From Bounded Rationality to Behavioral Economics

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1 Rational choice and psychology of choice: an unresolved dualism

> "Modern mainstream economic theory is largely based on an unrealistic picture of human decision making. Economic agents are portrayed as fully rational Bayesian maximizers of subjective utility.
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> This view of economics is not based on empirical evidence, but rather on the simultaneous axiomization of utility and subjective probability. In the fundamental book of Savage the axioms are consistency requirements on actions with actions defined as mappings from states of the world to consequences (Savage 1954). One can only admire the imposing structure built by Savage. It has a strong intellectual appeal as a concept of ideal rationality. However, it is wrong to assume that human beings conform to this ideal. "(Reihnardt Selten, 1999)

The trenchant opinion expressed by Reinhardt Selten reflects the present rapidly evolving debate on decision making theory and the parallel emergence of a new approach: Behavioral Economics, a growing disciplinary area at the crossroads between economics and psychology which is challenging both the epistemological assumptions of neoclassical economics and the foundations of decision making theory.

The challenge against the theory of rational behavior began at the height of its success and culminated with the publication of *Theory of Games and Economic Behavior* by von Neumann and Morghenstern in 1944. The first experimental results questioning the validity of the standard model of rational action date from the 1950s: Allais's experiments of 1952 and the empirical study of decision processes in firms conducted by Cyert, Simon and Trow in 1956.

To understand the origins of current changes, therefore, we must return to the 'golden age' of standard rationality theory: the 1950s. The success achieved by linear and dynamic programming in those years seemingly justified unlimited faith in the ability of optimization models to explain all economically significant forms of behavior. There was a widespread conviction that it was invariably possible and justifiable to reduce macrophenomena to rational forms of behavior and to represent rational forms of behavior as problems of constrained maximization.

Yet, as the model of rational decision-making became increasingly well-defined, so there was a corresponding extension of its domain of application; an extension which led to a growth of computational complexity and to advancements in the creation of new, sophisticated optimization algorithms.

This raised the problem of whether it was legitimate to ascribe individuals with the ability to perform extremely complex decision-making processes, resolving the problems connected with them by means of highly time-consuming and sophisticated algorithms, or whether models of rational behavior should only be interpreted in a normative sense as techniques aiding decision-making and suitable for use by experts, not by common decision-makers.

It was this dilemma that prompted Simon to advance his hypothesis of *bounded rationality* and to dispute the idea of perfect and all-encompassing rationality.

2 The separation between psychology and economics.

However, in those years a different solution of the dilemma was proposed by Milton Friedman, a solution that was highly successful and provided a (fallacious) point of reference for mainstream theory.

According to Friedman, although individuals do not possess the formal tools with which to calculate the optimum adequately, they behave *as if* they do - like bicycle riders who keep themselves in dynamic equilibrium even though they are unaware of the complex equations of the dynamics of motion, or billiard players who accomplish complex trajectories with their billiard balls although ignorant of the laws of rational mechanics. Friedman expressed skepticism about the possibility of discovering how business decisions are made through observation of behaviors, suggesting that individuals might actually be not aware of the mental processes involved in their actions. This observation was related to the idea that a part of relevant knowledge may be tacit, and it led Friedman to the extreme of prescribing that the *individual* expression of preferences must be disregarded.

A *reasonabl*e observation therefore became the *unreasonable* prescription of the Chicago school: the *'as if'* hypothesis was then supplemented with the further assertion that individual preferences are not observable, and indeed that they are *irrelevant* to proving the validity of an economic theory (Friedman 1953).

In order to explain why this position enjoyed such prolonged success, even though it was substantially misleading, we must examine the terms of the problem more carefully. In its standard version, the theory of rationality rests on the following conception of human behavior: there exists a set of conceivable actions that every individual may undertake and that give rise to certain consequences. Individuals possess a mental order of preferences concerning all the possible consequences of their actions. They evaluate these consequences, and, given the constraints, decide upon a particular action. They therefore make their choice coherently with their preferences and with the constraints upon them. This manner of proceeding is called rational ‘calculation’.

According to these assumptions, the theory of rational choice indicates to economic actors how best they can achieve their goals, and it is implicitly assumed (explicitly by Milton Friedman) that those who fail to conform are gradually excluded by a process of selection which permits only ‘rational’ operators to survive.

On this view it is therefore both pointless and uninteresting to investigate the psychological aspects of decision-making, because at most these could only aid explanation as to why certain individuals are unable to behave in an entirely rational manner.

The normative approach to decision-making theory was limpidly expounded in Lionel Robbins' *Essay on the Nature and Significance of Economics* (1932), in which he defined economics as the *science of choice*. In this approach, ‘calculation’ is therefore totally independent from individual mental activities, and it takes place irrespectively of the mental processes of single individuals. The role of rational decision making theory is viewed as being fundamentally normative; a view shared by the vast majority of economists for just under a century on the assumptions and the definitions provided by Robbins.

Robbins codified a ‘post-Austrian’ view in which economics and psychology are fully autonomous specializations with independent scientific statutes. As pointed out by Schumpeter in his “History of Economic Analysis”, the separation of economics from psychology came about only after many decades of heated debate:

> "In principle, utility, be it total or marginal, was considered a psychic reality, a sensation that became evident from introspection, independent of any external observation […] with directly measurable proportions. I believe this was Menger and Böhm-Bawerk's opinion" (Schumpeter, *History of Economic Analysis*).

From the outset, recourse to a psychological interpretation of 'utility' was evident:

> "Ferdinando Galiani (Della moneta, 1750) defined *utilità* as 'the power of a thing to procure us felicity.' Similarly, Jeremy Bentham at first spoke of utility as 'that property in any object, whereby it tends to produce benefit, advantage, pleasure, good or happiness' (*An Introduction to the Principles of Morals and Legislation*, 1780). But the meaning of the term has shifted continuously and even today 'utility' circulates with various, albeit cognate, connotations. By referring to the principle of utility as the principle of the greatest happiness of the greatest number, Bentham himself paved the way for this terminological license. The ensuing confusion prompted W. Stanley Jevons to insist that 'Utility is not an Intrinsic Quality,' but 'the sum of the pleasure created and the pain prevented' (The Theory of Political Economy, 1871)." (N. Georgescu Roegen, *Dictionary of the history of economic ideas*)

The introduction of utility as a psychological characteristic connected with the 'value' of human activities raised the question of how to *measure* the increasing or decreasing utility stemming from a particular choice. Such measurement did not appeared feasible to most economists. But then Pareto furnished proof that it was not necessary to resort to the utility function; rather, the 'new theory of value' could be grounded on the simpler notion of preference. The winning analytical strategy consisted in establishing some simple properties of preference orderings – completeness, transitivity, continuity and independence – which enabled the construction of an axiomatic model of choice. It was mainly the controversy between the French and Austrian schools that fuelled the long evolution of the notion of utility until it eventually culminated in the version codified by Robbins, Hicks and Allen.
Proof was gradually emerging that it was possible to adopt a utility function which was perfectly equivalent to the axiomatic model. The 1950s saw a series of disputes and much confusion with regard to this issue, as illustrated by Schumpeter in his *History of Economic Analysis*. (1968). By that time, however, Pareto's approach had gained general consensus, and most economists shared the opinion that the theory

> "…. has a much better claim to being called a logic of choice than a psychology of value" (Schumpeter, *History of Economic Analysis*).

In the *Theory of Games and Economic Behavior*, published in 1944, von Neumann and Morghenstern took a further step forward. They set out an axiomatic approach to the theory of decision making in conditions of uncertainty, by formalizing the Expected Utility hypothesis two centuries after Bernoulli's original definition of it. Though apparently innocuous, the assumption that in conditions of uncertainty individuals decide on the basis of expected utility contained restrictions in addition to those relating to the utility function under deterministic conditions, as noted by Allais (1979).

Debate on the notion of Expected Utility ensued and lasted for over a decade. It encompassed a number of controversies connected with the confusion generated by the epistemology of the Chicago school. In

1952, Friedman and Savage published their famous study on expected utility in which they constructed an expected utility curve which, they claimed, provided a reasonably accurate representation of observable behavior at the *aggregate level*.

As said, Friedman and Savage's approach considered the individual's expression of preferences to be *irrelevant*. Consequently, their method did not suggest empirical control for individual preferences: on the contrary, it imposed *a priori* restrictions on the expected utility function based on characteristics relating to the behavior of large aggregates of individuals: for instance, the fact that numerous middle-to-low-income citizens are ready to risk small sums of money on gambling implies that they are *risk takers*; analogously, the fact that those same citizens take out insurance means they are *risk averse*. The former property requires a convex utility function, while the latter requires concavity. In order to account for both these features of the population's behavior, Friedman and Savage suggested that the (aggregate) Expected Utility curve must have an 'S' shape for middle-to-low income values. Yet Friedman constructed a general shape for the curve without testing the characteristics on a real population: in fact, neither he considered empirical data on insurance, nor he made reference to reliable data on gamblers' incomes , that did not even exist at the time.

Friedman and Savage's study seemed to be a considerable theoretical achievement in regard to definition of the notion of utility. Yet this advance was based on an untenable general epistemological approach that was unfortunately successful and for long remained an unquestioned dogma for a vast number of economists.

As we will see in the next sections, both the 'as if' assumption and the methodological prescriptions on how to connect axiomatic decision theory with empirical data were successfully challenged by the new approach that emerged with Simon's and Allais's criticisms.

3 Maurice Allais's falsificationist approach to axiomatic decision theory

Maurice Allais's research pointed to conclusions the reverse of those obtained by Friedman and Savage's approach. He carried out experiments on individual preferences - using an ingenious falsificationist method - that showed systematic failures in the theory's predictions. In 1952, at a symposium held in Paris, Allais presented two studies in which he criticized the descriptive and predictive power of the 'American School's' choice theory, and especially Friedman's version of it (Allais, 1953). He submitted experiments in which subjects faced with alternative choices in conditions of risk systematically violate the assumptions of the Expected Utility theory.

His investigation methodology overturned the prescriptions imposed by the Chicago school because it was founded on observation of an *individual's* behavior and introduced an experimental method whereby the inherent difficulty of direct observation of individual preferences could be overcome by cross checking alternative choices.

The experiments proposed by Allais had the following two distinctive features.

First, the properties of the choice that characterize the expected utility function must be identified in axiomatic form; these properties are: completeness, transitivity, continuity and independence.

Second, subjects are presented with pairs of binary choices selected in such a way that one combination of the answers involves the violation of at least one of the axioms.

On this ground Allais showed that a large part of the subjects exposed to binary choices violated some axiom of the expected utility. An outline of one of the best known experiments follows.

Do you prefer Situation A to Situation B?

Situation A

Certainty of receiving 100 million (Francs)
Situation B:
A 10% chance of winning 500 million, an 89% chance of winning 100 million, a 1% chance of winning nothing

Do you prefer Situation C to Situation D?

Situation C
An 11% chance of winning 100 million, an 89% chance of winning nothing,
Situation D:
A 10% chance of winning 500 million, a 90% chance of winning nothing

Note that if Savage's postulate is correct, the preference A≻B ("A≻B" means "A preferred to B") should entail C ≻ D.[1] But the experiment contradicts this prediction:

> "What one finds, however, is that the pattern for most highly prudent persons, the curvature of whose satisfaction curves is not very marked, and of who are considered generally as rational, is the pairing A ≻ B and C<D. This contradicts the Savage's fifth axiom." (Allais, 1952)

Violations like the one just shown could be interpreted as signalling inconsistency in the system of individuals' preferences. A natural reaction to the discovery of these violations is to suppose that inconsistencies are not systematic; and it was perhaps for this reason that the initial reaction to Allais's experiment results was lukewarm. Many believed that his example was an extreme case, not a systematic one, in view of the particularly large sums at stake. Only later, after repeated experiments by Allais with actual modest sums being given to players, did the phenomenon emerge once again and thus had to be recognized as being systematic in character. (Camerer, 1995)
Since experiments showed a violation of the expected utility theory axioms, it was only natural to suspect that this violation depended on overly stringent characteristics imposed on the definition of the expected utility function.[2] Reaction to Allais's experiments led in fact to the proposal of more sophisticated versions of the utility theory in conditions of uncertainty which modified or moderated certain axioms, or generalized their characteristics.
As we shall see, this approach did *not* prove successful; rather, it confined the expected utility problem to a very specialized sector and limited its impact on microeconomics. In any case, in scientific circles, both in the area of probability theory and in the field of economic theory of choice, the scope of Allais work was not appropriately valued. Arrow justifies this underestimation by saying that if his study had been published by some of the most important American journals, future developments would have been achieved thirty years earlier. But this did not happen.

[1] Proof: If A ≻ B, then $U(100)>0.10U(500)+0.89U(100)+0.01U(0)$.
Rearranging this expression gives $0.11\,U(100) > 0.10U(500)+0.01U(0)$; and adding $0.89\,U(0)$ to each side yields $0.11\,U(100)+0.89\,U(0) > 0.10U(500)+0.90U(0)$. Which means C≻D.
[2] A similar reaction was provoked by the Ellsberg paradox.

4 A parallel criticism: Simon' Bounded Rationality

In the same period, the decision making model was about to be seriously questioned from another viewpoint and a different context: that of administrative and managerial behavior, which had hitherto entirely defied rationality analysis, despite the fact that rational planning analysis within organizations was highly developed. The success attained by optimisation methods brought out two critical aspects: on the one hand the extreme sophistication of many optimisation models made it impossible for them to be applied in most organizations; on the other, it was becoming clear that the amount of calculation needed to obtain an optimal solution could in some cases be insurmountably high. It was within this context, and in light of empirical observations on how organizations function, that the limits to the individual ability to make rational calculations became evident.

The theory of bounded rationality can be traced back to Herbert Simon's work at Carnegie Mellon with Dick Cyert, Jim March and Harold Guetzkow at the beginning of the 1950s. Their research programme dealt with realistic issues of economic organizations in a period when the conceptual apparatus available was entirely inadequate to the purpose.

The group examined methods for the control of decisional processes within companies. It did so from within the selfsame companies analysed and was thus able to conduct in-the-field appraisal of the behavior of *managers* and employees. The radical revision of the two notions of rationality and organization that characterizes Simon's theory, compared with the neoclassical tradition, originated from the extraordinary interaction of this group. In *Models of my Life* (1991) Simon recalls that the group gradually altered the language of discussion by introducing "semantic changes" which shed new light on the themes discussed: the notions of *bounded rationality*, *satisficing*, *problem solving* were thus developed in a context of highly interdisciplinary analysis.

The limitations of the theory available to the group at the time were evident: the Weberian analysis of rationality and bureaucracy that had enjoyed such prolonged success revealed its shortcomings when applied to the behavior of managers founded on the ability to solve problems and innovate in ever-changing situations. The traditional approach, as said, was centred on decision making as a choice; construction of the *decision context* was considered secondary, and so was the discovery of alternative strategies. The shift of attention was due in part to the effects of consumption theory, for in this theory consumption alternatives are assumed to be normally known by subjects; the only significant problem being the choice of the consumption plan that maximizes expected utility, bearing in mind the limits on the availability of funds.

Matters change entirely, however, when the same scheme is applied to contexts of production and organization. In this case, decisions are taken in an environment where it is extremely difficult, and at times impossible, to evaluate all the available alternatives and their consequences. Exploration of this world reveals that the decision is nothing but a final act of a complex process that *precedes it*, and through which the relevant information is gathered and the appropriate knowledge is structured.

By introducing the notion of *bounded rationality*, Simon picked up on both of these proprieties of the decision-making process. He argued that the real restriction on a rational decision was the need to *construct the context of the decision*. To do so individuals must search for all the relevant information and then construct a 'mental model' representing the decisional context.The difficulty of fully representing the latter and of organizing an appropriate *mental representation* of it marks out the bounds of rationality.

Simon initiated a new research strategy in order to uncover the secrets of human cognition. He took up one of Turing's central statements – if a problem can be clearly described with appropriate language, then it can be transferred into a form computable by a machine – and began to build artefacts of artificial intelligence. The artificial reproduction of certain aspects of human problem solving was a new strategy with which to understand the human mind; and the writing of computer programs that

made it possible opened the doors to 'artificial intelligence'. Simon worked in parallel on giving strong impetus to the empirical analysis of cognitive processes. His starting point was analysis of the game of chess, which Simon explored extensively from a theoretical as well as experimental viewpoint. His examination provides a striking example of the complexity involved in constructing good, or 'satisficing', strategies.
The game of chess focused researchers' attention on the question of complexity and on the limits of mental *calculation*. But Simon moved beyond the notion of calculation by first introducing the idea of 'symbolic manipulation' and then directly considering the determinants of cognitive processes (reasoning, categorizing, chunking,…). Experiments applying 'Protocol Analysis' were carried out: verbal ideas expressed during the game by players were taken down and analyzed in order to understand the cognitive processes involved.
Problem solving emerged as one of the crucial aspects of the players' mental activity. This analysis pioneered by Simon showed that players' mental activity systematically violates rational choice: chess strategies are inter-temporal decisions which require players to elaborate and re-elaborate their analyses; their decisions are based on a process of learning and mental model building repeatedly at odds with perfect rationality.
Moreover, by opening up the new field of artificial intelligence, problem solving theory and the connected experiments using protocol analysis made it clear that, despite the great progress achieved, the limit of the 'artificial' imitation of the players' mental activity was that it captured only the 'explicit thinking' (i.e. the *deliberate* mental processes) accessible through introspection.

The 1960s were therefore the years of the greatest challenge against the axiomatic foundations of rational choice. On the one hand, Allais's critique aroused renewed interest in psychology; on the other, Simon made clear that if human intelligence was to be thoroughly understood it had to be 'decomposed' into its many complex processes and elements: induction, reasoning and problem solving were, in Simon's view, the true protagonists in comprehension of human bounded rationality, and consequently yielded a more realistic picture of economic and organizational phenomena.

5 The 1980s: Revising the paradigm

The most natural way out of the *impasse* created by Allais's experiments was to consider the theory of expected utility as too restrictive, and therefore to seek an extended theory of expected utility. Many proposals were put forward, especially from the mid 1970s onwards, and all of them attempted to relax or slightly modify the original axioms of expected utility theory. The most widely cited of them were perhaps the *Weighted Utility Theory* (Chew and MacCrimmon), which assumed a weaker form of the independence axiom; the *Regret Theory* proposed by Loomes and Sugden (1982); and the *Disappointment Theory* propounded by Gul (1991). None of them had statistical confirmation over the full domain of applicability (Hey, 1991).
Kahnemann and Tversky's approach differed crucially from previous proposals in that it did more than modify certain axioms; rather, it restructured the problem by concentrating on the mental processes involved. The approach fit coherently within the analytical frame of *Bounded Rationality*, as the two authors explicitly acknowledged.
In 1987, Tversky and Kahnemann moved beyond Allais's experiments to show that when individuals take risky decisions, they exhibit a systematic inconsistency related to the *framing of the decision*. Tversky and Kahnemann ran the following experiment, which clearly elicited this effect:

Problem 1

Assume you are 300 $ richer than you are today. Choose between - A the certainty of earning 100$ - B a 50% probability of winning 200$ and a 50% one of not winning anything <u>Problem 2</u> Assume you are 500 $ richer than today. Choose between - C A sure loss of 100$ - D a 50% chance of not losing anything and a 50% chance of losing 200$

Readers responding to the two problems will probably opt for the adverse risk option in problem 1, and therefore choose an earning that is assured (answer A). And this was the choice made by the vast majority of participants in the experiment. Instead, the answer preferred in problem 2 will probably be the one in favor of risk-taking, and therefore answer B.
It was noted that the majority – who picked answers A and D – violated the theory of expected utility (the independence axiom of the theory), as in Allais's experiments.
Simple reflection shows that, in terms of expected utility, the two problems are *the same problem*; in fact, the entity's available wealth was considered *after* the choice had been made:

Problem 1				
Case A	400	with prob=1		
Case B	300	with prob=0.5	or	500 with prob=0.5
Problem 2				
Case C	400	with prob=1		
Case D	300	with prob=0.5	or	500 with prob=0.5

Therefore a large majority of individuals behave as *risk takers* when confronted by a problem presented in terms of *loss* (Problem 2) while they behave as *risk averse* when the same problem is presented in terms of gain (Problem 1). This behavioral inconsistency is called the '*framing effect*' and demonstrates that the representation (framing) of a problem may be crucial in 'ordering' the preferences.
Moreover, Tversky and Kahnemann observed that

> "…. the path of preferences observed in the two problems are of particular interest as they violate not only the theory of expected utility, but practically all choice models based on other normative theories. It must be noted that these data are not consistent with the "Regret" model proposed by Bell (1982) and Loomes and Sugden (1982) and axiomatized by Fishburn (1982)"

We again have confirmation that extended utility axiomatic theories – which explain violations of the expected utility theory by introducing new axioms or reducing the original ones – cannot receive experimental confirmation in all spectrums of experiments conducted to date.
On the contrary, numerous experiments have confirmed the above-described *framing effect*.. Kahnemann and Tversky's approach therefore appears to be the one that has attained the best experimental results, and it has had greater analytical potential.

Kahnemann and Tversky suggest that in order to understand a decision one must thoroughly analyze the *cognitive processes* that underlie it. It is thus necessary to examine how people represent problems; how the complex process of editing is carried out; and how mental models are built in order to make a particular decision.
A suggestion closely related to Simon's analysis of the decisional problem considers the decision to the final act in a *problem-solving* process. Problem-solving is the core of a subject's activities in taking a decision, and it is described as a calculation made to find a (satisficing) strategy. This 'calculation' is carried out under strong restrictions imposed by the cognitive limitations of individuals and which may generate systematic *biases*: that is, systematic deviations from the results that would be obtained by a 'hyper rational' subject, an omniscient calculator of unlimited power.
The 'guidelines for future researches' emerging from the bounded rationality approach and from Kahnemann and Tversky's results suggest that an explanation for biases and deviations from "Olympian" rationality should be sought by conducting deeper exploration of the cognitive processes lying behind decisions. This approach opens up a broad field of new experimental and theoretical analysis that will be briefly sketched later. Before these developments are considered, however, the last element of Friedman's 'as if' approach – the evolutionary justification of rationality – should be dealt with.

6 Lock-in: the persistence of many sub-optimal solutions in human problem solving

Individuals and organizations may systematically deviate from perfectly rational strategies for both cognitive and emotional reasons. The *cognitive* explanation of the limits of rationality originates from the pioneering analysis of strategic situations conducted by Simon in the 1950s. In 1956, Cyert, Simon and Throw carried out an empirical study of managerial decisions which revealed an evident 'dualism' of behavior: on the one hand, there was behavior guided by a coherent choice among alternatives typical of structured and repetitive conditions; on the other, behavior characterised by highly uncertain and ill-defined conditions, where the predominant role was played by problem-solving activities.[3]

> "Decisions in organizations vary widely with respect to the extent to which the decision-making process is programmed. At one extreme we have repetitive, well-defined problems (e.g., quality control or production lot-size problems) involving tangible considerations, to which the economic models that call for finding the best among a set of pre-established alternatives can be applied rather literally. In contrast to these highly programmed and usually rather detailed decisions are problems of non-repetitive sort, often involving basic long-range questions about the whole strategy of the firm or some part if it, arising initially in a highly unstructured form and requiring a great deal of the kinds of search processes listed above." (1956, p.238)

The core of the decision-making process is therefore the activity of *searching*. The conditions for application of standard choice theory are largely lacking because preference orderings are highly incomplete, decisions are simultaneously inconsistent, and choices are largely ineffective in relation to the goals pursued. The most important part of the process is driven by the ability of the subjects to formulate and solve new, unexpected and ill-defined problems.

[3] In this last set of conditions, not only must subjects gather information, they must also be able to select the information and knowledge that is effectively relevant to their purposes and to assimilate it into the system of knowledge that they already possess. To do so, they must have a 'level of competence' adequate to the situation of their choice; they must, that is, implement skills of learning and problem solving.

The notion of bounded rationality therefore assumed increasing importance in field studies on team decisions under ill-defined conditions within organizations. These studies induced March and Simon to radically rethink the traditional idea of 'planning'. They turned the notion of planning, based on the notion of optimal intertemporal decision making, upside down and substituted it with the notion of 'organizational learning', a process of collective problem solving which essentially involves the revision and correction of the procedures to accomplish goals. The most important feature of organizational problem solving is the ability of teams to revise their solutions and remedy the errors that they may have committed. This is the most revolutionary aspect of the recasting of the traditional view of organizational activities put forward in March and Simon's celebrated book *Organizations* (1958). Here, the notion of organizational learning is expounded with clarity, and the description of organizational decisions is realistically rooted in the notion of organizational conflict; the conflicting views of individuals in the same organization are considered to be the engine of the organizational learning. A few years later, in A *Behavioral Theory of the Firm* (1963) Cyert and March showed that organizational learning is a highly path-dependent process, and moreover that it is strongly biased by the constant emergence of erroneous beliefs and solutions.

> "….. when an organization discovers a solution to a problem by searching in a particular way, it will be more likely to search in that way in future problems of the same type; when an organization fails to find a solution by searching in a particular way, it will be less likely to search in that way in future problems of the same type. *Thus, the order in which various alternative solutions to a problem are considered will change as the organization experiences success or failure with alternatives.*
>
> In a similar fashion, the code (or language) for communicating information about alternatives and their consequences adapt to experience. Any decision-making system develops codes for communicating information about the environment. Such a code partitions all possible states of the world into a relatively small number of classes of states. Learning consists in changes in the partitioning. In general, we assume the gradual development of an efficient code in terms of the decision-making rules currently in use.
>
> Thus, if a decision rule is designed to choose between two alternatives, the information code will tend to confine all possible states of the world into two classes. If the decision rules change, we assume a change in the information code, but only after a time lag reflecting the rate of learning. The short-run consequences of incompatibilities between the coding rules and the decision rules form some of the most interesting long-run dynamic features of an organizational decision-making model." [Cyert and March, (1963) 1992, *A Behavioral Theory of the Firm,* p. 174]

To some extent, the emergence of erroneous behaviors is taken to be a natural outcome of the 'imperfections' and limits of human rationality. Throughout their analysis, March and Simon maintain that shortcomings and errors in organizational planning *are embodied in the nature of human decision making*; a view which induces them on the one hand to explore the limits of *individual* rationality, and on the other to find evidence of *organizational* errors.

6.1 The explanation of biases as resulting from constraints on search processes due to computational complexity

In a series of papers now considered classics (1950-1979), Simon explored the decision making process from both the theoretical and experimental viewpoints. Taking the behavior of chess players as a benchmark for understanding the limits on the capacity of humans to discover strategies, he modelled a player's search for a solution as exploration within the tree of alternatives: errors in this context are generated by the need to simplify the search by pruning most of the branches of the tree, so that the number of game configurations requiring exploration can be drastically reduced. Players need to *simplify* the game's strategic *representation* in order to dominate the problem mentally. 'Simplifying' the search by deleting large parts of the tree *a priori* generally leads to discovery of a non-optimal strategy. This strategy would lose against a perfectly rational opponent; but because perfect rationality is computationally unachievable (the number of states to be explored to find the winning strategy exceeds the available memory of any human being), both players construct an imperfect, sub-optimal strategy, and both commit systematic errors. The winner is the player whose errors are less important than those of his opponent.

In a more general context of problem solving under conditions of complexity, decomposition of problems into sub-problems is one of the heuristics most widely used by human beings to achieve a solution. The decomposition is recursively applied to each sub-problem until elementary and easily-solved sub-problems are identified. The simplicity of an elementary sub-problem, may enable the player to discover the optimal strategy with ease. This is apparently the key to reducing the complexity of the original problem, and it is frequently used by problem solvers. Unfortunately, however, the discovery of all optimal solutions to the sub-problems does not yield the optimal global solution to the original problem. In fact, it is possible to show that the conditions under which the global solution (composed by the optimal sub-problems solutions) is optimal are very restrictive, and consequently most decompositions patterns lead to sub-optimal global solutions. (Egidi 2004)

The origin of this unexpected property can be understood if we consider puzzle solving. Here, players must build a simplified representation of the game in order to discover a (boundedly rational) strategy. The optimal solution to puzzles consists in the shortest path from the starting configuration to the goal. Given the enormous number of game configurations that must be analyzed to get an optimal solution, in order to obtain a simple representation of the solution, players classify the states of the puzzle into a relatively small number of *categories*: large sets of game configurations are therefore aggregated into few categories. These categories are the result of a process of abstraction and classification based on the salience of symbolic features of the configurations of the game.

In the case of Rubik's cube, for example, the arrangement of the colours of the tiles along one, two or more corners are salient elements with which to categorize classes of configurations that are supposed to come progressively closer to the final configuration. These categories allow the identification of sub-goals into which the original puzzle is decomposed. For example, one of the most popular strategies for solving the cube is based on a procedure by which players as a first step must form a cross on the top of the Rubik's Cube so that the colors of the edge cubes match the colors of the center cubes. To make the cross players must sequentially move a first corner, the central tile on the top face, the other three corners facing the same top face, into the right positions.

Each sequential position of the corners is mentally represented as a 'class of configurations' because it is defined by the positions of a limited number of tiles, while the positions of all the other tiles are irrelevant.

In other words, players consider classes of configurations as elementary building blocks during the search for a strategy. By discovering a procedure, they keep in mind a sequence of actions that connect classes of configurations together, assuming an *order* among them. Consequently, by simplifying the representation of the game through categorization, players build up an 'aggregated game' in which the configurations are aggregated states. They must conjecture the distance from the states to the target: that is, they must conjecturally order the categories in relation to their *distances* to the final goal. Frequently, however, the order that players conjecture does not hold for all elements of the categories: for example, when solving the Rubik's cube puzzle, players may 'naturally' believe that the class of configurations 'four corners in the right place' is closer to the goal than the class of configurations 'three corners in the right place', but this is not necessarily true for *all* elements of these two categories.

Players thus produce relatively simple and abstract representations of the strategy by categorization, but their evaluation of the order among the categories may be inaccurate. Owing to this distortion, the players do not always approach the goal along the shortest path; on the contrary, at least for some configurations, they achieve the goal by following a tortuous path that, in some steps, gets further away from the goal.
The most intriguing aspect of this situation is that, while the paths to the goal generated by a single procedure are optimal for some of the elements (the 'right' ones) but not for all of them, when players solve the puzzle for the 'right' elements, the optimality of their decisions will be confirmed. They consequently cannot easily perceive that they have made a wrong classification and modify their decomposition pattern accordingly.
It is evident that there are different categorizations and decomposition patterns to each problem. Some of them maintain the features of the original problem, but the vast majority do not and this generates decision biases. The set of all different decomposition patterns may be represented in a 'landscape' with different levels of 'fitness', i.e. with different degrees of sub-optimality (see section 7). In other words, when a player constructs one simplified representation of the problem by identifying some basic categories with which to describe the game, he discovers one point in the landscape. To move to a different point, i.e. to discover a different representation of the problem, the player must re-define some of the categories, or some relations among them. Learning a new game strategy is a process of redefining categories, and it is consequently a *cognitively effortful* process. This explains why it is so difficult to discover more efficient strategies of a game, and why players may remain locked into a sub-optimal strategy.
Experiments in puzzle solving (Egidi 2004) confirm the stability of sub-optimal representations, giving further support for Cyert and March's original explanation of biases in organizational behaviors.

6.2 The mechanization of thought

So far, we have seen that experimental data on puzzle solving show that, once most individuals have identified a strategy, they are likely to remain anchored to it even though it is not optimal. The first experiment in this domain dates back as far as 1942, when Luchins (1942) and Luchins and Luchins (1950) ran experiments with subjects exposed to mathematical problems for which there were different solutions with different levels of efficiency. The authors showed that when subjects had identified the optimal solution for a problem in a given context, they 'automatically' and systematically transferred it to a different context where it was sub-optimal. This process was called 'mechanization of thought'.
Experiments with *Target the Two* (Cohen and Bacdayan 1994, Egidi and Narduzzo 1997) confirm that a similar process is involved in behavior by a team, and in an even more evident and persistent manner: groups of subjects jointly engaged in solving a shared problem may remain even more stably 'trapped' in sub-optimal solutions than single individuals. In fact, whilst difficulties encountered by a single subject when solving a problem in a new way depend on whether a new solution can be discovered, and are influenced by cognitive limitations on individual learning, this is all the more the case of a group, because it must find new ways to cooperate in problem solving by devising and adopting an alternative solution jointly.

7 The evolutionary justification of rationality

Even though the most influential evolutionary approach to justifying rationality is Friedman's, the evolutionary justification was put forward by many important authors before and after Friedman did so.

The approach was first formulated by Alfred Marshall, who in articles published in the 1870s sketched a model of the mind and used it to describe the processes by which routines arise, and the mechanism of innovation and creativity within organizations (Rizzello,2003).
However, although Marshall's evolutionary view attracted many admirers among economists, it remained as a pure methaphor for half a century until the emergence, in the late 1930s, of debate on the realism of marginalist principles.
The debate arose after several authors – among them the Oxford Research Group – had argued that the empirical evidence did not show that entrepreneurs followed the marginalist principles of profit-maximization/cost-minimization in running their firms. (Hall and Hitch, 1939)
Harrod (1939) responded to these criticisms by claiming that profit-maximization was not observed in many firms partly because the information – marginal revenue and costs – necessary for such calculations was hard to obtain. But, he added, the 'best' decisions would nonetheless arise from a process of 'natural selection'.

> "New business procedures would then be analogous to new mutations in nature. Of a number of procedures, none of which can be shown either at the time or subsequently to be truly rational, some may supplant others because they do in fact lead to better results. Thus while they may have originated by accident, it would not be by accident that they are still used. For this reason, if an economist finds a procedure widely established in fact, he ought to regard it with more respect than he would be inclined to give in the light of his own analytic method."
> (Roy F.Harrod, 1939, *Oxford EP*)

Fritz Machlup (1946, 1947) and George J. Stigler (1946) joined the debate to defend the marginalist principle. But the best-known evolutionary view was put forward by Armen Alchian (1950, 1953), who argued that the neoclassical theory of the firm was not about firms as such but industries. Individual firms, Alchian maintained, essentially followed routinized procedures (as Harrod claimed), but it was the *industry* which adhered to the marginalist principles.
The first important breakthrough in the evolutionary approach was achieved by Nelson and Winter, who deepened the distinction between routinized and innovative behaviors and argued that the evolution of organizations does not necessarily lead them to optimality (Nelson and Winter, 1982, Winter, 1975, 2005).
In similar vein S. Kauffmann showed with his NK model (1989) that evolution by mutations may produce sub-optimal configurations in which a system may stay locked. His basic idea was that evolution is a process of collective problem-solving undertaken by organisms in their environment: the evolution of an organism, or in general of a complex biological system, is guided by its 'fitness', that is, by its reproductive success in the environment. The characteristics that determine the fitness of an organism can be represented in a discrete space because they are a set of 'traits' that can assume different values.
In Kauffman's original approach 'traits' can be proteins or genes, each of which can assume different 'configurations' or 'values' (alleles). An organism is characterized by N traits, each of which assumes a given value. A mutation is nothing other than a change in the value of a trait (allele). Consequently, to explore the effect of single mutations on the organism fitness we must change the values of the traits one at the time. A crucial property of the traits is 'epistasis': when a mutation is introduced, it normally happens that the effect on the organism's fitness depends on the values of other traits.
Call K the average number of genes that contribute to the fitness variation of the organism when a mutation occurs, i.e. the average number of epistatic interactions. K may vary from K=0 (total independence) to K=N-1 (total interdependence). In the former case, (K=0) the effect of a mutation on the fitness depends solely upon the single gene that is affected by the mutation; therefore by comparing the different effects of different mutations on the same gene, we can discover the allele that produces

the higher increase in the fitness. If we sequentially make the same comparison on all the genes, we can discover for every gene the alleles that make the best contribution to the fitness. We can thus increase the fitness of the organism until its maximum value by acting on each gene independently. This means that an organism with zero epistatic interactions may achieve an optimal configuration in response to a sequence of random mutations.

> "The assumption that each gene contributes to overall fitness independently of all other genes is clearly an idealization. In a genetic system with N genes, the fitness contribution of one or another allele of one gene may often depend upon the alleles of some of the remaining N-1 genes. Such dependencies are called *epistatic interactions* "(Kauffman, 1989, p. 539).

Kauffman shows that as the epistatic interaction grows, the number of local optima increase, and an organism affected by mutations may remain trapped once it has reached a local optimum.
Again we have an explanation of why complex systems, which can metaphorically represent individual or organizations, may remain trapped in sub-optimal configurations (see also Franken et al., 1999).
Kauffman's model provides important support for Nelson and Winter's views in the field of the evolutionary approach to organizations. When discussing the limits of competition, they emphasize that market mechanisms may not be able to select the best organizational structures and, again, that inefficient firms may survive in the long run.
In a similar intellectual context Levinthal and March (1993) single out a number of 'myopias' and 'traps' into which an organization may fall during the process of organizational learning. The two authors show, for example, that an organization tends to give priority to the short-term perspective over the long-term one ('temporal myopia'), and, because of this myopia, the long-period survival of the organization may be jeopardized. The temporal myopia trap has also been reported by research in the psychology of individual decision-making. In this area, the trap is most evident in the tendency of individuals to prefer small and immediate benefits over more substantial benefits that will accrue in the future. It is also manifest in the tendency of individuals to avoid small, immediate losses or sacrifices, preferring greater losses more distant in time. Therefore, we have both empirical evidence and formal models to show that individuals or organizations may remain trapped in sub-optimal strategies despite the working of competitive mechanisms.
This suggests that the idea (Friedmann's) that rational behavior arises through selection due to evolution is a metaphor with a limited range of application. Moreover, the large body of evidence on violations of the axioms of expected utility theory induces the charge of inconsistency against the methodological approach of Chicago school, as in the following harsh evaluation by Sidney Winter:

> It does seem clear to me that the idea of 'as if' maximization, along with its associated constellation of highly skeptical attitudes regarding the value of direct observation, is basically a defensive maneuver that serves to protect a seriously flawed theory. (Winter, 2005, p.9)

8. Decomposing Rationality and opening the Pandora Vase of human intelligence

A relevant (and only partially explored) aspect of cognitive traps is their 'stability': in many contexts, errors and violations of rationality are systematic and persistent. A number of experiments (Camerer 2004, Tversky 1977) show, in fact, that when subjects are made aware of *biases* connected to their choices, they only minimally adjust their behavior.
Tversky 1977 comments on these findings thus:

> "…Daniel Kahneman and I have studied the cognitive processes underlying the formation of preference and belief. Our research has shown that subjective judgments generally do not obey the basic normative principles of decision theory. Instead, human judgments appear to follow certain principles that sometimes lead to reasonable answers and sometimes to severe and systematic errors. Moreover, our research shows (Tversky and Kahneman, 1974; Kahneman and Tversky, 1979) that the axioms of rational choice are often violated consistently by sophisticated as well as naive respondents, and that the violations are often large and highly persistent. In fact, some of the observed biases, such as the gambler's fallacy and the regression fallacy, are reminiscent of perceptual illusions. In both cases, one's original erroneous response does not lose its appeal even after one has learned the correct answer."

We have thus far reviewed the explanation of biases and errors in puzzles and games playing based on incomplete representation of the problems, i.e. on purely cognitive features of human behavior, and examined the available evidence.

As we have seen, Luchins and Luchins show that when subjects have identified the optimal solution of a task in a given context, they automatically transfer it to contexts where it is sub-optimal. Luchins and Luchins's experiments demonstrate that, once a mental computation deliberately performed to solve a given problem has been repeatedly applied to solve analogous problems, it may become *routinized*. Its routinized use enables individuals to pass from deliberate effortful mental activity to partially automatic, unconscious and effortless mental operations.

This routinization of thinking is the emergent part of a more complex and general question: to what extent are our actions the effect of a deliberate mental computing activity, and conversely, to what extent is such mental activity accessible through introspection? This was a core question addressed by Kahneman's Nobel Lecture (2002), where he distinguishes (see Figure 1) two modes of thinking and deciding: what he calls *intuition* and *reasoning*. Kahneman notes that there is considerable agreement among psychologists on the characteristics that distinguish these two cognitive processes. Following Stanovich and West (2000), he calls them respectively System 1 and System 2.

> "The operations of System 1 are fast, automatic, effortless, associative, and difficult to control or modify. The operations of System 2 are slower, serial, effortful, and deliberately controlled; they are also relatively flexible and potentially rule-governed. As indicated in Figure 1, the operating characteristics of System 1 are similar to the features of perceptual processes. On the other hand, as Figure 1 also shows, the operations of System 1, like those of System 2, are not restricted to the processing of current stimulation. Intuitive judgments deal with concepts as well as with percepts, and can be evoked by language."

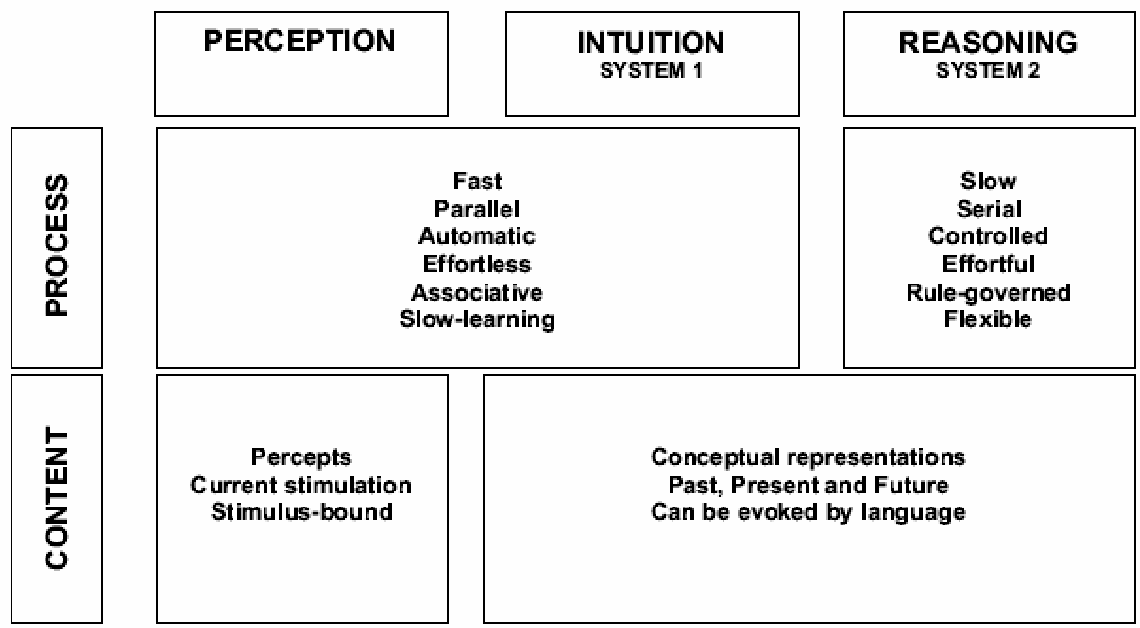

Figure 1 - Kahneman's description of cognitive processes

The distinction between System1 and System2 was first drawn by Schneider and Shiffrin (1977), who called them respectively 'automatic' and 'controlled' processes; since then many analogous two-system models have been developed under different names, as discussed by Camerer (Camerer et al., 2004)
The question raised by Luchins and Luchins fully matches this distinction because it shows how a process of reasoning – typically composed of slow, serial and effortful mental operations – comes to be substituted by an effortless process of automatic thinking.
Of course, understanding the inverse process is matter of equal importance: the question is how it happens that automatic mental activities are accessible to conscious thinking, and to what extent they may be used in deliberate cognitive activities. While some aspects of these questions being clarified by neurophysiology, and particularly by using brain imaging techniques, traditional psychological experiments, too, have furnished a great deal of important information.
The crucial element in understanding how automatic processes interact with deliberate mental processes is 'accessibility'. Accessibility is a continuum, not a dichotomy: experimental evidence shows that the more a person acquires information and competence in a particular domain, the more he becomes able to recall and use the automatic part of his knowledge. This implies that accessibility has different levels and that some operations demand more mental effort than others.

> "The acquisition of skill selectively increases the accessibility of useful responses and of productive ways to organize information. The master chess player does not see the same board as the novice, and the skill of visualizing the tower that could be built from an array of blocks could surely be improved by prolonged practice." (Kahneman Nobel Lecture)

The concept of accessibility is related to the notions of stimulus salience, selective attention, and response activation or priming. Following Kahneman again

> "Physical salience also determines accessibility: if a large green letter and a small blue letter are shown at the same time, 'green' will come to mind first. However, salience can be overcome by deliberate attention: an instruction to look for the smaller letter will enhance the accessibility of all its features. "(Ibid.)

In parallel with the two types of cognitive processes, psychologists define two types of memorization. On the one hand there is 'procedural memory', which is automatic, unconscious or non-conscious and is reflected in our actions. Well known examples of the use of procedural knowledge are driving a car and acquiring grammatical competence: in grammar acquisition, in fact, using plurals and the past tense in accordance with grammatical rules is automatic. The same happens in the repeated playing of games, where routinization leads to procedural knowledge (Cohen and Bacdayan, 1994).
On the other hand, there is 'declarative memory'. Declarative knowledge is effortful and open to conscious inspection, and it requires symbols. The most evident examples are mathematical operations and symbolization.
The distinction between explicit/controlled and automatic/unconscious mental processes has a parallel in the distinction between the 'constructivist' and 'ecological' *orders* suggested and analyzed by Vernon Smith. The former order, the 'constructivist' one, is related to declarative, controlled processes, while the latter refers to automatic processes. There is an obvious relationship between this view and Hayek's idea of institutions as an order not generated by intentional design. I refer to Vernon Smith's Nobel Lecture, which shows in masterly manner how markets and other economic institutions are pervaded by the interaction between constructivist and ecological rationality. (Vernon Smith, 2002).
The distinction between the two cognitive systems helps us move toward a new, more complex explanation of systematic deviations from pure rationality. Without describing all the consequences of this new view, here I merely point out that recent evidence from the neural sciences further emphasizes the importance of emotional processes.(Camerer et al., 2004 forthcoming)

The discussion in the previous sections relates to the limits of rationality due to constraints in System2, the controlled process of reasoning (based on symbolic manipulations). The processes of editing and building a representation of a problem are seemingly related to the threshold between the two systems, and to the dynamic of interaction between them. In fact, on the one hand we have the "routinization" of thought; on the other, the emergence or "elicitation" of unconsciously memorized items used as elementary building blocks in deliberate reasoning. A clear example is provided by chess.
Chess grandmaster performances are based on ability to process and deliberately use more than 20,000 chessboards stored in the procedural memory. To some extent, these items can be considered the basic building blocks in representation of the game and discovery of a satisficing strategy. The difficulty of substituting some or all of these basic items with new ones can, as we have seen, explain the general suboptimality of strategy building.

Concluding remarks

The economic methodology inherited from the Chicago school becomes untenable when formal demonstration is made that problem solving leads generally to sub-optimal stable solutions: the 'as if' justification of perfect rationality proves to be a fallacious metaphor; errors and violations of rationality are recognized as systematic; and the limits of rational behaviors can no longer be defended with the idea of a process of selection of the best.

With the waning of this approach, the cognitive characteristics of choice processes are regaining ground in the long-standing debate between psychological and normative view. Both the *bounded rationality* and the *behavioral economics* approach hold that the crucial aspect of the *deliberate* decision-making process is the ability to construct new representations of problems. The evolution of analytical tools and experimental outcomes is shifting the focus of attention from the *coherence/incoherence* of choices to the *representation and editing* of problems. The distinction between two types of cognitive processes – the effortful process of *deliberate reasoning* on the one hand, and the automatic process of *unconscious intuition* on the other – can provide a different map with which to explain a broad class of deviations from pure 'olympian' rationality.

How human actions arise as the joint effect of these two cognitive processes, how institutions function as the joint effect of tacit and explicit knowledge, are becoming crucial issues for decision theory; issues whose examination will yield better understanding of human rationality.

Such analysis requires establishing an inextricable connection between psychology and economics: a demanding and important task which raises questions concerning one of the fundamental statutes of the neoclassical construction of economic theory: Lionel Robbins' idea that economy is a normative science whose tenet is the logic of means and ends.

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