CONSUMER LEARNING, CONNECTIONISM AND HAYEK'S THEORETICAL LEGACY

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This paper revisits Hayek's theory of learning, focusing on consumer learning. Starting from what we already know of Hayek's theory on the topic of knowledge and learning, we illustrate how this theory relates partially to the connectionist types of models already used to represent consumer learning processes [Mistri, 2000]. Generally speaking, and in Hayek's view, acquiring knowledge can be said to be the condition that enables the market to tend towards a coordination of its agents' plans. This aspect of the approach adopted by Hayek, and by the majority of what might be loosely defined as the "Austrian school" [Boukaert and Godard-van Der Kroon, 2000; Kirzner, 1992; Loasby, 1984; Oakley, 1997; Rizzello, 1997; Vaughn, 1994; Witt, 1994; Wubben, 1994], emphasizes an important difference that—as concerns knowledge and the implementation of information—can be traced back to the Walrasian approach as well as to Hayek. According to Hayek, the implementation of knowledge takes place through an exchange; the process of developing knowledge is considered as the acquisition and processing of information available in the marketplace [Rizzello, 1997].

In this light, the exchange serves the same purpose as the auctioneer in the Walrasian model. But while in the Walrasian model the exchange takes place when the auctioneer identifies the point of equilibrium where there is no excess demand for any good equates to 0, on the assumption that those taking part in the exchange have all the information they need, in Hayek's model the exchange can be seen as a means for gaining knowledge to achieve an efficient coordination of the individual consumption plans. In Hayek's view, the market can be seen as an institution that enables agents to restrict the space of uncertainty, and thus to learn. This interpretation of the market stems from Hayek's approach in his fundamental study of 1937, *Economics and Knowledge*, where he criticizes the theorists' concept of a general economic equilibrium.

My aim here is not to go into the merit of Hayek's comments on the general economic equilibrium theory in terms of the empirical relevance of said theory, but merely to point out how Hayek's position on the matter of knowledge and learning is linked to the ideas that Hayek illustrated in *The Sensory Order* and anticipates the methodologies for representing learning processes as proposed by the cognitivist approach. This would justify a return to Hayek's critical analysis and an assessment of the epistemological relevance of his approach to knowledge in light of the more modern connectionist approach.

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This paper is divided into two basic sections. The first part returns to the theory of knowledge, relating it to Hayek's criticism of the general economic equilibrium theory, restricting the present analysis to the equilibrium of exchange. The second part represents a bridge between economics and the cognitive sciences and illustrates Hayek's "connectionist" position, which I believe is consistent with his concept of knowledge in the economics of exchange.

SPONTANEOUS ORDER AND SENSORY ORDER: THE PROBLEM OF KNOWLEDGE IN HAYEK

This section focuses on Hayek's criticism of the theory of competitive equilibrium (as concerns the traders' market), according to which the traders' aim to maximize individual utility functions on the strength of the knowledge of the fundamental market data that all the agents possess. One may wonder what type of knowledge consumers need and how the exchange can generate an extension of individual knowledge sufficient to bring them closer to knowing what Hayek [1937, 51] calls the "social mind". After briefly illustrating Hayek's criticism of the theory of perfect competition, based on the assumption of a completeness of information, I shall go on to illustrate Hayek's approach to the traders' coordination and knowledge.

In *Economics and Knowledge*, Hayek emphasizes how a certain circularity of the general economic equilibrium theory depends on the assumptions made in said theory about the knowledge the agents have, and how it disregards the way in which agents arrive at their predictions on the future state of the world. In the market, knowledge is disseminated among the agents and is the outcome of an adaptive process; the coordination of plans is a process that is progressively reinforced as subjects organize the fragments of knowledge they possess and, in doing so, adapt their knowledge of the outside world [ibid., 1937].

Hayek is interested in understanding how the economic agent organizes his knowledge, which is always partial. The market is the abstract place where this progressive change in his knowledge takes place, not a physical place, but a place of relationships and connections. The conceptual nature of Hayek's spontaneous order differs from the nature of the balance in the general economic equilibrium theory. For the equilibrium of exchange to survive, certain strong assumptions are needed on the nature of information, or of certain parametric quantities, in which individual consumer preferences have a relevant role. Hayek [ibid.] points out that it is hardly plausible to assume that the parametric quantities describing the traders' behavior in the market remains constant, because they will change progressively as exchanges take place. Learning processes derive from the nature and intensity of the interactions between the traders: these processes prefigure an interdependence of consumptions.

In Hayek's logic, the emergence of new information, along with changing tastes, is important to the stability of the equilibrium because new information can induce a change to originally-established plans [ibid.]. Let's assume, contrary to the hypothesis of standard theory, that the tastes of a generic consumer, j, can change due to the effects of: (a) social interactions from which "interdependent preferences" derive; (b) individual cognitive changes of Piagetian type [Mistri, 1999]; and (c) the introduction of “new” goods as a consequence of technological progress. The consumer’s universe appears to be complex, where forces of various kinds come to bear, the effects of which are not always predictable. The consumer has to make a continuous effort to decipher signals reaching him from the market; from a cognitive standpoint, this effort is translated into a work of categorization and classification, as Hayek illustrated in *The Sensory Order*. The consumer’s acquisition of knowledge is part of a more general acquisition of knowledge, a central topic in Hayek’s economic analysis. From the cognitive models that represent the acquisition of knowledge as the organization of information, we can move on to the modeling of the acquisition of knowledge by the typical consumer, who moves in an environmental context dominated by uncertainty, which can take different forms depending on its trigger factors [Heiner, 1983]. The uncertainty is assumed to consist of the difficulty exhibited by the consumer in estimating the potential utility of a product or basket of products. Being rational, the consumer, *j*, will seek to improve his knowledge of said basket; he can only do so within the context and limits of his own cognitive architecture, using specific heuristics.

We are dealing with those difficult situations that Simon [1976] describes, in which the subject must collect various kinds of information and process it in various ways to arrive at a reasonable sequence of actions, (that is, a procedural solution to the problem) [ibid, 134]. Simon’s definition of procedural rationality, as intuitively outlined here, appears to be congruent with the present problem, which consists of identifying a procedure for improving the consumer’s knowledge of the relationship between the features of the goods and their potential utility. Standard consumer theory—at least the one that Hayek worked on—assumed that the consumer has a complete set of information and is thus capable of “knowing” how useful each product can be and of converting a collection of “physically” identifiable goods into an “economically ordered” set. However, if we introduce the assumption that the information is incomplete, this means that the purchasing decisions are necessarily suboptimal [Loasby, 1984]. The consumer can contain this suboptimality by using suitable learning strategies. An example of the consumer’s procedural rationality is described in the “experimental consumer” model, where consumer learning occurs as follows: consumer *j*, presumably uncertain as to the potential utility of a given product, *a*, improves his understanding of said utility by means of a sequence of acts of consumption [Khilstrom, Mirman and Postlewaite, 1984].

If the question of learning lies at the bottom of Hayek’s theory of the coordination of the actions of subjects, and therefore of market traders, it is clearly important to understand and represent the learning processes. The numerous approaches to learning stem both from the lack of a unified theory of learning and from the variety of methods used to describe learning processes. Because there is no unified theory of learning in psychology, it is difficult for the economists to become anchored to an unequivocal conceptual system. The term “learning” is used to indicate a wide range of different phenomena, which share the fact of seeming to be the way in which a person adapts to outside stimuli. The researchers’ interest in, and approach to, the topic vary. The behaviorist approach is founded on the conditioning paradigm, based on the link between stimulus and response. The cognitivist approach is based on the agent's capacity to process information and, in this sense, the cognitivists are interested in understanding what happens in the internal states of a mind when it is learning, assuming that changes in said internal states reflect changes in the knowledge of the agent concerned. However, the cognitivists differ in their views on how mental stimuli should be considered. According to one approach, mental states have to do with a different type of reality from physical states and can be characterized in terms of symbolic descriptions. Another approach emphasizes the role of the biological substrates of mental processes, considered as emerging entities produced by the action of a large number of elementary biological processes. This approach stems from Hebb's [1949] work on the role of cell assemblies, which has led to the now abundant literature on connectionism and the neural nets.

Hayek's [1952a, Ch. 1] criticism of behaviorism is based cognitively on the fact that a given stimulus does not necessarily prompt identical internal representations. So a more adequate explanation is needed for the relationship between stimulus and internal representations: Hayek finds this in the theory of cell assemblies, filtered by contributions from *Gestalttheorie*. Hayek [1952a, Section 7.15] claims that the approach of *The Sensory Order* can be interpreted as an attempt to extend the question posed by the Gestalt school concerning the perception of configurations to all kinds of sensory perception. Hayek's idea is that we need to find the rules behind the isomorphism detectable between physiological structures and sensory representations, between the neural order of the fibers and impulses and the internal phenomenal order. In Hayek, these processes are analyzed long after the publication of *Economics and Knowledge*; they can be found in *The Sensory Order*, published in 1952. At a glance, this work might seem to be a mere intellectual curiosity, unrelated to the mainstream of his scientific interests. In my opinion, however, *The Sensory Order* should be seen as a scientific contribution consistent with the rest of Hayek's work, at the base of which lies the problem of knowledge and of the formation of a spontaneous order. In his *Preface* to *The Sensory Order* Hayek describes how his interest in psychology developed in the scientific climate of Austria in the early postwar years, with the vonMises, Bohm-Bawerk, Menger school in economics and the Gestalt school in psychology.

Hayek considers scientific psychology a necessary complement to a more general theory of social science, with particular reference to the theory of human actions. *The Sensory Order* fits into this philosophy of the representation of knowledge, to which he relates the idea of spontaneous order. Hayek [1973] adopts the same term "order" to indicate both the spontaneous process of coordination between the actions of single agents in a market and the process that gives rise to the "cell assemblies" lying at the heart of his scientific investigation in *The Sensory Order*. It thus seems justified to speak of an isomorphism between the knowledge organizing methods in *Economics and Knowledge* and in *The Sensory Order*. The brain is composed of cells whose combinations enable differentiated levels of representation and knowledge to be obtained, both through connections that are established at a given time and through functional specialization of different areas of the brain. What has been said on the topic of the brain's organization might tempt us to think that the basic concept of the neural architectures can be extended to human society, as if it were just one great brain that plastically organizes its own knowledge. In fact, Hayek does not go so far as to consider the human brain as a metaphor of society, but it is worth noting that the way in which human concepts form is influenced by the architecture of the brain. On this aspect of Hayek's psychological theory, I refer critically to the contribution from Smith [1997], who rejects the connectionist approach, criticizing *The Sensory Order* in particular for what is claimed to be an explicative weakness on psychological grounds. Smith claimed that the connectionist approach, which he calls the Hayekian-Hebbian approach [ibid., 23], fails to account for the complexity of mental processes and particularly for the decisional ones, though it appears adequately linked to the topics of economics. Smith sees a sort of parallelism between the nerve impulses and prices, in that both are signals that serve in decision-making. Smith's interpretation returns to a theory of decisional processes that fits entirely into the behaviorist theory (based on the stimulus-response relationship) and fails to grasp the intrinsic sense of the criticism of behaviorism raised by the connectionists and, in a far from negligible degree, shared by Hayek.

In the analysis of *The Sensory Order*, knowledge is the outcome of an adaptive process forming cell assemblies, which do not necessarily combine in the same way in different people. Even similar mental representations are the outcome of brain cell combinations that are never identical. The different ways in which subjects organize sensory perceptions are coupled with different ways in which these subjects materially gain access to knowledge of events, which are derived in subjective terms. On this issue, Hayek makes the point that not only do "objects" not really exist in a permanent and stable way, but even the knowledge that human beings have of these objects is not objective, because there are different ways in which the brain organizes sensory perceptions. *The Sensory Order* implicitly holds the key to interpreting the diversity of representations and expectations of economic subjects. Hayek's approach to knowledge and to the sensory order theory appears mainly concerned with basing a theory of economic action on information and on how said information is processed. This is a concern that emerges with the onset of two important scientific revolutions—the revolution of the cognitive sciences and of the theory of information by Shannon and Weaver [1949]. In particular, interest in the organization of knowledge and the learning processes lies at the very heart of the cognitivist revolution. Cognitivist psychology deals with the question of how organisms know or acquire knowledge of the world effectively [Bower, 1975, 221]. Knowledge enables living organisms not only to survive even in a normally hostile environment, but also to satisfy needs and draw up plans for the future.

FROM BEHAVIORISM TO CONNECTIONISM

Hayek's approach to knowledge is based on a criticism of behaviorism that anticipates much of cognitivism and makes identifying a link between consumer learning and the coordination of the market of exchanges plausible. This section illustrates the cognitive aspects of Hayek's approach to learning, emphasizing how it anticipates certain precepts of connectionism and attributing a significant role to classification processes. Cognitivism is therefore the scientific current of psychology that takes the place of behaviorism, which had represented the "hidden paradigm" of economic consumer theory. The theory of revealed preferences is an extension of the behaviorist approach to economics. This approach is based mainly on Samuelson's [1948] elimination of all psychological elements from the determination of consumer choices; it is not concerned with understanding how preferences are formed. In methodological terms, this position is not "wrong"; assuming preferences as given, as they are revealed in actual acts of consumption, enables an "energy saving" in the conceptualization of the problems of bounded maximization by the consumer. In a cognitivist perspective, however, the consumer optimization problem is bounded not only by the entity of his initial endowments, but also by the amount of information he possesses initially and may acquire subsequently. The cognitivist revolution matured at a time when Hayek was completing *The Sensory Order* and seems consistent with Hayek's position, dominated by concern with understanding the forces that generate learning. Cognitivism, meanwhile, was distinguished from connectionism, with which it nonetheless shared fundamental epistemological concerns. Hayek is fully entitled to consider himself a cognitivist, although *The Sensory Order* may represent a contribution not far from the neural nets approach, in parallel with contribution from Hebb [1949].

In the behaviorist view, learning is reflected only in behavioral changes; in the cognitivist view, learning reflects changes in the internal states of mind. The cognitivist approach is based on the brain's ability to process, qualify, store, preserve, and use information. Dealing with learning as a scientific problem in the social sciences, and the cognitive sciences in particular, means: (a) defining learning from the phenomenological point of view, (b) deriving an adequate theory of learning capable of relating learning to the physiological substrate, and (c) deriving a suitable formal model of learning processes. Phenomenologically speaking, learning can be seen as change in knowledge. Rumelhart and Norman [1978] divided the learning process into three modalities, accretion, structuring, and tuning. By accretion, we indicate the addition of knowledge to existing models or representations. This is a process in which new knowledge is included in a model suitable for preserving the new information and including it in existing structures. Learning sometimes means creating new models to represent new knowledge that cannot find a place in the old models; sometimes it can involve reorganizing existing models. Finally, tuning consists of adapting knowledge to a specific task. The second point to consider is the derivation of a suitable learning theory. In connectionism, knowledge is assumed to be distributed between neural connections and learning consists of reinforcing certain types of connection. Mental patterns can be represented by neural assemblies (that is, groups of neurons that are close together or particularly well connected). It has been suggested that new experiences tend to be included in existing patterns. With successive experience, the net of connections that is established becomes more and more stable. In a way, this concept of learning resembles the method Hayek used in *The Sensory Order* [1952a, Section 5.13]. The third point concerns the formalization that, in the connectionist approach, takes the form of the neural nets.

Questions relating to learning begin to emerge in economics when we analyze the genetic processes lying behind the optimizing behavior adopted by economic agents.

To assume that learning processes exist in economic agents means primarily to assume that they move in a world of environmental uncertainty, and of cognitive uncertainty. An economic agent therefore moves under the restraint of a "bounded rationality" [Simon, 1972], as regards both his knowledge of the outside environment (limited by the information obtainable) and his "processing" technologies. It is worth noting, as concerns the information processing technologies (along the lines of what Hayek [1937] said), that every subject tends to develop common sensory stimuli using a personal information code. Hayek [1952a, Section 2.59] points out that sensory qualities are not originally connected in any way, nor are they an original attribute of single physiological impulses. The whole set of qualities is determined by the system of connections by means of which the impulses can be transmitted from one neuron to another. The distinctive quality of the single impulse, or group of impulses, consequently derives from the position it occupies in the global system of connections. Hayek [ibid.] points out that the system of connections is acquired over time by means of experience, or "learning", with a consequent relative personalization of the mental schemes and of how knowledge is represented.

Connectionism can be seen as a paradigm of the organization of knowledge, a way to conjugate cognitive processes with the structure of the nervous system. However, the debate on the explicative validity of the neural nets approach that derives from connectionism is still open, as is the discussion on the degree of realism with which neural nets (that is, the models that represent them) can represent the architecture of the brain and the dynamics that take place therein. Discussion on the fundamentals and explicative consistency of neural net models prompts caution in their use in economic analysis. The weakness of artificial neurons lies in their lack of flexibility and a certain mechanicism in comparison to natural neurons [Rizzello, 1997, 137]. There are various models of neural nets [Bose and Liang, 1996; Churchland and Sejnowski, 1992; Quinlan, 1991; Rumelhart and McClelland, 1986], each of which attempts to represent specific assumptions on how certain knowledge is organized. The logical structure of each model is justified by the consistency with the processes that it aims to represent so, in the practical case of consumer learning too, it is primarily a matter of clearly defining what we intend by said process. The introduction of neural nets as algorithms for simulating learning processes seems to introduce elements of controversy in relation to the capacity of the Bayesian approach to represent learning. On this point, it is worth mentioning Salmon's comment that " the major difficulty with Bayesian learning seems to be that there is substantial evidence that Bayes' theorem lacks empirical relevance and hence its procedural justification is weak " [1995, 245]. I have no intention here to prompt debate on the superiority or inferiority of the Bayesian approach with respect to the neural approach, since my analysis is limited to the epistemological relevance of Hayek's approach, which is based on the cell assemblies theory and shows no specific interest in relation to the Bayesian approach.

Concerning the methods for representing the organization of knowledge it seems useful, albeit not exhaustive, to use the modeling method derived from the connectionist approach, which focuses on the changes that an increase in knowledge generates in the cognitive structures of j and identifies a substantial isomorphism between evolution in the structure of the information set and evolution in the structure of the neural connections; Hayek [1952a, Ch. 2] attributes a central role to this isomorphism . The nerve cells are not connected randomly with each other to form casual nets; by means of specialized synaptic contacts, each cell establishes certain connections with certain postsynaptic target cells and not with others [Kandel, Schwartz and Jessel, 1995, Ch. 2]. Knowledge and thus the recall of events, situations, objects, etc., is represented in the brain by relatively durable configurations of synaptic connections and is distributed among said connections. This concept is anticipated by Hayek [1952b, Section 3.34], who attributes an essential role to the concatenations, by which he means the durable effects that groups of stimuli can impress on the organization of the nervous system.

The knowledge stored in the system is distributed among many different units, each of which contributes towards representing different items of information. The neural nets store information in the connections between the nodes; learning consists of reinforcing some of these connections and extinguishing others. Information is processed in the layers comprising the neural net. The most basic neural net models are composed of a single layer of input nets receiving stimuli from the outside world and a single layer of neurons that process the information and represent it to the outside.

On a more complex level, some models are based on the inclusion of a layer of internal units that perform a preliminary essential processing of the information. The input units represent the incoming information elements and are activated by the stimulation derived from the information arriving from the environment. This information makes these units emit a signal. Each input is linked to a corresponding weight that takes the importance of the input signal into account. The distribution of the weights on the connections is due to the fact that certain inputs are more important than others in the way they combine to produce an impulse. The weight can be seen as a measure of the intensity of the connection. The internal units thus receive the signals from the input units and the weights of the synaptic connections defining them are modified on the strength of these signals. These internal units emit signals for the output units and, here again, the signals may modify both the weight of the output units and the force of the connections between internal units and output units.

The cognitivist and connectionist concepts of learning respond to different methodological concerns, but both aim to deal with the problem of categorization and classification. Hayek [1952b, Ch. 3] considers classification to be preliminary to the creation of plans of action, including purchasing plans, explaining that human action is guided by the classification of objects and events that responds to a system of sensations and concepts with a common structure, also because human beings have similar nerve structures [ibid.]. Though *The Sensory Order* anticipates certain connectionist ideas, it is equally true that Hayek owes a great deal to cognitivism, which emphasizes the importance of individual mental patterns, which are structured sets of concepts concerning objects, events, and actions [Schank and Abelson, 1977] formed over time by progressively incorporating suitably structured new information in the body of knowledge. For the consumer, the problem lies in how to categorize and classify the goods, and the categorization methods defined in the more strictly cognitivist approach clearly differ from those of the neural approach. This very question of categorization enables similarities and differences to be identified between the neural ap-

TABLE 1
Similarities and Differences between the Neural Approach and Hayek's Approach

Topics	Neural Nets	Hayek's Assemblies
physiological structures	networks of neurons connected by means of synapses	assemblies of cells or neurons
internal structures	given, stable connections are defined	flexible, individually fuzzy connections are defined
the concept of learning	consistency of internal representation with a model	individual accretion of knowledge
the learning procedure	adjustment of synaptic weights	concatenations between cell groups, which may not necessarily be expressible in quantitative terms
equilibrium/coordination	neural nets provide a model of learning more consistent with the theory of market equilibrium	the theory of cell assemblies provides a model of learning consistent with the approach of the coordination of plans

proach to learning and Hayek's "cell assemblies", which can be considered as a bridge between cognitivism and connectionism. Table 1 identifies the similarities and differences that, in my mind, are most significant.

Despite the explicative limitations detectable in the artificial neural nets, it nonetheless seems interesting to consider their use in the case of the learning consumer. In the connectionist approach we find two fundamental simulations corresponding to two fundamental learning strategies. The first involves *supervised* learning, in which the neural net refers to suggested patterns. In this case the consumer is faced with already-constructed classes of goods. The second entails *self-organized* learning, as illustrated in the self-organized models (SOM) proposed by Kohonen [1995], in which the neural net constructs its own patterns in the manner it deems most suitable, using what is normally called competition between cell assemblies, with a consequent endogenous formation of classes.

CONSUMER AND BOUNDED RATIONALITY

In this section the consumer learning process is given a cognitivist representation that takes into account the logical structure of both Hayek's and the connectionist approach. A definition of learning is given entirely within the search for methods suitable for classifying goods, showing how this classification depends on characteristics subjectively derived by the agent involved. The link with Hayek's theory is obvious and the resulting concept of learning enables the similarities and differences with respect to the neural modeling method to be assessed. Learning can be considered to be a refinement of the classification strategy represented by the reorganization of the synaptic connections. From this point of view, the consumer's learning behavior presupposes that he is in a situation of bounded rationality and must proceed with a progressively more and more refined classification of a product or group of products, and that he is seeking a strategy that enables him to classify the goods with a minimum research effort. As a first approximation, we can assume that *j* possesses a specific order of preferences, $\geq_j$, on a set of goods $\{a_i\}$, where $i = 1, 2,..., l$, which can be represented in the simplex R^l_+; these goods can be conceived as *abstract goods* representing classes of products. At the same time, we can say that the information that *j* needs is limited to the system of corresponding prices, which we can indicate using the vector p_i, where $i = 1,2,...,l$. The purchases are all defined at an initial time $\Delta t_t \in T$, where T is *j*'s whole time horizon. We thus establish an instantaneous equilibrium for *j* according to the rules of constrained maximization.

This pattern can be developed assuming four alternative hypotheses, that is, that

a) *j* has a clearly-defined order of preferences, $\geq_j$, and that he reaches his decisions in a sequence of time periods, $<\Delta t_i>$, where $i = 1, 2,..., n$; in this way we introduce an environmental uncertainty, which can be represented by means of probability distributions on the expected states of the world [Savage, 1954];
b) *j*'s order of preferences changes with time, in a sequence of periods, $<\Delta t_i>$, where $i = 1, 2,..., n$; this hypothesis, with the development of multiple-period consumption plans, , consequently makes *j*'s choices suboptimal;
c) *j* possesses a definite order of preferences, $\geq_j$, on a set of classes of goods, but that he is incapable of assessing the potential utility of a specific product, a_k, and consequently of classifying it; testing the product by means of an act—or sequence of acts—of consumption, will enable him to refine his judgement;
d) *j* possesses no definite order of preferences, $\geq_j$, and that he constructs this by sequentially testing the goods belonging to one class. Thus *j* is a rational consumer not only because he maximizes his utility function, but also because he learns through a sequence of consumptions to evaluate the utility of a class of goods, when he is capable of assessing the potential utility of a product without necessarily testing it.

There are essential conceptual differences between cases (c) and (d). In case (c), the test consumption gives rise to a simple increment in the information set and does not necessarily mean that *j* has to modify his order of preferences after the training process. In case (d), sequentially testing the goods becomes an instrumental strategy designed to modify the structure of preferences. In certain conditions, such an assumption becomes a compulsory contribution to the realism of the hypotheses. Suffice it to consider the more general problem of the "formation of preferences" during a person's lifetime [Mistri, 1999], or the introduction of a new product. As Lancaster [1966, 133] said, the introduction of new products casts doubts on the realism of standard consumer theory, since it is impossible for *j* to know in advance about the potential utility of goods that have yet to be invented.

In the above illustrated cases, the problem for *j* is how to place the goods he has referred to on a scale that defines $\geq_j$. If we assume that *j* is capable of doing so in relation to the abstract goods mentioned before, we can legitimately assume that he may have difficulty in doing so for certain actual goods. To eliminate the consequent uncertainty he will have to "test" the goods (advertising often refers to this idea of "testing"). The test enables the consumer to assess the utility of the product, so that he can avoid regretting the content of his basket. It is equally obvious that no rational consumer will want to test all the goods potentially available to him, so he will tend to construct a basket of goods by means of a previously-defined method for sampling the universe of available products. However, if the consumer's behavior were limited to this procedure alone, it would present limited elements of rationality. Instead, we can assume that this testing procedure serves to improve his expertise in classifying goods even without having to actually purchase and consume them. The uncertainty exhibited by *j* in relation to the potential utility of a product, a_k, appears more relevant when a product can be defined on the basis of a set of attributes [Lancaster, 1966], because *j* has to classify a product on the strength of a system of parameters that describe its single features. The concomitant presence of a number of attributes may make *j*'s judgement somewhat "fuzzy" and this lack of focus is all the greater, the less competent *j* has become in classifying the goods. It is common knowledge that an order of preferences "assigns an order" to the goods, drawing binary comparisons between them. The binary comparisons between the members of a set of *n* goods amount to:

$$(n^2 - n)/2. \tag{1}$$

It is immediately obvious that a set of goods involving even a relatively small number of trademarks and/or models will give rise to an excessive number of binary comparisons, which even for a very patient and sufficiently wealthy consumer, is not always economically feasible. For instance, for a set of 20 different trademarks and models, the number of binary comparisons would already amount to 190.

If *j* were to implement all the binary comparisons through test consumptions, he would adopt a strategy obliging him to make a whole sequence of consumptions, all but one of which would be suboptimal. Generally speaking, a value can be attributed to the potential utility of each product and then the difference between these utility values, u_i, where $i = 1, 2,..., n-1$, and the maximum potential utility of the best product, u^*, can be measured. The problem for *j* lies in how to minimize any regret induced by having consumed goods with a lower utility than the maximum potential utility of the "best" product available, that is,

$$min \sum_{i=1}^{n-1}(u^* - u_i), \text{ where } i = 1, 2,..., n-1. \tag{2}$$

To satisfy equation (2), *j* needs the concept of product classification to be based on the assessment of the products' characteristics and, implicitly, on the concept of memorization. On this aspect, the reader can refer to Bernardo and Blin [1977], Hauser and Urban [1979], Ozanne, Brucks and Grewal [1992]. Since they cannot take place simultaneously and instantaneously, but only through a sequence of events, the binary comparisons on the goods in R^l_+ call for the existence of a codified memorization of the products and their features, and of the relationship between their features and their utility. Bernardo and Blin [1992] assume that the goods can be represented by means of a matrix of features rather along the lines proposed by Lancaster in his pioneering work [1966]. In Lancaster's view, a product can easily acquire the connotation of a vector, **C**, defined on the space of the features, z, whose versors, c_i, where $i = 1, 2,..., n$, indicate the dimensions of said space. Lancaster made a good point concerning the objectivity of the features and the subjectivity with which j considers their utility, which can be expressed by means of weights that are assigned to the features themselves. This procedure is preparatory to the method typical of the neural nets and is entirely consistent with Hayek's approach on the formation of concepts, as described in his *Counter-revolution of Science: Studies on the Abuse of Reason* [1952b].

Taking a neural approach, a rule of consumer learning, intended as an adjustment of the weights assigned to the products' features, can be derived by transforming the vector **C** into a new vector **C'** according to the rule $T[\mathbf{C}]^T = \mathbf{C'}$, where T is the opportune transformation. This formula is based on the isomorphism detectable between the vector representation of the goods and the vector representation of the cognitive structures offered by the PDP (Parallel Distributed Processing) models. The general principle is that learning, intended as the organized acquisition of knowledge, mimics in the model (that is, in the neural net) what is believed to occur in our brain when we learn. Learning is described as the creation of connections between neurons and the cortical areas through the synapses. The connections may have a variable geometry, in the sense that the same stimulus can give rise to different connections in different people. Hayek raises a point that is subsequently developed by neural net theory and that may have a significant fallout on the theorization of consumer behavior. In analyzing the relationship between the formation of internal images and the formation of connections, we can assume that the isomorphism between the structure of the synaptic connections and the structure of the internal image is fuzzy. The assumption of a fuzzy isomorphism enables us to understand how a neural net, however "incomplete", can recognize a pattern [Churchland, 1995], but can also lead to the risk of classification errors. Such a possibility is more immediate in the logic of Hayek's idea of cell assemblies.

CATEGORIZATION AND HEURISTICS OF REPRESENTATIVENESS

Here I assume that the consumer, j, defines his utility function on classes of goods; these are classes of goods that he constructs according to the internal logic Hayek describes and that, in "extreme" form, can give rise to formal vector representations useful in conceptualizing, but difficult to apply in practice. The vector formalization of classes of goods is explained below, while a discussion of its applicability is developed in the subsequent section.

In the previously-mentioned vector logic, the characteristics of the goods are measured on versors. The length of each versor indicates the "weight" that j attributes to each characteristic of the typical product considered as representative of the class. I previously assumed that a sequence of consumptions can be used by j to improve his knowledge of the products, so that he is capable of constructing product classes. In a cognitivist view, we can assume that, by means of the concatenations described by

Hayek, the consumer *j* constructs a map of the product characteristics by coupling physical, structural features of the goods with utility values and assigning a value to each characteristic, according to the logic of multiple-attribute utility functions [Keeny and Raiffa, 1976, Ch. 5]. The construction of the vectorially- represented typical product obliges *j* to perform two types of mental operation. The first refers to determining the weights to assign to each characteristic, defining said weights in terms of *ad hoc* parameters. The second consists, in the situation where a real product has not been purchased and/or tested, in the probabilistic estimation of each parameter. For the purposes of establishing the respective weights of the typical product's characteristics, we have to remember that a multiple-attribute product, x, can be represented as: $x_k = (x_1, x_2..., x_n)$, where $(x_1, x_2..., x_n)$ is the space of the characteristics. The structure of the characteristics, described by the relative weight of their parameters, is constructed by *j* through the training processes that I referred to before. Once these processes have been completed, *j* possesses a system of classes. A new problem emerges when, supposing that *j* possesses a system of classes, he now has to assign a real product to a given class, (to assess it) without having had the opportunity to test the product. To perform this operation, *j* has to infer whether the parameter of each characteristic falls within a satisfactory range around the value of the corresponding parameter for the typical product.

Let's consider a real product, x^*, and assume that it equates to a typical product, x_k, (that is, it belongs to the same class, C_k); in this way, we can say that two products represented in vector form, x^*_1, x^*_2, are equivalent in terms of their characteristics if they belong to the same class, C_k, so that:

$$\{x^*_1 \sim x^*_2 \rightarrow [x^*_1 \in C_k \text{ and } x^*_2 \in C_k]\}. \tag{3}$$

If one of the two products is the typical product, x_k, we can say that the real product, x^*_k, belongs to the class C_k if each parameter of the characteristics of the product falls within a specific range, h, around the corresponding parameter of the typical product, x_k. In his estimation of said parameters, we assume that *j* is a consumer *à la* Tversky and Kahneman [1982] (that is, he uses heuristics and *representativeness* in particular, a heuristic used to indicate that the estimation of a characteristic is done on the basis of its context [Kahneman, Slovic and Tversky, 1982]). For example, *j* may infer that a certain motor car is economical because it is Japanese, or that it is sturdy because it is Swedish. This inferential method coincides to some degree with the logic of *Gestaltpsychologie* and is based on the principle of "field organization" [Hayek, 1952a, Section 3.71].

Representing consumer learning vectorally is entirely consistent with the internal cognitive processes that are typical of human beings, but remains far from succeeding in representing the extreme complexity of the real processes. A neural net capable of representing the real processes would be extremely complex in terms of the algorithms involved and would have to cope with the composite nature of the learning process. Throughout *The Sensory Order*, Hayek emphasized the complexity of learning processes, which involve both internal forces and social modeling forces. In the behavior of a consumer, classifying the goods is an activity preliminary to the

TABLE 2
The Learning Consumer

Issues	Neural	Hayek's
selection methods	by determining product classes	by determining product classes
formation of classes	mainly on the basis of pre-established models	on the basis of processes of socially -influenced individual processing
role of preferences	preferences can be attributed	preferences can be influenced by the class-forming process
characteristics of the goods	expressed by vectorial parameters	may be expressed vectorially only as a first approximation

decision process, in the sense that it is needed to establish the consumer's order of preferences. Different forces take part in this process of classification, however, so it risks becoming a sort of "Penelope's shroud", continuously woven and unraveled. The problem is that the characteristics of a product do not really exist in absolute terms, as we see from Hayek's analysis, but are evaluated in terms of the results that correlate with them. We thus move into the terrain of intentional behavior that Hayek explored in *The Sensory Order* [1952, Ch. 5], suggesting topics for reflection that are useful in the analysis of consumer learning. By using a product, the consumer gains an idea of the relationship between the characteristics of the product and the results obtainable, which can be summarized in an order of preferences; he makes himself a sort of map or model of the interaction between the objects and their potential utility, which represents a practical application of Hayek's general analysis of modeling intentional states [ibid.]. It may therefore be useful to summarize (Table 2) the similarities and differences between the learning consumer of neural type and the one who learns *à la* Hayek.

COMPLEXITY OF CATEGORIZATION AND MARKETING

In Hayek's theory of cell assemblies, we have seen that very similar categorization processes can be generated by concatenations between different neurons. Even the individual consumer may have difficulty in correctly classifying a product and errors can give rise to cognitive dissonance phenomena [Festinger, 1957]. Here lies a discrepancy with respect to the abstract neural models, which explains why enterprises encounter some difficulties in communicating a certain image of their products. If the vector representation of a product were unequivocal, there would be no communication problems between the enterprise making the product and the customer being prompted to purchase it. On the basis of Hayek's considerations, however, it seems evident that the enterprise's methods for defining classes are unlikely to be the same as the customer's. Generally speaking, in implementing a marketing strategy an enterprise seeks to infer the customers' product classification processes from certain social and economic characteristics of the target customers, hypothesizing the existence of market “segments”. Customer segmentation is based on the assumption that some correspondence exists between a segment (or class) of customers, defined on the basis of certain features, and a class of goods, also defined on the basis of their characteristics. If the two classification processes are not isomorphous the customer will have a different perception of the product from the one the enterprise intended to give him.

One way in which enterprises seek to reduce the difference between their own and their customers’ classification processes is unquestionably through advertising, through which customers are submitted to learning processes (that is, they are prompted to reclassify both the products and the way in which they “see” the product in the market). A consumer-educating strategy is not easy and enterprises have a very “fuzzy” knowledge of the factors which can influence a customer’s attitude. An enterprise may well know that customers classify products, but given the complexity of the interrelations between the forces actually modeling the consumer’s attitude, fail to detect the structure underlying said classification process.

We have seen that an important characteristic element of Hayek’s approach lies in the adoption of a cognitivist method that owes a great deal to *Gestalt* psychology. Gestaltism enables the emphasis to be placed on the role of social field factors in modeling the consumers’ preferences and their classifying processes. By “modeling”, we can mean learning through observing the behavior of others. Lewin [1951] points out that needs can change when changes take place somewhere in the psychological field or in the cognitive structure of subjects; according to Lewin, all this is consistent with the fact that the whole space of a person’s life must be considered, in Gestaltist terms, as a field connected in its various parts. Of course, enterprises pay a great deal of attention to the processes that form consumer attitudes, with a view to developing processes for influencing them, an influence that may be socially mediated. However, for this form of conditioning to be successful, it must be consistent with the fundamental cognitive structures of the consumer, who belongs to a social-psychological field. Hence the difficulty of formally representing the highly complex learning processes of a real consumer.

CONCLUSIONS

As we have seen, Hayek’s precepts on the organization of mental processes are significant not only in terms of what they have contributed to cognitive scientific theory and the newborn neural nets, but also for their impact on the topic of economic behavior. Though Hayek’s work anticipates the concept of neural nets as a model of neural organization and therefore also of learning processes, it is also true that Hayek’s stance is more difficult in relation to the hard modeling of neural nets. It is nourished by epistemological concerns deriving from the experience of *Gestalttheorie* and by the will to grasp the complex interactions between the structure of the nervous system and the social forces that influence real behavior in some way. So while similarities exist between Hayek’s cell assemblies and the neural nets, Hayek pays particular attention to the role of culture-developing processes and the value of individual uniqueness in the dynamics governing the formation of neural structures.

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