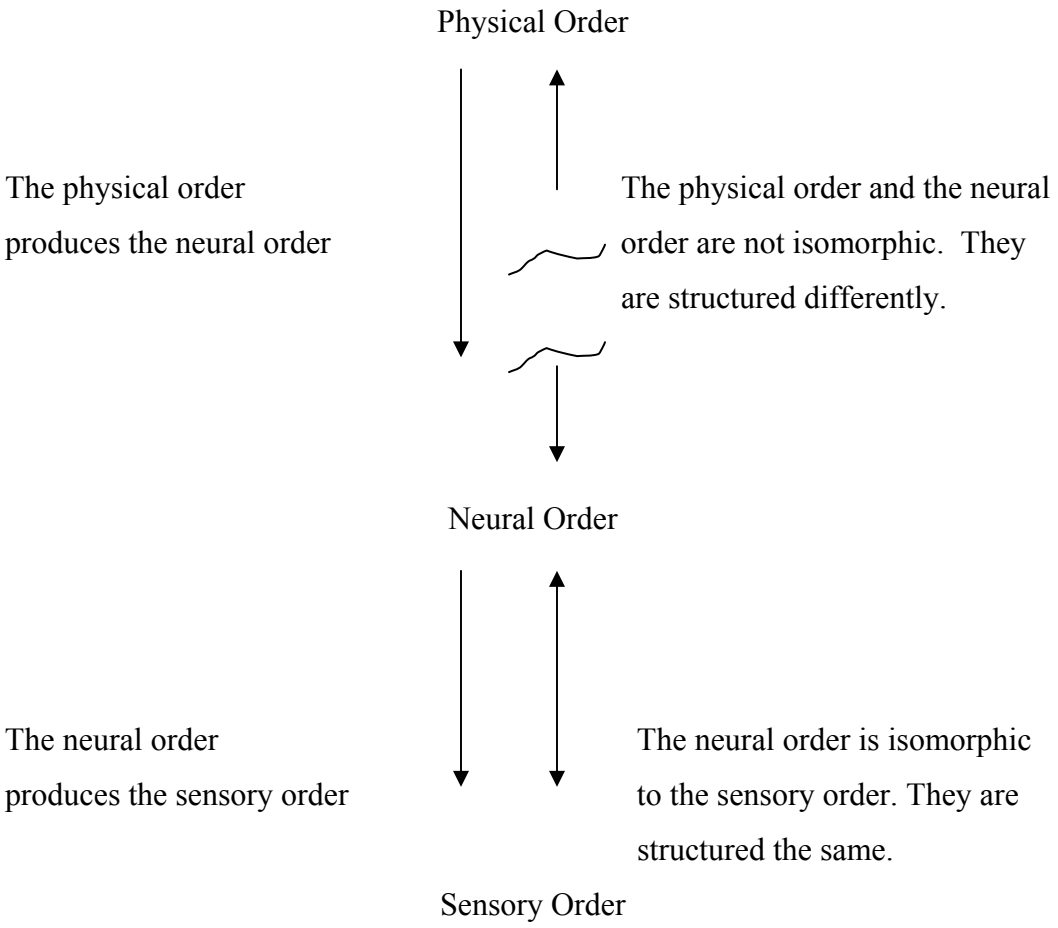
Hayek's answer depends on the idea that our brains are structured organs. For Hayek's theory, the crucial aspect of the brain's structure is the set of connections among nerve fibers. If nerve A fires, nerve B fires and C does not. If nerve D fires instead, C fires and B does not. In many animals, including humans, the network of connections is very complex. These connections govern the organism's capacities for cognitive processes and how it responds to external reality.

Thus, for Hayek, theoretical psychology must establish the relations between three "orders": the physical order and the isomorphic neural and sensory orders. The physical order, the order of events described by natural science,[4] is external to the brain and produces the neural order. The neural order, the set of connections between nerve

[4] Hayek considers the physical order to be "objective" and the phenomenal order to be only a "first approximation" of this "objective world." This does not mean, however, that the physical order is comprised of qualities or structures somehow "given" to us. For Hayek, what we know about external reality is problematic and necessarily fallible. Moreover, Hayek says, "By saying that there 'exists' an 'objective' world different from the phenomenal world we are merely stating that it is possible to construct an order or classification of events which is different from that which our senses show us and which enables us to give a more consistent account of the behaviour of the different events in that world" (1952a, p. 173).

fibers in the brain, produces the sensory order of phenomenal experience. But the physical order is different, as noted earlier, from the neural order and thus necessarily different from the sensory order. Figure 1 illustrates.

Figure 1

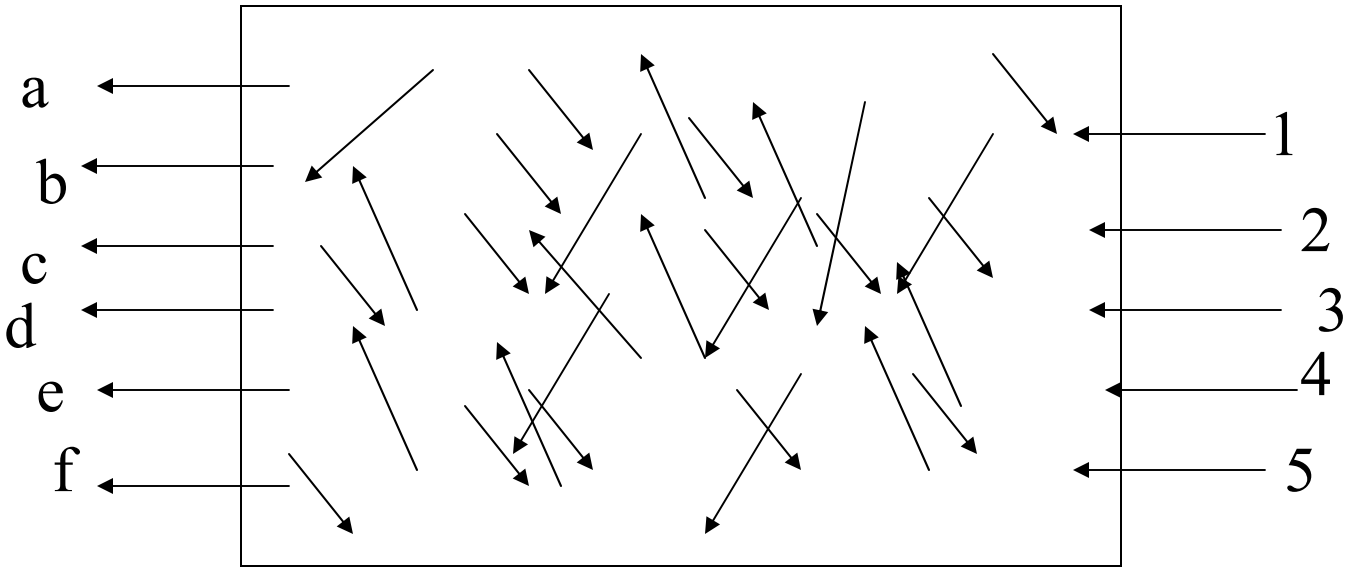


The central nervous system is made up of fibers that carry impulses, most of which are in the brain. The rest are afferent fibers and the efferent fibers, carrying impulses up to and down from the brain, respectively. The consequence of a given set of

impulses running up to the brain is an induced pattern of impulses running down from the brain. What that induced pattern of impulses will be depends on what happens in the brain. It depends on the set of connections among nerve fibers.

An organism for which the induced constellation of efferent impulses bore no relationship to the incoming afferent impulses would not be responding to its environment. We would deny that it is thinking. Figure 2 illustrates. An organism for which the induced constellation of efferent impulses bore a fixed and simple relationship to the incoming afferent impulses would be responding to its environment, but only in ways we would likely call "mechanical." Figure 3 illustrates. We would deny that it is thinking. We recognize an organism's behavior as governed by mental phenomena when the organism is responding to its environment, but in ways more complex than reflex action. Figures 4 & 5 illustrate. The connections among nerve fibers create regularities or rules in the behavior of the organism. These rules create, in the language of information theory, "mutual information" between the outputs and the inputs to the brain.

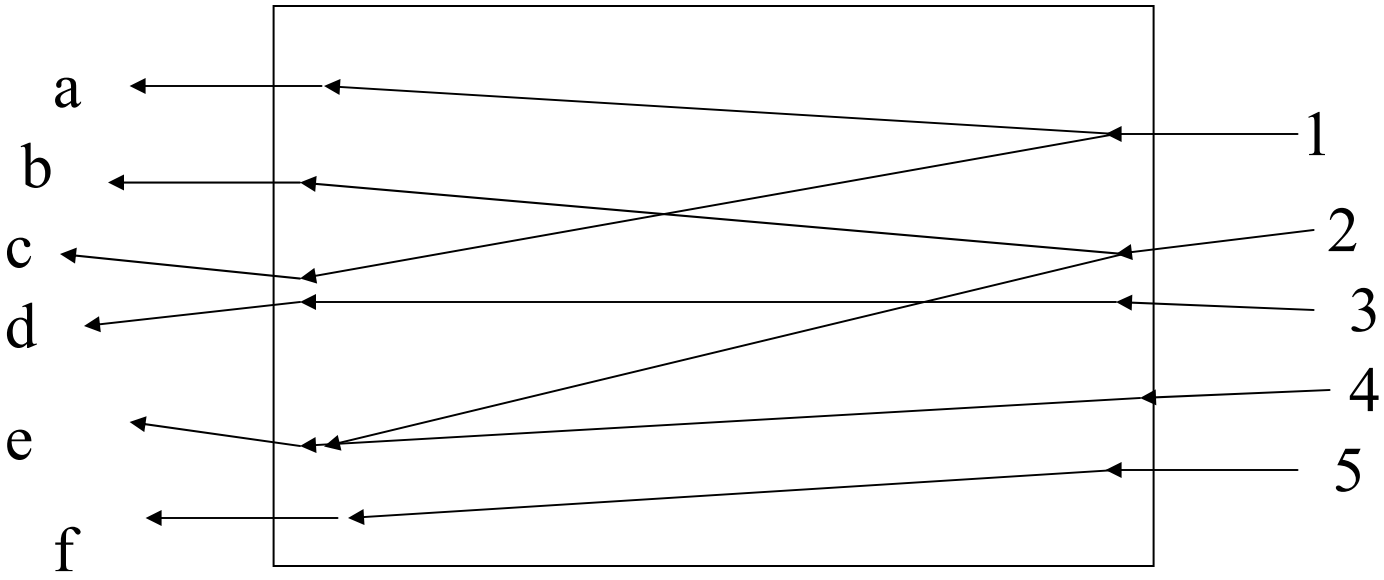
Figure 2



The arrows represent nerves. Those labeled **1** through **5** are afferent fibers. Those labeled **a** through **f** are efferent fibers. The box represents the brain, where impulses coming up the afferent fibers are translated into impulses traveling down the efferent fibers.

In this case, the nerves are not connected in any stable patterns, but only in random and changing patterns. There is no neural order. Thus, there is no relationship between the pattern of firings of the afferent nerve fibers and the pattern of firings of the efferent never fibers. The organism represented does not follow any rules, nor does it think.

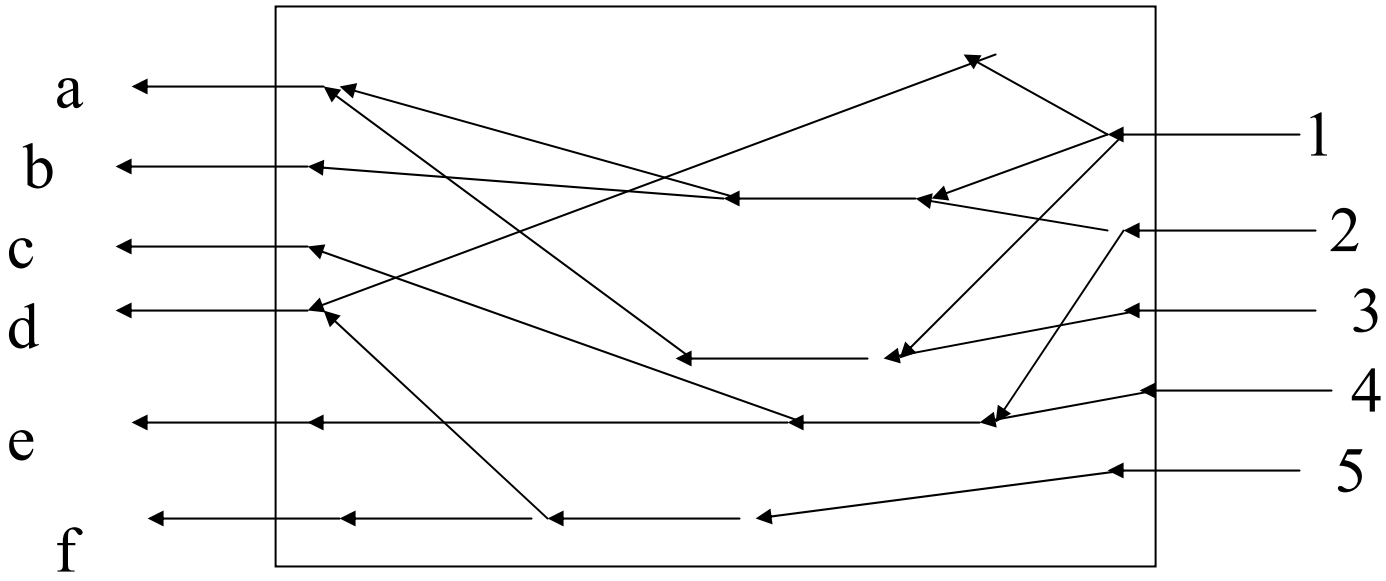
Figure 3



The arrows represent nerves. Those labeled **1** through **5** are afferent fibers. Those labeled **a** through **f** are efferent fibers. The box represents the brain, where impulses coming up the afferent fibers are translated into impulses traveling down the efferent fibers.

In this case, there is a neural order. Thus, there is a relationship between the pattern of firings of the afferent nerve fibers and the pattern of firings of the efferent nerve fibers. The relationship, however, simple and does not change over time. Thus, the organism responds to its environment only in ways we consider "mechanistic." It does follow rules, but it does not think.

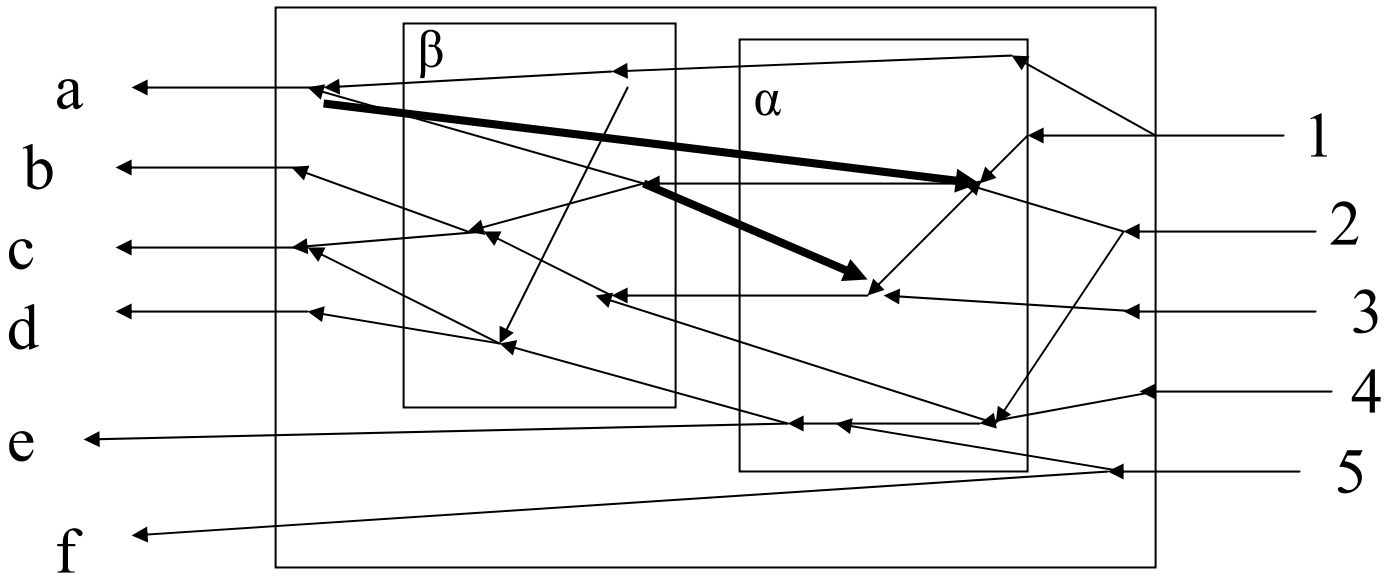
Figure 4



The arrows represent nerves. Those labeled **1** through **5** are afferent fibers. Those labeled **a** through **f** are efferent fibers. The box represents the brain, where impulses coming up the afferent fibers are translated into impulses traveling down the efferent fibers.

In this case, there is a neural order. Thus, there is a relationship between the pattern of firings of the afferent nerve fibers and the pattern of firings of the efferent nerve fibers. The relationship is not as simple as in Figure 3. The organism represented is capable of more complex responses to its environment.

Figure 5



The arrows represent nerves. Those labeled **1** through **5** are afferent fibers. Those labeled **a** through **f** are efferent fibers. The large box represents the brain, where impulses coming up the afferent fibers are translated into impulses traveling down the efferent fibers. The smaller boxes represent substructures within the brain.

In this case, the neural order is arranged hierarchically. Most of the fibers going out of box α are inputs to box β, which receives most of its input from box α. Box α performs low-level classifications, which are then reclassified by box β. The connection from nerve **5** to nerve **f** represents the possibility of pure reflex action even in a relatively complex organism. The two heavy arrows illustrate the possibility that there may be feedback loops within the hierarchical structure of the brain. The organism represented in this figure is capable of more complex behaviors than the organism represented in Figure 4. Increasing the number of nerves and the number of sub-boxes increases the potential complexity of the organism's behavior. For sufficiently complex organisms, mechanistic descriptions of the organism's behavior may fail to communicate as much information as descriptions referring to mental states and categories. While there is a relationship between the pattern of firings of the afferent nerve fibers and the pattern of firings of the efferent nerve fibers, the relationship may be too complex to express in mechanistic language. It may be necessary to refer to what the organism is "trying to do," what it "likes" and "dislikes," and what the organism "remembers" or has "learned."

The set of connections among nerves induces a model of the organism's environment. A model of this sort does not require a central nervous system. Stuart Kaufmann notes that

> complex living systems must "know" their worlds. Whether we consider *E. coli* swimming upstream in a glucose gradient, a tree manufacturing a toxin against a herbivore insect, or a hawk diving to catch a chick, organisms sense, classify, and act upon their worlds. In a phrase, organisms have internal models of their worlds which compress information and allow action. (Kauffman, 1993, p. 232).

Central nervous systems, however, generally permit more elaborate models to guide action. They permit, therefore, more elaborate patterns of action. Hayek recognized that these models are at root *classifications* and that the mind, therefore, is a classificatory device. Kaufmann makes the same point. "I permit myself the word 'classified' because we may imagine that the bacterium responds more or less identically to any ligand binding the receptor, be it glucose or some other molecule" (Kauffman, 1993, p. 233).

Perhaps the key insight of Hayek's approach is that the set of connections creates a classification over sensory inputs. In a simple system an individual nerve firing would induce one invariant response in the organism. If A fires, do x. This simple stimulus-response mechanism constitutes a particular kind of classification of environmental states. If A fires, the environment is in a state that makes x good to do; if A does not fire, the environment is in a state that makes x bad to do. In a more complex system, the behavioral implication of A firing would depend on whether B and C are firing as well. Since there are four combinations of B and C firing or not, the firing of A could induce as many as four different responses of the organism. A system of still greater complexity might have internal states dependent on its history; these internal states would be a further source of variation in the behavioral implications of A firing. In all these systems, the simple and the complex, the intertemporal pattern of nerve firings induces a behavioral response. Such patterned responses of the organism constitute a classification based on ongoing flows of nerve firings that generate a *model* of the organism's environment in the context of a prior interpretation of the environment, what Hayek calls

the "map," that has proved useful in the past. As Hayek mentions, the model reflects the ongoing adaptation of the organism to incoming sensory impulses and thus indicates an anticipatory state to the perceived environment. The "sensory order" is an aspect of this model. Our sensory model of the world tells us that some things are hot and others are cold, some things are blue and others are red.

Relatively complex central nervous systems will operate by "multiple classification." The classificatory structure will be "multiple" in at least three senses. First, the same stimulus may be shunted into more than one taxonomic box at the same time. Hayek gives the example of a signal that might make more than one bell ring (p. 50). Second, as we have seen, the way a signal is classified will depend on what other signals are coming in at the same time (pp. 50-51). Finally, and most importantly, the classes at one level may be grouped to form classes at a higher level. In a system with this property "the distinct responses which effect the grouping at a first level become in turn subject to a further classification (which also may be multiple in both the former senses)" (p. 51). A system of classification that is multiple in this third sense can produce a relatively complex model of its environment. (See Figure 5.)

Hayek says that the interlaced system of connections is build up by experience. In part it is the evolutionary experience of the organism's species that determines the set of connections among nerve fibers. In part, however, it is the organism's individual experience that decides. We consider each process, phylogeny and ontogeny, in sequence.

Natural selection has produced some of rules that govern the brain's activity in response to incoming impulses (Hayek 1952, pp. 102-103). These rules translate afferent impulses into efferent impulses. When an organism happens to be governed by mental rules that give it differential reproductive success, those rules are passed on.[5]

As we have said on another occasion, the simplest version of a central nervous system matching Hayek's description

> would put any impulse cluster into one of two boxes. We might think of one box as carrying the label "go right" and the other "go left." Biological

[5] To be consistent with modern biology, we should speak of "inclusive fitness," not differential reproductive success.

> evolution would tend to select, from among such simple organisms, those whose central nervous systems tended to say "go left" when more nourishing environments existed to the left and "go right" when more nourishing environments existed to the right. Natural selection would tend to favor those spontaneous variations that generated more complex responses ("go left then right") to environmental stimuli. Emergent species would, then, tend to have ever more receptor sites, ever more nerve fibers, ever larger brains, and, in consequence, ever more complex ways of classifying and responding to incoming signals (Butos and Koppl 1997).

The mind is rule governed. According to Hayek, mental activity in the brain uses rules to classify the impulses clusters coming up afferent nerve fibers and it is this classification of impulse clusters that constitutes the sensory order. To perceive, say, "green" is find a certain set of impulses classified by the central nervous system in the same way as others which induce the perception of "green." The experience of "green" is a property of the mind's taxonomic framework, not the external world. If evolution has done its job, however, the classification giving us the experience of color will reflect something worth knowing about the outside world

Roger Shepard (1992) provides good examples of how the physical order shapes the phenomenal order in the course of biological time. Our visual system transforms the continuous variation in the wavelength of light into qualitative changes in color. The phenomenal order of color perception is not like the physical order of continuously varying wavelengths. Our color perception differs from the corresponding phenomena as represented in the physical sciences. In generating this different picture, however, biological evolution favored the emergence of a sensory order that reflected something worth knowing about the world. The salient phenomenal difference between red and green might have evolved so that our ancestors could distinguish wholesome "red" from dangerous "green" fruit. This sharp contrast, as opposed the subtle gradations of a continuously varying scale, might have helped our ancestors to make better choices about what to eat. They would have enjoyed, therefore, a fitness

advantage over others. (Shepard [1992, p. 525] proposes this fruity explanation only as an example of the general idea. His more empirically grounded examples are too time consuming to enter into here.)

The process of natural selection plays a role in forming the organism's set of neural connections. The organism's personal history plays a similar role. The connections that confirm expectations, and thus seem to help the organism, are strengthened and their impact on its behavior grows. The connections that lead to disappointed expectations are weakened and their impact on its behavior shrinks. Here, however, the organism makes its own evaluation of the outcome of any behavior. Instead of differential reproductive success we have, presumably, feelings of "pleasure and pain" governing the process in conjunction with biologically programmed learning algorithms.

Evolution establishes certain connections. Many properties of the set of connections (and perhaps many specific connections) are determined by the history of the organism's species. The history of the individual then operates on these connections at, as it were, a higher level to form higher order classes of connections among nerve fibers. Evolution may also establish a set of possible patterns of connection, implementing one rather than the others on the basis of the organism's personal history. As we shall see, Hayek dodges the question of how much to attribute to evolution and how much to attribute to the organism's individual development. As we have just hinted, it is also probably true that the division between "innate" and "learned" is too neat. If evolution sets out an array of possible developmental paths and if the path taken depends on individual experience, what is "determined phylogenetically" and what is determined "ontogenetically"?

Hayek's view of the mind as taxonomic order follows from the motivating insight of his theory. According to Hayek, "we do not first have sensations which are then preserved by memory, but it is as a result of physiological memory that the physiological impulses are converted into sensations. The connexions between the physiological elements are thus the primary phenomenon which creates the mental phenomena" (1952a,

p. 53). Interpreters often fail to understand this basic insight of Hayek's theory. In the next section we will call this the *pons asinorum* of Hayek's psychology.

Hayek's view of the mind and its evolution implies that the mind is a kind of map of the external world. The map says, for example, that red fruit is good to eat and green fruit is not. In some sense, perhaps, the map is not "true." Some red fruit kills and some green fruit nourishes. If the map was determined phylogenetically, however, it was probably useful to the species, at least in the period in which the model evolved. If the map was determined ontogenetically, it was probably useful to the individual, at least in the period in which it evolved. In many cases, the map results from a combination of ontogenetic and phylogenetic influences as well as, of course, from chance.

Hayek explicitly declined to judge which mental rules were determined phylogenetically and which rules were determined ontogenetically. He says, however, that "as far as the highest centers are concerned," it "perhaps may be justified in some measure" to assume they arise only in the course of the "development of the single individual." Such an assumption, however, "certainly does not apply to the connexions existing at the lower levels, which form and essential part in the complete process of classification" (Hayek 1952a, p. 103).

Interpretation for Hayek occurs as a consequence of the operation of a unified cognitive structure comprised of a mutable but relatively stable "map" reflecting the individual's past experience and a more fluid "model" reflecting the current and anticipated environment (Hayek 1952a, pp. 107-18). The map and the model are not fully separate because the significance of the model comes from its position within the map.[6] As McQuade (2005) notes, the map represents the individual's "previously experienced environment in the sense that it" represents a "classification of the stimuli that have impinged on the system from that environment" while the "pattern of impulses generated in the map by the current stimuli" reflect a "model of the current environment" that is "characteristic not only of the experienced stimuli but also of the usual implications of these stimuli." The map is a something like a set of implications waiting to happen. From this set, the model pulls out the implications relevant to the organism's

[6] Refering to the model and the map, Hayek says, "it will be the position of the former within the latter pattern which will determine the significance of the new impulses" (1952a, p. 116).

current environment. The model is "anticipatory and embodies the system's expectations of likely subsequent stimuli" (pp. XX-YY). Thus, we find in *The Sensory Order* a classificatory process and the resulting interpretation it produces a description of an emergent order generated by a stable framework or map that supports within it an expectational model of the current and anticipated environment.[7] Some aspects of the mind's map are quite invariant for the individual. They are the product of evolution of the species and cannot be altered by the organism's personal experiences. Others are more variable products of the individual's experience.

In the final chapter of *The Sensory Order*, Hayek draws out some philosophical conclusions from his theory. Among them is an argument that the mind cannot explain itself. It is an argument for the existence of logically necessary limits of knowledge. Hayek's argument of the limits to knowledge has important economic implications; we discuss this matter below in Section IV-B and C.

The mind, in Hayek's theory, is a classificatory device. It is characteristic of a classificatory device that is it more complex than any object it classifies. It is more complex in the sense that the number of classes into which it might place an object is greater than the number of such classes that actually fit the object. Consider a device to sort oranges into two groups, small and large. The device has two classes into which it might place any orange. But any orange fits only one of the two classes; it is either large or small, but not both. Hayek's argument is at least similar to Georg Cantor's demonstration that any set is smaller than its power set, as Hayek noted.[8]

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[7] As McQuade and Butos (2005, p.4) put it: "The network of connections … between the component neurons, which changes as a long-term result of the stimulus-induced patterns of activity, effectively functions as a 'map' of the environment as experienced in the past in that it enables the emergence, from a given stimulus, of an induced pattern of impulses characteristic of that stimulus and of other potential stimuli which have accompanied the given stimulus in the past. This pattern of impulses generated in the map by the current stimuli is, therefore, a 'model' of the environment as currently experienced."

[8] Let S be any set, whether finite or infinite. Let P(S) be the set of all subsets of S, including the empty set and S itself. P(S) is the power set of S. Cantor's diagonal argument shows that P(S) is larger than S in the sense that no function from S to P(S) can cover all elements in P(S). Imagine we had such a function, f, and consider the set W in P(S) such that $w \in W$ iff $w \notin f(w)$. Let $t=f^{-1}(W)$, that is, $f(t)=W$. If $t \in W$, then, by virtue of the defining property of W, $t \notin W$. But if $t \notin W$, then, by that same defining property of W, $t \in W$. Thus, $t \in W$ iff $t \notin W$, a contradiction. We conclude that no function from S to P(S) can cover P(S). In this sense, the power set of any set is always bigger that the original set; it has a greater "cardinality."

If the mind is a classificatory device, it can classify only objects less complex than itself. That is, it can give to any object a description ("large" or "small" in our orange example) that has fewer categories than the mind uses in making such a classification. Thus, if a given mind wishes to explain (or describe or model) itself or another mind of similar complexity, then it must simplify. It cannot give a complete explanation of itself because it cannot be more complex than itself. We can fully explain only phenomena that are simpler than ourselves. When we turn to more complex phenomena, we can give only relatively vague or general explanations. Our models of complex phenomena simplify. For them, we must content ourselves with an "explanation of the principle."

Note that the limit to our knowledge that Hayek shows us is not merely that of some "bound" to our calculative prowess. It is a logically necessary limit that would exist even if our rationality were infallible. We address the economic significance of this self-reflective character of Hayekian ignorance in Section IV-B below. In addition, because of this logical limitation of the mind to explain itself, there must always exist mental processes which it can never fully explain or articulate. Thus, Hayek's theory establishes the cognitive basis for tacit knowledge. Aside from relocating rationality to be more than a fully specifiable and explicit characteristic of cognitive functioning, the idea of tacit knowledge also carries momentous implications for the economic system's capacity for coordinating individuals plans, given that some part of each individual's knowledge is necessarily tacit.

Our overview of *The Sensory Order* has been very brief. A more detailed account of our understanding of Hayek's cognitive theory will emerge in the sections to follow where we criticize some interpretations of it with which we disagree and apply Hayek's theory to questions in methodology and economic theory.

III. Some Common Errors of Interpretation of *The Sensory Order*

A. Misinterpretation I: The Pons Asinorum of *The Sensory Order*

A *pons asinorum*, literally, "bridge of fools," is any concept or problem difficult for beginners to master. The term once referred principally to Euclid's fifth proposition, namely that the angles at the base of an isosceles triangle are equal. Beginners struggle greatly with this problem. It is the problem you have to master at the start of your study of Euclid. Until you have crossed the *pons asinorum*, you have not properly entered the field and you cannot yet form independent opinions on the subject.

As we indicated earlier, Hayek's psychology has a *pons asinorum*. The central insight of Hayek's theory has proved too much to master for many would-be critics, exponents, and commentators. Recall our quote from Hayek: we "do not first have sensations which are then preserved by memory, but it is as a result of physiological memory that the physiological impulses are converted into sensations. The connexions between the physiological elements are thus the primary phenomenon which creates the mental phenomena" (1952a, p. 53). Memory precedes perception. Hayek plainly labels this idea "the central thesis" of his book (p. 52).

Often, Hayek is taken to offer the opposite view, which appeals more to intuition and common sense. We have sensations, experiencing, perhaps, "green" or "warm." These sensations are stored away in memory. The mind then sets to work on these stored memories and abstracts classes of objects. The concrete comes first, the abstract later. Perception precedes memory. Hayek, however, explicitly rejects "the traditional view" that "experience begins with the reception of sensory data" which "form the raw material which the mind accumulates and learns to arrange in various manners" (p. 165). "Every sensation," Hayek notes, "even the 'purest', must . . . be regarded as an interpretation of an event in the light of the past experience of the individual or the species" (p. 166). For Hayek, the abstract comes first, the concrete later. He even wrote an essay on the point called "The Primacy of the Abstract" (Hayek 1969).

Hayek's idea of the primacy of the abstract is similar to the idea of Kantian categories. The great philosopher Immanuel Kant argued that our experiences of the

world require prior ideas or "categories" such as space, time, and causality. We cannot interpret any observation as "this causing that" unless we are already equipped with the "category" of cause-and-effect.[9] Hayek's "physiological memory" acts like Kantian categories, but there are important differences.

The categories of our mind are shaped by our philological and ontological history. Thus our "synthetic *a priori*" ideas are not fixed for all time. All people share some ideas and mental rules because they were crafted by the evolution of the species. These aspects of mind are our common heritage. They are variable in biological time, but not in historical time. They cannot be expected to change much, if at all, over a relatively short span of time such as five or six thousand years. But over longer stretches, say 100,000 years, they are more malleable. Let a few million years pass and they are more malleable still. The more malleable ideas and mental rules seem less like Kantian categories and more like the products of induction. They are parts of the organism's "map" and thus seem "*a priori*," but they emerge from personal or cultural history and thus seem "*a posteriori*." Nishiyama (1984) argues that Hayek breaks down the very distinction between *a priori* and *a posteriori*.

For Kant, "necessity and strict universality" are the "infallible tests for distinguishing" knowledge *a priori* from knowledge *a posteriori* (Kant 1787, p. 26 [section II of "Introduction"]). But if Hayek's theory of mind is right, then what we know *a priori* might be false or at least contingent. The qualitative distinction between green and red, for example, reflects nothing in the spectrum of visible light. The stick in the water looks bent, though we know it is not.

A third example shows that our "knowledge" may exist in unexpected forms. Different cultures have different incest taboos. But some prohibitions seem to be universal, including the prohibition of intercourse between siblings.[10] The psychological mechanism that enforces the taboo is imperfect, however. Sufficient proximity between very young children will prevent them from acquiring sexual desires for each other later in life. Children raised together on Israeli kibbutzim almost never marry. We "know"

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[9] Among the many introductions and overviews the reader might consult, see "The Internet Encyclopedia of Philosophy" article on Kant's metaphysics, available at http://www.utm.edu/research/iep/k/kantmeta.htm.

[10] The sibling marriages between Ancient Egyptian leaders does not seem to be a genuine counter-example.

that it is dangerous to produce offspring with people with whom we were in very close contact at early ages. This "knowledge," however, is not perfectly correct.

B. Misinterpretation II: *The Sensory Order* is not subjectivist

A "subjectivist" traces all explanation in the social sciences back to the "subjective" mental states of social actors. These subjective states are not necessarily the only causes at work. Other factors certainly enter. The subjectivist, however, always checks to be sure that his theories and models are consistent with a normal human understanding of real people. Would a real person really do that? If so, the theory might be true. If the theory imputes to anyone implausible thoughts, motives, or actions, then the theory is rejected as false or improbable.

It is sometimes argued that in *The Sensory Order* Hayek abandoned subjectivism or at least adopted a weaker form of it. Caldwell (2004a, p. 362), for example, argues that Hayek's evolutionary turn in the 1950s involved his de-emphasizing or even displacing methodological dualism by complexity theory.[11] In this interpretation, *The Sensory Order* marks Hayek's move out of a relatively hermeneutic subjectivism to which he had been increasingly turning and into a distinct "scientific subjectivism" (p. 260) based on his theory of complexity. Caldwell (2004b) explains that Hayek reacted to the criticisms by Nagel and Popper of his "scientism" essays to move away from methodological dualism to the simple versus complex division because "his earlier distinction, based on the traditional natural science – social science division, did not fit well with the prevailing philosophy of science of the day" (p. 249). This methodological issue is briefly addressed below (see Section III-C), but suffice it to say here that while we agree that Hayek interests did indeed turn toward the theory of complexly organized phenomena, there is no compelling evidence suggesting that Hayek rejected methodological dualism or, indeed,

[11] Vanberg (2004) also cites Hayek (1952a) in arguing that Hayek rejected methodological dualism. Unlike Caldwell, however, Vanberg provided a definition of the term and under the definition he chose Hayek was indeed not a methodological dualist. According to Vanberg, methodological dualism is "the claim that the nature of its subject matter, namely purposeful and intentional human action, requires economics to adopt a methodology that is fundamentally different from the causal explanatory approach of the natural sciences" (p. 157). We prefer a more mild definition, according to which methodological dualism is simply the repudiation of any "reductionism" that attempts to link specific actions to specific "objective" causes. We think this is the version of the doctrine defended by Mises and Hayek.

that such a rejection is required. In fact, once we accept that mind is itself a self-organizing complex phenomenon, we have to acknowledge that our theories of agency and social phenomena cannot pretend to somehow "reduce" subjective descriptions of human action to "objective" descriptions. Doing so would require our assuming that individuals are nothing more than simple clockwork automatons whose subjective states might well be represented by simple algorithms. As Koppl (2005) points out: "What Hayek discovered with complexity was not a path out of methodological dualism and into science, but a scientific defense of methodological dualism."

The Sensory Order may seem to deviate from subjectivism because of its scientific style and purpose. If the reader will stay with it until the end, however, he will discover a ringing endorsement of subjectivism in the book's final chapter on "philosophical consequences." There, Hayek explicitly defends "*verstehende* psychology" (p. 192). "In the study of human action," Hayek says, "our starting point will always have to be the direct knowledge" of "mental events" (p. 191). We "use our direct ('introspective') knowledge of mental events in order to 'understand,' and in some measure even to predict, the results to which mental processes will lead in certain conditions" (p. 192). Hayek calls this an "introspective psychology" which takes "our direct knowledge of the human mind for its starting point" (p. 192). Hayek could hardly be more explicit or more thoroughly subjectivist.

C. Misinterpretation III: *The Sensory Order* violates methodological individualism

Barry Smith (1997) and others have argued that Hayek's theory of mind is inconsistent with methodological individualism. In Hayek's psychology, Smith believes, there is no "room for planning, for self-control and for the deliberate self-shaping of the conscious subject." Hayek breaks "the connection . . . between reason, choice and action."

Smith seems to neglect Hayek's (1952a, pp. 191-194) explicit defense of methodological dualism. "The conclusion to which our theory leads," Hayek argues, is that although the mental activity is "produced by the same principles which we know to operate in the physical world, we shall never be able fully to explain [them] in terms of

physical laws" (p. 191). In some sense, perhaps, Hayek's theory is "reductionist." But it shows us that any reduction of the mental to the physical can be made only "in principle." We cannot describe thought and action without using words such as "plan" and "purpose." The concluding paragraph of *The Sensory Order* may be worth quoting in full.

> Our conclusion, therefore, must be that *to us* mind must remain forever a realm of its own which we can know only through directly experiencing it, but which we shall never be able fully to explain or to 'reduce' to something else. Even though we may know that mental events of the kind which we experience can be produced by the same forces which operate in the rest of nature, we shall never be able to say which are the particular physical events which 'correspond' to a particular mental event. (1952a, p. 194)

Hayek's methodological dualism vindicates our use of the language of planning and purpose, which Smith curiously imagines to be inconsistent with Hayek's theory of mind.

Perhaps Smith and others have neglected Hayek's discussion of "Mechanical and Purposive Behaviour" (pp. 122-127). The point of this discussion is that the sort of system he describes will not behave in a "mechanical" way even though each principle of its operation looks perfectly "mechanical" in isolation. A system's behavior is "mechanical" if it responds in similar ways to similar stimuli.[12] Your car always goes forward in drive; it never "decides" to go backwards. A mechanism, Hayek points out "cannot 'purposively' adapt its operations to produce different results in the same external conditions." A mechanism "is essentially 'passive'" because its actions depend only on "external circumstance" (1952a, p. 122). People and many other animals are not mechanisms. They learn new behaviors. They make similar responses to dissimilar stimuli and dissimilar responses to similar stimuli. This extra-mechanical behavior is just what you would expect from a system built on the 'mechanical' principles Hayek describes. Such a system, Hayek explains, "will, as a result of its own operations,

[12] "By a 'mechanism' or a 'mechanical process' we usually understand a complex of moving parts possessing a constant structure which uniquely determines its operations, so that it will always respond in the same manner to a given external influence, repeat under the same external conditions the same movements, and which is capable only of a limited number of operations" (Hayek 1952a, p. 122).

continuously change its structure and alter the range of operation of which it is capable." Indeed, continues Hayek, it "will scarcely ever respond twice in exactly the same manner to the same external conditions." It will learn "entirely new actions" and look "self-adaptive and purposive." It will be "active" because "the character of its operations" at any point in time will be determined by both "the pre-existing state of its internal processes" and "the external influences on it" (pp. 122-123).

In an adaptive system of the sort Hayek describes, "mechanical" principles of operation produce non-mechanical behaviors in part because the system engages in multiple classification of its environment. Each stimulus invokes many responses, some of which may be mutually incompatible. The system typically executes a self-consistent subset of them, which subset is determined by a process of higher-level reclassification. Each novel subset represents a new action for system. The system's "model" adapts in response to experience. This adaptation causes the "same" stimulus to produce one response on one occasion, another response on another occasion. The child tries to touch the flame once, but not twice. This underscores the fact that *The Sensory Order* offers a theory of learning in the sense of an individual's ability to adapt to the external environment and in the sense of his capacity to generate new knowledge about the environment.[13]

D. Misinterpretation IV: *The Sensory Order* describes ontogenetic development, not phylogenetic development

Many scholars neglect the role of biological evolution in Hayek's psychology. Smith (1997) and Khalil (2002) are examples. They imagine that the connections and classifications Hayek describes are a result of ontogenetic development only. They are, however, the result of both phylogeny and ontogeny. Here again, Hayek has been perfectly explicit.

Hayek's brief statement of his theory comes in his second chapter, "An Outline of the Theory." The fifth and last section of that chapter is entitled, "The Central Thesis."

[13] Butos and Koppl (1999) develop this point to suggest that Kirznerian "alert entrepreneurs" may be modeled as "Hayekian learners."

There, Hayek says explicitly that the system of connections to which he appeals in explaining the sensory order "is acquired in the course of the development of the species and the individual by a kind of 'experience' or 'learning'; and that is reproduces, therefore, at every stage of its development certain relationships existing in the physical environment." The structure of mental life is determined by *both* phylogenetic *and* ontogenetic development.

If we recall that the immediate object of Hayek's study is, again, the sensory order, the role of biological evolution is clear. The sensory order that gives us sights and sounds obviously depends on the existence of specialized organs such as eyes and ears. These are products of phylogeny.[14] Hayek refers to biological evolution throughout the book. He thinks it likely, for example, "that, in the course of evolution, the original direct connexions between particular stimuli and particular responses are being preserved, but that control mechanisms are being superimposed capable of inhibiting or modifying these direct responses" (p. 85). If they are sufficiently complex, the operation of such "control mechanisms" is called "thought"! Parallel to this mental development "a similar organization will operate on the motor side" (p. 86).

The impression that Hayek refers only to ontogeny and not phylogeny may owe something to the fact that Hayek is not interested in determining how much weight to give each factor. At the time Hayek was writing, there were probably insufficient grounds for deciding the relative importance of phylogeny and ontogeny in determining mental function. As Hayek (1952a) says:

> But as we are concerned with the genesis of mind as such, it is comparatively unimportant what for the individual are constitutional and what are experiential factors; indeed, it is at least likely that what for one species or at one developmental stage may be of experiential origin, may in other instances be constitutionally determined. What is important for our purposes is that it would appear that the principle which determines the formation of the mental order may operate either in the ontogenetic or in phylogenetic process" (pp. 102-103).

[14] We do not imply, however, that the organs are sufficient for a sensory order to exist. See Hayek (1952a, pp. 83-84).

As this passage suggests, Hayek dodges the issue because its resolution does not alter the fundamentals of his theory.

E. Misinterpretation V: *The Sensory Order* explains personal paradigms

Khalil (2002) suggests that Hayek's cognitive theory is about the development of "personal paradigms." Hayek did recognize that different people have different mental maps and models. This follows from the simple fact that individual experience plays a role in shaping them, but we believe it is worth remembering that the book's title refers to the sensory order, not to "personal paradigms." According to Khalil, the role of such paradigms is to "fashion sensory input after itself" in that "cognition partially depends on one's mental matrix or one's world view" (p. 334). While Khalil is correct to note that the "mind is not a mirror," he claims that "the mind appropriates the world according to already made classes of objects and relations" (p. 334).

The infelicity of his terminology becomes apparent once we recognize that *The Sensory Order* provides a way to understand cognitive functioning as the operation of an adaptive classifier system (see below, Section IV-D). That is, it describes a system that engages in self-organizing activity that reconstructs those classes of objects and relations in response to external stimuli and the correspondence of such activity with a changing external environment. We are not aware of the *The Sensory Order* describing this process as one that depends on an individual's "world view."

Hayek's cognitive theory explains how we could all have the same basic mental structure. We have the same biological history. As we have seen earlier, Hayek's theory redeems "*verstehende* psychology." We can understand each other because we have more or less the same mental make up. Hayek's cognitive theory supports an argument against "polylogism," the doctrine that different cultures have different logics.

IV. Ok, You've Read *The Sensory Order*. So What?

A. *The Sensory Order* and the Hayekian Research Program

Credit for the resuscitation of *The Sensory Order* should probably be given to Weimer (1979). From his perspective as a cognitive psychologist Weimer drew attention to the theoretical coherence of Hayek's psychology and, as importantly, identified its methodological and epistemological significance in terms of broader social theory. Despite the recognition Hayek's cognitive theory has received from outside economics by scholars such as Gerald Edelman, Joaquin Fuster and Edward Boring, its influence for researchers in economics and the social sciences must be described at best tangential. It is certainly true that we have witnessed a recent explosion in America and Europe of "Hayek studies." And this renewed interest in Hayek's work has sustained a research program that continues to yield advances in our understanding of many areas in social theory. As astonishing as this Hayekian renaissance has been, however, the significance of his cognitive work for the social sciences seems far less established. We believe that this lacuna (or possibly neglect) within the social sciences is surprising and unwarranted.

Leland Yeager's (1984) short essay highlighting certain connections between *The Sensory Order* and *The Road to Serfdom* was probably the earliest published treatment of its kind from the rank of economists. Unfortunately, it seems to have had no real impact on other economists. By the early 1990's, however, a few researchers (apparently unaware of Yeager's article) published papers that indicated a newly emerging appreciation for Hayek's cognitive work (see, for example, Streit 1993, Butos and Koppl 1993). Since then, a steady but small stream of papers have been published on Hayek's cognitive theory. The principal paths of this work concern insights from *The Sensory Order* for methodological issues (for example, Birner 1999), the theory of economic expectations, and more recently the mind and market as Hayekian adaptive classifier systems.[15]

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[15] Several other recent developments, which deserve special treatment but which are not discussed here, suggest increased interest in Hayek's theory of mind. Vernon Smith's Nobel lecture makes extensive reference to it and to the "neuroeconomics" of Kevin McCabe and others. A widening Interest in *The Sensory Order* is demonstrated by a 2003 conference sponsored by the American Institute of Economic Research that brought together scholars from neuroscience, psychology, and economics, including Gerald Edelman, D. North, V. Smith, Richard Posner, and other luminaries to discuss the contributions of Dewey and Hayek for embodied cognition. The term "cognitive economics" is used by a group of Italian researchers associated with

B. Observations on the Methodological Ramifications of *The Sensory Order*

Hayek wrote extensively on the methodology of the social sciences and even though a cursory account is beyond our purview here, some general remarks seem to be in order. His *Counter-Revolution of Science* (1952b), which is perhaps his most important work in this area, brought to the fore the special kinds of problems social science inquiry presents. The book principally explores the pitfalls of scientistic approaches in which methods suitable for the study of phenomena in the hard sciences (such as physics) are erroneously thought to also apply to social phenomena. One of Hayek's most enduring insights was to connect scientism, which he argued constituted a methodological abuse of reason, with constructivist rationalism, which he considered a flawed epistemological position about the individual's capacity to know.[16] This enabled him to produce an integrated and compelling philosophical position regarding the possibilities and limits of what social scientists and social reformers are likely to achieve as well as a base from which to argue for the often neglected advantages of spontaneous, self-organizing liberal institutions. The critical advance made by *The Sensory Order* in regard to Hayek's philosophical position is that it establishes a *cognitive* basis for the epistemological argument against constructivist rationalism and the methodological argument against scientism.

The Sensory Order is a multi-dimensioned and complicated work that speaks to a variety of insights. Earlier, we referred to it as a response to the mind-body problem. But on another level it can be seen as a cognitively based theory of epistemology in which constraints on individual knowledge form a principal motif. As noted above in Section II, Hayek argues that in the mental realm what we know about the eternal world is an *interpretation* constructed by our cognitive classificatory apparatus. Sensory inputs are channeled by a "system of rules" that arrange these inputs to form a stable (yet mutable) structure of connected, lattice-like pathways. Because these inputs are classified according to pre-existing categories, their meaning is necessarily relational in terms of certain qualities

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Salvatore Rizzello, author of *The Economics of the Mind* (1999). These scholars cite *The Sensory Order* as an important foundation for their work.

[16] See, for example, Hayek's essays "The Theory of Complex Phenomena" and "Rules, Perception and Intelligibility" in *Studies* (1967) and "The Errors of Constructivism" and "The Pretence of Knowledge" in *New Studies* (1978).

its shares with previous inputs and not with the characteristics of external things in and of themselves. That is, in Hayek's theory we can never know things as they really are, but only in terms of the categories we have inherited from our biological development and those we have individually formed experientially. For Hayek, then, precise yet unspecifiable constraints exist on what an individual cognitively can know, and these constraints, reflecting the relational quality of perception and the very structure of the classificatory categories, enter at the foundational level of cognitive functioning.

The epistemological basis for Hayek's constraints on knowledge argument also emerges from his argument that knowledge is embedded in tacit rules. Recalling that for Hayek knowledge is an interpretation generated from the classificatory functioning of the mind, the sorting rules that govern the pathways along which any sensory input will be channeled are integral to overall cognitive functioning. As we consider higher order mental activity, the rules governing these processes must themselves become more complex and nuanced. Hayek's argument requires that as a logical matter these rules must at some point become tacit or inarticulable. For all skilled operations, from piano playing to pitching a baseball to generating new ideas, cognitive functioning involves repertoires so deeply internalized that the performer cannot fully describe them or account for how the observed behaviors are actually produced. The concert pianist's fingers fly across the keyboard in ways they could not happen if each note were consciously played. The everyday observed manifestations of tacit knowledge, like riding a bicycle or the intuitive shortcuts medical diagnosticians sometimes excel at, reflect the constitutionally constrained ability of our mind to fully explain itself. Hayek's argument of the division of knowledge in the context of how markets work and of alternative institutional arrangements (such as central planning) is justly famous. Less well-understood, however, is the particular innovation of *The Sensory Order* in establishing the significance of such constraints at the cognitive level. In so doing, Hayek provided an argument that carries important implications for the limits on what we as individuals can know and explain.

In terms of the explanatory power in the social sciences, Hayek maintained that for phenomena in this realm, the best we can do is to garner predictions of patterns. The physical sciences, Hayek pointed out, enjoyed the capacity to produce highly precise predictions of the values of variables not because they were more advanced, but because the

phenomena they dealt with was simpler than that of the social sciences. This insight, as noted earlier, lead Hayek to rail against the hubris of the social sciences in trying to cloak themselves in the mantle of the physical sciences. These methodological precepts provided Hayek with a strong integrating argument permeating much of his social theory. In addition to the implications of the constraints on knowledge argument for comparative institutional analysis, it is also clear that strong linkages exist between his methodology (and its foundation within *The Sensory Order*) and his interest in complexly organized adaptive phenomena.

C. *The Sensory Order* and Expectations[17]

Hayek's cognitive theory provides an account of the *generation* of knowledge that permits the individual to achieve a closer fit with external reality. At the same time, it sustains a perspective in which creativity and novelty are essential aspects of cognitive functioning. Thus, the flip side of the Hayekian "constraints on knowledge" argument is one in which cognitive activity encompasses emergent properties similar to all adaptive-classifier systems.[18] This aspect of *The Sensory Order* carries implications for applications in economic theory.

In terms of the knowledge constraining perspective typically associated with Hayek, the cognitive problem Hayek sets out to resolve is identical to the social problem he has addressed over the years: how do complex phenomena like the mind and markets resolve inherent limitations on knowledge?

In the cognitive domain the individual's construction of a coherent interpretation of reality, both as it is and as it might be, emerges from rules governing the operation of the mind. This interpretation, as Hayek points out, is incomplete and thus the behaviors it supports will not generate full conformity and compatibility with the environment. The "restlessness" which motivates action thus has an epistemological basis in Hayek and helps to bring into sharper relief the necessity of learning and acting by trial and error. The Hayekian view of expectation formation (unlike Simon) emphasizes the individual as a

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[17] This section draws on more detailed treatments in Butos and Koppl (1993, 1997) and Butos (1996)
[18] See Butos and McQuade (2002, p, 123ff). We discuss adaptive classifier systems in greater detail in Section IV-D below.

complex phenomenon functioning in a complex social environment. And in both domains the order that emerges is a byproduct of the rules that are followed.

The main elements of a Hayekian theory of expectations involve four central points. First, expectations are formed in the context of ignorance about reality. The epistemological uncertainty in Hayek's theory is not simply (and in some sense, trivially) a result of uni-directional calendar time, as emphasized by Shackle and Lachmann, but also a result of abstract and inherent constraints on what can be known cognitively. The mind constructs a representation of the external world that is necessarily incomplete. Second, an individual's expectations derive from a knowledge-generating classificatory apparatus. The mind constructs theories of reality by organizing and interpreting sensory data. Such rules operate at the conscious and tacit levels of cognitive activity. Expectations are formed as a result of rule-governed creativity.

Third, cognitive activity functions as a mechanism of adaptation. A "goodness of fit" criterion permits the individual to appraise the usefulness of theories of reality and the expectations they generate. Disappointed expectations induce revision. Expectations are self-corrective and forward-looking in that inappropriate expectations at the individual level are subject to a weeding out process. And fourth, expectations are formed endogenously as a necessary consequence of the role which sensory inputs play in Hayek's cognitive theory. Hayek's theory does not cast individuals as cognitive islands who can step outside themselves epistemologically or divorce themselves cognitively from the wider social reality they not only inhabit but to which they must also adapt. Thus, expectations will ordinarily correspond to the habits, practices, norms, and traditions of the society or, in other words, to the social rules governing action. For Hayek, these rules are products of social and even, in the case of the sensory order, biological evolution. In this evolutionary view actions and expectations have a tendency toward coherence and coordination.

Our discussion has attempted only to outline in a highly abstract manner the general principles of an Hayekian theory of expectations. If, as has been argued above, expectations are rules of action geared toward an individual's successful adaptation to the environment, then the rules that are selected and employed will bear some correspondence to the environment. Individuals' expectations and behaviors are thus situationally endogenized by virtue of individuals adapting behavior to the existing "filtering conditions" or social rules of

the game. Consequently, market outcomes will be generated that are not only unintended but, depending on these filtering conditions, also may be disorderly and arguably undesirable (see Butos and Koppl 1993, 1997).

D. Knowledge-Generating and Adaptive Classifier Systems

As we have seen, *The Sensory Order* provides an account of a particular adaptive classifier system – the central nervous system – that produces a *classification* over a field of sensory inputs. Other systems may be analyzed in similar terms. In particular, the market economy may be viewed as an adaptive classifier system. In using the term "adaptive classifier system," we are extending John Holland's (1976, 1992) conception of "classifier systems" which refers to "a vehicle for using genetic algorithms in studies of machine learning" (1992, p. 171). Yet, there are relevant distinctions to be maintained between an adaptive classifier system as used to describe the central nervous system and those adaptive systems of interest to researchers in artificial intelligence. As noted by McQuade (2005, p. XX), Holland is "dealing with systems whose adaptive capability… arises because its components are subject to a form of selection" whereas adaptive classifier systems are those "in which the component interactions result, as a side effect, in a form of structural self-organization that is the basis for the adaptive capability." We use the term for any set of interacting elements that may be reasonably thought of as forming an adapting system with defined capacities for learning.

Adaptive classifier systems can be studied from the perspective of the knowledge they generate and embody. In this connection, Hayek's theory of mind contains two related but distinct elements: first, our knowledge of the external world is always an interpretation and second, this knowledge has been constructed by the brain. The former draws attention to the inevitably of our ignorance, i.e., the idea that necessary, though unspecifiable, constraints exist on what we can know, while the latter highlights the generative properties of cognitive functioning as a creative process capable of exhibiting emergent characteristics. Both elements, we hold, are essential for developing a fuller appreciation of the richness of Hayek's contributions. In particular, we wish to suggest that the fecundity of *The Sensory Order* in this latter sense has not yet been fully grasped by Hayekian scholars and social

theorists and thus remains one of the important underdeveloped areas of Hayek scholarship.[19]

As noted earlier, *The Sensory Order* provides an account of a particular adaptive-classifier system – the central nervous system – that produces a *classification* over a field of sensory inputs. The specific form and character of this classification depends in Hayek's theory on the configuration of the pathways and sorting mechanisms by which the brain organizes itself. But this classificatory structure enjoys a certain plasticity or mutability that reflects the capacity for adaptive responses by the individual in the face of the perceived external environment. Positive and negative feedback helps to maintain a rough consistency between behavior and the actual environment. The way an individual responds to external conditions is fully dependent upon the particular classifications he generates, which is to say that for Hayek individual knowledge is the adaptive response of an individual based on the classification the brain has generated. In short, sensory inputs are transformed via the mechanisms of the brain into an output – a particular classification that we call knowledge embodied in adaptive behavior.

For human cognitive functioning, we also recognize that this process (though necessarily involving in Hayek's theory tacit rules and mechanisms), has the capacity for self-conscious and reflective activity, thus providing substantial scope for critical, argumentative, and self-reordering properties. Thus, the implicit story contained in *The Sensory Order* is that individuals are not mere processors of information, passively responding to stimuli. Instead, Hayek teaches us that cognitive activity, despite being constrained by rules and its own physiology, should be understood as an active, input-transforming, knowledge-generating adaptive system. The cognitive problem Hayek deals with is not about how knowledge is harvested or discovered, but with the process of its generation. While Hayek's treatment of the knowledge problem in the catallactic domain clearly emphasized the discovery and use of decentralized knowledge, his treatment of knowledge in his cognitive work should be seen as an account of its

[19] Thomas McQuade has been instrumental in developing this line of inquiry. Scholarly treatment of *The Sensory Order* has principally centered on its relevance for Hayek's own development and its connections to his methodology (see, for example, Streit 1993, Birner l997, Horwitz 2000, Caldwell 2004a) in contrast with the direction pursued by Butos and Koppl (1993), McQuade (2000, 2005) and McQuade and Butos (2005) that has sought to develop and apply insights of *The Sensory Order* to economics.

generation. The intriguing question that *The Sensory Order* raises is whether its insights can be applied to the social domain.

This might be approached by noting that specific capacities for classification and the possibility for higher cognitive functions obviously differ across different kinds of organisms and, thus, for different kinds of adaptive-classifier systems. The suggestion being advanced here, then, is really two-fold: first, it seems sensible to recognize that the capacity to produce knowledge in the sense of generating a classification over a range of inputs is not a uniquely human characteristic, and second, that we should expect classificatory capacities to differ across entities dependent on their structure, complexity, and other characteristics associated with their adaptive capabilities (see Kaufmann 2000, especially pp.114-116). As Plotkin (1994, p, 229) notes: "The fleshy water-conserving cactus stem constitutes a form of knowledge of the scarcity of water in the world of the cactus." Once we move beyond a conception of knowledge in our social science that confines its significance to human cognitive functioning, a pathway opens up that helps us to understand social orders from a perspective rooted in the theory of complex adaptive systems, or more specifically of the theory of "knowledge-generating orders" This approach is entirely consistent with Hayek's cognitive theory by virtue of associating knowledge with adaptive responses and has been developed with particular insight by Thomas McQuade's work on adaptive classifier systems and knowledge-generating orders (see McQuade 2000, 2005; McQuade and Butos 2005).[20]

Such a conception sees the production of knowledge as an emergent property of adaptive systems and contingent on the context from which it was generated. The human mind is one such system and it produces a particular kind of knowledge specific to it. But other kinds of adaptive systems, from relatively simple ones (such as the cactus Plotkin mentions) to the more complex (such as the human mind) will be expected to generate different kinds of knowledge depending on their structures and functional properties. Accordingly, it would seem useful to model different kinds of knowledge-generating orders for the purpose of analyzing their capacities for generating knowledge of a particular kind and other adaptive and emergent properties. Of particular interest to

[20] Applications of the mind as a knowledge-generating order are directed toward, respectively, a Kirznerian view of the entrepreneur and the Keynes-Hayek debate in Butos (2003, 2004).

economists is the market order, understood as a framework for agent interaction under certain institutional arrangements regarding the exchange of property rights in which a particular kind of classification is generated as market outcomes, principally in the form of prices. The opportunity would seem to exist to apply this "sensory order" perspective to the analysis of different social arrangements and structures beyond the typical Austrian question of the discovery and use of knowledge and toward questions concerning the generation of knowledge understood as emergent characteristics of such social structures (see, for example, "Big Player" theory in Koppl 2002 and Koppl and Yeager 1996). Within the social realm, complex routines and feedback mechanisms require us to see such orders as not simply aggregations of agents and their capacities, but as involving a transformation of individual knowledge into a unique kind of social knowledge that could not have been otherwise produced. One way to state this is to observe that only the market order can generate market prices. This points to a different approach in understanding the role and implications of different institutional arrangements, but it is an approach very much in keeping with insights gleaned from Hayek's cognitive theory.

E. Further Developments: The Economics of the Mind

Salvatore Rizzello's *The Economics of the Mind* (1999) is perhaps the first full length study that explores the cognitive approach to economics from a perspective explicitly based on what he calls the "neurobiological" work of Hayek and the 'psychological" analysis of Simon. In calling for a reappraisal of Hayek's *The Sensory Order* in terms of deepening our understanding of individual rationality and behavior, the role and formation of institutions, and the economics of path-dependency, Rizzello provides yet another voice from within the ranks of contemporary economists that draws on Hayek's cognitive theory. In particular, he has been inspired to explore the "economics of complexity, creativity, and uncertainty, i.e., the economics of the mind" (p. 168). Rizzello aims to use cognitive theory to provide a more carefully worked theory

of agency and then to use that platform to construct (or modify) an economics suitable for studying organizations, institutions, and market processes in an evolutionary context.[21]

We are encouraged by Rizzello's work and the impetus it is likely to provide for applying Hayek's cognitive theory to economics. Identifying and especially demonstrating the usefulness of such connections has proven difficult and the work that has been done in this regard has often been met with skepticism from other Hayekian scholars.[22] All the same, the ongoing work of Rizzello and others has without question added a far richer texture to our understanding of the individual than available from mainstream work. The fault lines, it seems to us, principally occupy those intersections where the objective is to move beyond the level of the individual to that of many interacting individuals and the institutions that arise at such levels. While there are, as Rizzello and others suggest, connections and analogies between a cognitive-based theory of the individual and the social nexus, the precise ways that such connections matter and the implications they carry for social theory are not as clearly spelled out yet. Thus, in following Rizzello, although we may identify in Hayek's work a kind of "cognitive path-dependency" arising from the interactions between the relatively fixed "map" and the more fluid "model," it is not quite obvious why we require this theory to understand market level path-dependence or, more generally, how the cognitive theory specifically generates a coherent theory of social institutions.[23] As Hayek himself argued, we enter a far more complex realm once we move from an isolated individual to many interacting individuals. The analytical problems this creates for the social theorist are not aggregative or additive ones, but perhaps ones best understood as problems in complexity, whereby complex minds with the capacity to generate emergent characteristics interact in various ways and in so doing generate highly complex

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[21] Also see Rizzello and Turvani 2000; Rizzello (2004).

[22] In commenting on the theory of Hayekian expectations in Butos and Koppl (1993), Garrison (2001, p. 24) impishly pokes fun at the neurobiological approach that Rizzello (and others) find useful. As we and Rizzello make clear, the physio-chemical processes of cognitive functioning are not germane to questions of interest to economists but the *results* of those processes in the form of cognitive outputs, i.e., the classifications that individuals generate, are. This is why Garrison's flippant, though amusing, critique is irrelevant. Caldwell (2004a), perhaps motivated by an essentially methodological take on *The Sensory Order* and despite a favorable tip of the hat to Rizzello (and the "neuroeconomics" work of Kevin McCabe), is also curiously hesitant about the relevance of Hayek's cognitive work for economics, although he admits that this recent position is different in unnamed ways from earlier beliefs (see n. 7, p. 270).

[23] See Rizzello (1999), especially Chs. 3, 11, and 13.

structures and institutions also having emergent characteristics. That economists interested in such questions should also have available an articulated and increasingly well-regarded literature from cognitive psychology is simply a fortuitous byproduct of the fertility of Hayekian ideas whose full impact in this area is probably not yet fully realized. Much work, in short, remains to be done.

V. Conclusion

It has been over a quarter of a century since the second "Hayekian Revolution" was jump-started with his award of the Nobel Prize in Economics. The renewed interest in Hayek has been a worldwide phenomenon, attracting a large and steady flow of scholarly articles, books, and conferences from economists and other social scientists. Strangely, *The Sensory Order*, what may be one of Hayek's more prescient contributions, remains generally underappreciated. We do not offer an explanation for this neglect, noting that even the highly acclaimed recent study of Hayek by Bruce Caldwell (2004) also sees its economic significance largely confined to certain methodological problems. We believe, contrary to this mainstream view, that current Hayekians are wrong to think that the value-added of Hayek's cognitive theory has been more or less fully realized. In this paper we have tried to highlight what we take to be the principal seminal contributions of *The Sensory Order*.

In doing so, we hope to have clarified some directions in which Hayek's insights may be further developed. There may be others. Our emphasis on Hayekian expectations originates from our firm belief that any theory of the market process requires some kind of articulated theory of learning. In the absence of same, it seems difficult, if not *ad hoc*, to make claims about the conditions under which markets will tend or not tend toward the coordination of individual plans. While it is certainly possible that other theories of learning may contribute to our understanding of the market process, Hayek's approach seems well-suited to addressing such matters at the cognitive

level, as opposed for example to those, such as ones based on Popperian insights, that view learning from a methodological vantage point.

We have also suggested that Hayek's cognitive theory provides an explicit model of a knowledge-generating order. This carries potentially important implications in two senses. First, it requires viewing individual agency in decidedly active terms. Once we begin to conceive of individuals with knowledge-generating capacities, human behavior can no longer be viewed in simply passive and responsive terms. In moving to the social level, the idea of a cognitive knowledge-generating order at the individual level has an analogous counterpart in understanding the market process as uniquely a price-generating order. This perspective seems especially useful for the comparative institutional analysis of systems that differ with respect to their capacities for generating market-level knowledge in the form of prices, quantities, and other economically relevant characteristics.

More than his mentor Ludwig Mises, Hayek engaged in constructive and sometimes heated debate with academics and intellectuals of his time. In doing so, he situated himself at the center of some of the "great debates" of the twentieth century, including controversies in the areas of business cycle theory, capital theory, socialist calculation and central planning, and monetary theory. Hayek's fortunes waxed and waned throughout these episodes. But now Hayek's contributions in the areas which we have discussed in this paper may provide a renewed appreciation for his role (albeit posthumously) in the further development of economics. From many quarters the increased interest within the profession in questions of rationality, social institutions, and evolutionary and behavioral economics may well profit from a Hayekian perspective. If so, what Koppl (2002) has referred to as an "emerging new orthodoxy" in economics may well be an enduring legacy of the second Hayekian revolution.

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