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The Distributed Cognition Approach

2005/09

UNIVERSITÀ DELL'INSUBRIA
FACOLTÀ DI ECONOMIA

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Printed in Italy in September 2005
Università degli Studi dell'Insubria
Via Ravasi 2, 21100 Varese, Italy

Extending the Bounded Rationality Model: The Distributed Cognition Approach

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September 2005

Abstract
The way Simon, and the major part of the scholars, presented and used bounded rationality directly refers to human computational capabilities (or "brute-force"). Despite its broad powers of explanation, some problems arise when taking into account the way the human cognitive system really works. In order to avoid these problems, we present an alternative model of rationality, where computation plays only a part, together with the implemented role of external resources, emotional and other non-strictly-rational variables.

Key-words: bounded rationality, distributed cognition, external resources, decision-making, problem solving, emotions

"[T]here is a desperate need for a more complete understanding of the cognitive literature by organizational behavior researchers."
Ilgen D.R., Major D.A., and Spencer L.T., 1994

Introduction

Rationality, intelligence, and, broadly speaking, human cognition have always captured the greatest interest since Greek philosophers began inquiring into their nature.
Far from these first thinkers, today the applied social sciences need to reach a more detailed understanding of human behavior: how, when and why we act. In particular, psychological and economic modeling tries to define human behavior through hypotheses on rationality. One of the most important approaches is that of bounded rationality, introduced by Herbert Simon.
The model, though a very far-reaching and powerful one, defines human behavior in a narrow way and fails to focus on relevant cognitive resources. We attempt to enrich and increase complexity of the bounded rationality model in order to uncover human cognitive capabilities, arguing that rationality is limited, but not in the sense Simon put

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it.
After defining the main elements of the bounded rationality model (Section I), we try to outline its strengths and weaknesses (Section II and III). The last section before the conclusion (Section IV) is dedicated to defining our approach to extending rationality.

I. The bounded rationality model: An overview

The concept of bounded rationality was first introduced by Herbert Simon in one of his first and most well-known works (1947). Since 1947 Simon himself returned to the point many times (see, for example, 1955; 1978; 1979; 1983) and other scholars also used bounded rationality (for example, see Cyert and March, 1963; Nelson and Winter, 1973; Kahneman and Tverzky, 1982; Williamson, 1975).
Despite the huge number of Authors grounding their works on the concept or just mentioning it, bounded rationality (henceforth BR) remains "little used" in its fundamental implications (Foss, 2003). Here, we can distinguish between analytical theories that improve the original model (Simon, 1955) and theories that describe further implications or applications of the original definition (Simon, 1947), without analytical, i.e. formal mathematical, references. However, most theories refer to BR as a powerful analytical basis, without questioning or modifying it directly (Foss, 2003; Conlisk, 1996). For this and other reasons, that will be addressed below, we prefer to refer our hypotheses directly to Simon's approach (see also Lipman 1995, p. 43).
As for Simon, "rationality is concerned with the selection of preferred behavior alternatives in terms of some system of values whereby the consequences of behavior can be evaluated" (Simon, 1997, p. 84). That is to say that rationality is about (1) the selection of alternatives through a (2) system of values that allows individuals to (3) behave in some way that can be submitted to (4) evaluation in its actual and potential consequences. Hence, rationality is concerned first with problem-solving and decision-making activities, and then with the evaluation of results. However, the described process implies other necessary elements.
"Alternative selection," has to do with alternative searching. To express it more precisely, nothing can be selected if we do not look for alternatives first. Thus, the process of seeking alternatives is fundamental in decision-making. It is worth noting that alternatives are to be made, i.e. they are produced by the individual engaged in the decision-making process. Since alternatives are not exogenously given, we focus our attention on two distinct possibilities. First, if the individual accesses to all possible alternatives, i.e. she/he is capable of creating a map of actual and potential effects of her/his behavior, we say she/he is fully-rational. Second, if the individual cannot produce the overall range of alternatives, i.e. she/he has limited computational capabilities and/or doesn't have full access to environmental data and variables, we say he/she is capable of bounded rationality only.
The former is the *economic man* of the neoclassical approach describing "how people *ought* to behave, not how they *do* behave" (Simon, 1959, p. 254). The latter is the *real* decision-maker, essentially limited in his/her computational capabilities by internal and external limits.
In other terms, to use Simon's own definition, "rationality is bounded when it falls short of omniscience. And the failures of omniscience are largely failures of knowing all the alternatives, uncertainty about relevant exogenous events, and inability to calculate consequences" (Simon, 1979, p. 502). Broadly speaking, limits on rationality derive from natural constraints of human perception and from the fact that we are incapable of

computing the overall range of possible events. The first set of constraints relate to the environment, while the second refers directly to human rational capabilities (1955, p. 101).

These assumptions make management science focus on the way individuals make decisions and solve problems within organizations, and hence in any kind of social organization and group. Focusing on social organizations gave Simon a more detailed approach on the rationality issue. He tried to show that decision-making needs to relate with advancements in psychology and social psychology studies (1947; 1959). This aspect was underlined in order to question how relevant are, for example, role-based mechanisms or motivation within organizations (1959). Simon had a wide view of the problem, since bounds to rationality were not seen as limited to the lack of computational capabilities, but extended to all sorts of variables (both material and products-of-thought) that do limit human rational resources.

The concept of bounded rationality can be mainly defined in relation to the neoclassical one. This is the way the Author did it, and this is the common way it is usually defined (Todd and Gigerenzer, 2003). Following this line of argument, once the result is obtained, it needs to be evaluated (see step 4 above). And then, if rationality is bounded, which kind of result do we obtain? The answer is a quick one. The hypothesis is that human rationality cannot map all environmental variables, create all the deriving alternatives, scan them, and then select the optimal option. In other words, if we are not able to maximize, we can only make an approximation to the optimal option. Therefore, individuals with bounded rationality reach *satisficing* results, i.e. they can only approximate the optimal result that is typical of the neoclassical equilibrium theories.

Here the role of search mechanisms is crucial. Individual decision-making is based on seeking alternatives, and selecting them on the basis of a definite set of values. The metaphor Simon uses in order to explain this kind of searching is the decision tree (Simon, 1997; Newell and Simon, 1972), where each alternative is expressed by a payoff (see below). In his 1955 article, he analytically formalized this approach and developed it further in his works with Alan Newell on artificial intelligence (see Newell et al., 1958; Newell and Simon, 1972). It emerges that the idea of rationality is completely related to computational capabilities (March, 1978, p. 590) rather than to the broader cognitive system. Behavior can always be defined through algorithms, even if in an imperfect way, and the bounded rational woman/man compute (the acts of searching-evaluating-selecting) which alternative could be more appropriate.[1]

The result leads then only to the *satisfacing* and not to the optimal option. Following this approach, Simon rejects the principle of the *one-best-way*, introducing the concept of *second best*. This implies that solutions to problems or selection of alternatives can be only sub-optimal, in the real world. Moreover, we may obtain, and we normally do, more than one sub-optimal alternatives (or solutions) to a given situation (or problem). Thus, the bounded rationality model tries to take into account variety and complications in decision-making processes.

[1] This is not the case of the so called “maximizing under constraints” approach to bounded rationality (Stigler, 1961). As Todd and Gigerenzer wrote, “[i]ntroducing real constraints does makes this approach more realistic, but maintaining the ideal of optimization, that is, calculating an optimal stopping point, does not. What is lost is psychological plausibility, because such an ideal of optimization invokes new kinds of omniscience, being able to foresee what additional information further search would bring, what it would cost, and what opportunities one would forgo during that search.” (2003, pp. 45-46). See also Consisk (1996) on this point.

The result is a serious challenge to the traditional neoclassical model that remains, it maybe, consistent in normative-prescriptive terms but completely fails in its descriptive-behavioral attempts (for a clear distinction between the two aspects, see March, 1978; but also Frank 1988; Etzioni, 1988).

II. Main implications of the BRM

The original model has been applied in a very broad number of cases (Foss 2003; Conlisk 1996). The most important element from these contributions is that of underlying particular aspects of the general theory; although they introduce little improvement on the analytical side (with few exceptions, for example see Selten, 1998). In this section we provide the most relevant implications of the bounded rationality model (BRM), as developed both in Simon's and in other Authors' works. In any case, we do not mean to review the literature, as contributions such as those of Foss or Conlisk greatly increase the scope.

Substantive and procedural rationality

Simon placed great emphasis on the distinction between *substantive* and *procedural* rationality (see also Munier, Selten, et al., 1999, p. 234). He described that difference stating that "we must give an account not only of *substantive rationality* – the extent to which appropriate courses of action are chosen – but also *procedural rationality* – the effectiveness, in light of human cognitive powers and limitations, of the *procedures* used to choose actions" (Simon, 1978, p. 9; italics in the original text).
According to substantive rationality, the rational character of decision-making is concerned with the result one could get following the "appropriate" actions. Whereas procedural rationality points out the procedure and the process by which people make decisions. According to Simon, bounded rationality belongs to the latter category, because it does not look only at the result one could get, but at the way people make decisions (Simon, 1978).
In contrast, the traditional model of rationality (i.e. the neoclassical) mixes the two aspects. The model is based on variable maximization (procedure), where we obtain the only possible appropriate behavior as a result (substantive).
Although there are several reasons that support Simon's claim, our contention is that it may turn out to be misleading. As mentioned, both the neoclassical and the bounded rationality model can be viewed as examples of procedural rationality. In addition, from this procedural perspective, differences seem to disappear. The result – the so-called *optimum* or neoclassical *equilibrium* – is closely connected to the way through which it is achieved.
In order to make our point, we assume, as Simon does (Simon, 1947/1997, p. 121),[2] that rational decision-making can be described as a "tree" game in which nodes correspond

[2] Newell and Simon were aware of the limits of the decision tree: "If we are to construct a theory of the subject's thought processes, and to refer in that theory to the set of behaviors he considers, we must include in that set even behaviors that, though considered, prove infeasible, illegal, or in some other way impossible. We must, so to speak, represent the subject's wishes and dreams as well as more realistic thoughts. There is no essential reason, of course, why such considerations should remain covert. […] The situation where the subject considers alternatives beyond those included in the game tree or other representation of the genuine behavior possibilities is not the only one that makes it difficult to describe the environment objectively. Another whole set of difficulties arises out of the fact that the subject may recode the situation completely" (1972: pp.60-61).

to positions and branches represent the alternative *moves* from each position. According to Newell et al. (1958), we assume that each move can lead to positions with known payoffs: (+1) meaning a win, (0) meaning a draw, and (-1) meaning a loss.
If we define decision-making in this way, for each turn we are able to define the best move. Since our cognitive and computational capabilities are limited, and the environment often reaches high levels of complexity, we can cope only with a *small fraction* of turns. Therefore, we will never get the best position available, because we cannot scan and see the entire tree. The best move at a certain turn may lead us to a losing position, at the end.

FIGURE 1
The decision tree

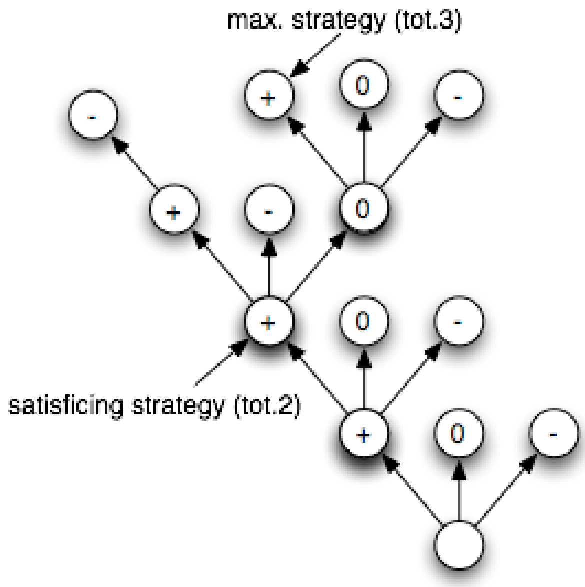

Figure 1 shows a visual example of what a decision-tree is. The best position after turn n. 3 is still not the best after turn n. 4. That is, in order to attain a maximizing strategy, we have to know all the possible consequences connected to each alternative. Simon's idea of bounded rationality makes precisely this point. Since we are limited, that is, we cannot know everything relevant to our choice, we just make a decision that is (or may be) the best at a certain time. But it is not the best *ever*.
The conception of optimum used in this case is clearly procedural, because it mainly concerns strategies, procedures, and behaviors. Here, the term "bounded" refers to the individual limited use of that maximizing strategy, leading to the optimum result, i.e. the one-best-way strategy. And then, the term "rationality" does refer to that procedure, i.e. to human computational abilities. This is exactly the point we are addressing: we may argue that Simon does not reject the neoclassical model of rationality (NCM), namely, the maximizing idea based on computational capabilities. He rejects the fact that humans can employ it in the way the neoclassical approaches put it (Newell and Simon, 1972).

Bounded rationality and optimizing

Is rationality really anything different from what was originally thought to be? Does the fact that humans cannot fully employ neoclassical procedural rationality imply any change in terms of rationality modeling? And, if so, what would this change?

The most likely answer is that the concept of rationality does not in fact change. Bounded rationality theory just points out that the result we can get is only a satisficing one, i.e. we get *approximating* solutions (Simon, 1955, p.101ff; 1979). The described process is merely a computational one. When we get approximating results, we are supposed to make computations on external and internal variables, limited by our perceptive system and bounded rationality. If so, rationality remains a maximizing procedure, namely, the "brute force" or computational procedure that humans can only partly employ.

Nevertheless, bounded rationality challenges the neoclassical model, at its very basis, (or the SEU of Morgenstern and von Neuman, 1944). It has been, and still is, a powerful concept directed to opening the "brain as a black-box" hypotheses of the traditional economic theories. Simon opens human economic reasoning to other disciplinary domains, such as psychology, social psychology, computer science, cognitive science, politics, and so on. In other terms, it was an outstanding first step towards the search for a more realistic way to define human behavior.

The static model

We claim that the way in which bounded rationality is modeled can be thought of as static. We explain our point through a simple example. Imagine a large enterprise's senior marketing manager deciding on the right price of the top product. She/he could take into consideration the common variables – such as operative costs, break even analysis, possible mark-ups, competitors' prices, market prices, value added, market share, penetration forces, sector and general forecasts, and more – in order to fix the right price. In solving the problem and making the decision, she/he should cooperate and coordinate with his/her team/staff. Once data are gathered and the needed variables are defined in their trends, she/he must decide.

Following Simon's and not only his model, this is the point when the manager really starts thinking, as in the decision tree case (see below), i.e. mapping and evaluating the alternatives. The final price might then greatly or slightly differ in relation to the approach followed. In other terms, suppose the executive uses, on one side, the break-even analysis (BEA) and, on the other, the market leader's (ML) price as a benchmark.[3]

We have three possibilities: 1) the two prices are equally likely; 2) the BEA is higher than the ML price; 3) the BEA is lower than the ML price. The right alternative can be chosen in relation to other environmental variables, i.e. depending on corporate marketing policies (aggressive, follower, etc.).

However, further problems do arise at different levels; and, for example, (a) the way alternatives are represented lead to different solutions (BEA can be modeled using a huge number of methods), (b) the mean (BEA, ML, or both) chosen can even lead to

[3] One can think of mixing the two approaches (BEA and ML) into a third that is defined by shared information. We can call it the hybrid approach (HA). In this case, we have a 3x3 matrix, in which the first diagonal expresses the same result, i.e. when the three approaches lead to the same price. So that, we have seven different alternatives; but the problem doesn't change in its logical arguments.

change policy, (c) the degree of motivation or responsibility the manager maintains can influence the aseptic decision tree procedure (these are standard arguments in the organizational behavior debate, and stem from its origins; see for example Maslow, 1954 or Weick, 1969). It clearly appears that considering the last three points leads to a more interactive way to think about the decision-making process, i.e. bounded rationality has no dynamics; it is significantly a static one.
To put it in the way that Beach and Mitchell do, we infer that bounded rationality does not deal with *progress decisions*, i.e. decisions that make progressive tests on the fitness of the expected results (plans) with environmental variables and actual process development (Beach and Mitchell, 1998, p. 14). Describing these decisions through a decision tree leads to a high degree of complexity that might not be so easy to manage and interpret. Moreover, in actual decision making and behavior, sometimes the mean-end relation is not evident, as it ought to be in the model (Beach, 1997).

III. Using the BRM: major constraints and problems

The main difficulty that bounded rationality encounters is that of explaining the overall range of *successful* performances (Hanoch, 2002). In this case, the argument of bounded rationality is leaking.[4] While it is empirically grounded that individuals display severe computational limits, they actually carry out very complex tasks that do not simply approximate the best solution. This can be easily demonstrated using two different claims.
On the one hand, following Simon's approach, the optimum result can never be reached (Simon, 1979). We suggest, additionally, that the optimal result cannot even be envisaged. This is a relativity-based position, and we can argue that if we don't know what the optimum is, why do we "approximate"? What result should we obtain if it cannot actually be calculated? So, successful individual behavior can be evaluated through many procedural methodologies, through which the computational remains the one related to the non-reachable and non-thinkable optimum (Silver and Mitchell, 1990).
On the other hand, we can come back to the emergence of creativity; it "is a form of decision making that requires heuristics rather than logical, comprehensive calculation" (Stroh, Northcraft, and Neale, 2002, p.113). How can we explain the breaking of computational schemes? What happens when individuals "create" a highly successful solution without computing at all? The history of human discoveries displays plenty of these amazing and highly successful results. How can the bounded rationality theory explain that?

Procedures and results

In order to illustrate our point, let us introduce an important distinction between procedures and results. This is a common distinction in managerial science, where efficiency is the measure of the way in which results are organized, that is the procedures (or processes), while effectiveness is the measure of results on the basis of the original goal. The first refers to means, the second to goal evaluation (Drucker, 1973; Mintzberg, 1989; and also Simon, 1947, chapter 9).

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[4] This derives also from works by Beach and Mitchell (1998) and Beach (1997; 1998).

In the case of the neoclassical approach to rationality, we have "maximizing" or "optimizing"[5] procedures and "optimum" results (see Table 1). Let us use these terms without directly referring to the neoclassical tradition of thought. In the first instance, *optimum* can be considered as an *end-state* notion[6]. That is, we do not care about how to get a certain result: we just look at the outcome of a decision whether it is optimum or not (efficacy). According to that, optimum results can be regarded as *the best* results possible (i.e. always *successful*), in given conditions, i.e. *ceteris paribus*.
Secondly, optimum can also be considered as an outcome that is strictly defined by a given *strategy*. In this case, the term *optimum* refers to a procedure that is the *optimizing* strategy or *brute force* strategy (efficiency). Therefore, we may have an *end-state* optimum or optimum result (that we may call *the best* or *always successful result*) that may be independent to the optimizing strategy. To sum up: optimizing procedure is not equivalent to the optimum result or, likewise it can be said that procedural effectiveness may not coincide with the best result possible. In other terms, if we focus on results and on procedures independently, we might obtain different outcomes (Mintzberg, 1989).
The case should be that of, for example, the top manager of a medium-sized enterprise "sensing" a great opportunity in terms of increasing the corporate market share and revenues, and taking a high risk at his own responsibility, i.e. without following the standard internal procedure. The problem there concerned is that of reaching the effective result in the most efficient way. In other words, he has to re-organize costs in order to reach the higher market share. The internal procedure ought to differ significantly, being that it involves consulting human resources, marketing, product, and sales directors first, and starting with the usual decision-making procedure. Supposing that the two approaches are "perfect," i.e. without transaction costs, the players fully-rational, and so on, "the best," result, in this case refers to the efficient procedure, or to the effective result. However, usual decisions have to deal with multiple tradeoffs and externalities. In a real life situation – i.e. with transaction costs, instable environmental conditions, and so on – these two procedures often greatly differ. In some cases, what we called 'sixth-sense' and what can equally be defined as creativity, intuition, personal attitude, leadership, etc., counts and leads to results that "fit" the situation.

TABLE 1.
The meanings of optimum

	END-STATE	**PROCEDURAL**
OPTIMUM	ALWAYS SUCCESSFUL OR THE BEST RESULT	OPTIMIZING OR BRUTE FORCE STRATEGY

Our main claim is that Simon simply fails, in assuming that highly *successful results*, or *optimum ones*, can *only* be obtained by a brute force strategy, as if it is the *only* rational

[5] We use the terms "maximizing" and "optimizing" as synonyms, even if they are usually employed with slightly different meanings. In fact, maximizing is the process of reaching the maximal result, on a given set of variables; in this sense, it maintains a mathematic flavor. Optimizing is the best result, i.e. maximization of the entire spectrum of variables. While Simon refers to the first, the neoclassical Authors normally refer to the second.
[6] We derive the term "end-state" from (Hempel, 1958).

strategy. That is, Simon seems to deny the possibility of getting an optimum result without employing an optimizing procedure. Bounded rationality theory just states that the ensuing result from this strategy can only be approximating, because of human limits.

Explaining successful outcomes

Generally speaking, we may claim bounded rationality theory is fairly grounded when it deals with explaining human failures; but it fails in coping with other situations that do not necessarily involve unsuccessful outcomes or biases. Hence, the question that still challenges the theory of bounded rationality is: If we could get a successful (workable) result using a different strategy, would brute force rationality be exploited? Would we still be bounded in that way?

In summary, bounded rationality is based on the following assumptions that are somehow misleading:

(1) maximizing strategy is the only way to get successful results;
(2) the notion of bounded rationality refers to the extent to which we can employ the brute force strategy;
(3) the notion of satisficing concerns the results that the limited humans could get by employing an optimizing strategy;
(4) humans can only partly employ this strategy because of their limits and the complexity of the environment.

We accept (3) and (4), but we reject (1) and (2). This is due to the fact that these two assumptions cannot allow us to explain and account for all those situations in which humans successfully carry out complex tasks. The distinction between maximizing strategy and optimum results turns out to be important for another reason we will detail in the following section.

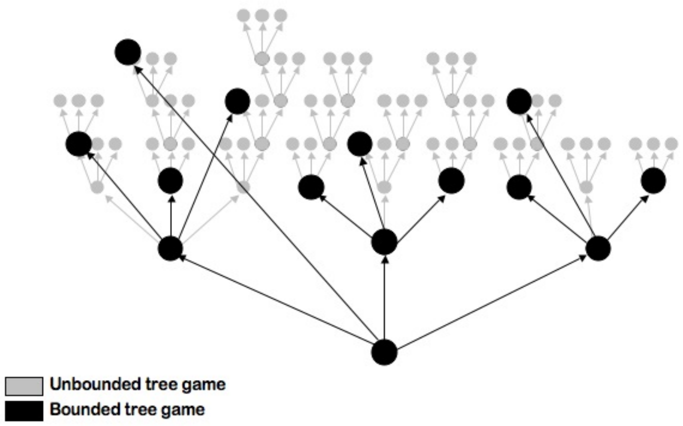
Beach and Mitchell (1998) presented a theory of decision making that is intended to overcome these difficulties; it is the so-called *image theory*. As they explain in summary (1998), the theory is based on "three different schematic knowledge structures" (p.12) that decision makers use to "organize their thinking about decisions" (p.12). These structures are called images, and are: (1) Value image. This first structure is related to general principles on which behavior (both individual and organizational) is based. It deals with what is behaviorally right or wrong and it is not difficult to argue that it relates to one's personal moral beliefs; (2) Trajectory image. This image is related to the goals (p.12) one tries to achieve; it underlines that everyone, in achieving determined objectives (real or abstract ones), generates a personal view (vision) about the future possible outcomes and everyone has hopes and fears about goal achievement. Here, emotions seem to be called into action, but nothing is explicitly mentioned in the text (on this point see page 12). This trajectory image seems to be very dynamic, in the sense that it constantly modifies, depending on the type of goal set, and on the means one has to achieve it. Depending on the type of goal and of the decision (procedural or one-shot) the image can dramatically change; (3) Strategic image. Here the plans set to get the result are central; concrete actions are called tactics, while more abstract anticipation of future events is called forecasting (pp.12-13). This image needs the second to come into existence. This is the "hard core" of the theory, in the sense that it can be re-conducted to previous decision-making theories (Simon 1955, 1957; March 1978; Simon and March 1956; etc.). Strategy can change with the addition of

information, that is to say with modifications in both environmental and internal (cognitive) variables.
Despite the powerful set of analytical and empirical work around image theory, the arguments for "images" are still to be found. However, we refer to this theory as one of the best attempts to move forward from the first approaches to the topic of decision making, and our work intends to be a contribution, going in the same direction as image theory. As we will explain below, our objective is to analyze the inner core of human cognitive capabilities in order to provide theories of decision making with a powerful set of concepts that are able to frame human behavior. To this extent, our theory of decision making integrates (if not comprehends) image theory.

The notion of heuristics

In order to overcome all the difficulties related to explaining successful outcomes, Simon introduces a sort of *ad-hoc* argument. He argues that humans often employ what he called approximating mechanisms (Simon, 1955, p.101ff; 1979). These mechanisms, called *heuristics*, or rules of thumb, allow us to have a general picture of the problem one is facing. That is, they reduce the cognitive and computational demand to solve a problem or make a decision (Simon, 1957; Hanoch, 2002). We claim that this is somehow an *ad-hoc* explanation, because it cannot be fully integrated into the general model of bounded rationality. Some questions immediately come up: Is heuristics part of the rational process? Or is it just a *trick* to solve complex problems?

FIGURE 2
The decision tree revisited



Our argument arises from the above mentioned distinction between procedures and results. One of the assumptions that bounded rationality theory makes is that computation (that is formalized through optimizing procedures) is the only way to get successful but satisficing results. If that is true, heuristics can only get satisficing results, because it *approximately mirrors* the optimizing procedure. It follows that the notion of heuristics itself cannot explain why humans may get successful results; it can be related to a game tree, with ex post explanations only. To make this point clearer, let us consider Figure 2. Here, from the initial point, the decision maker can immediately reach a high alternative at the fifth level, or she/he can make the first choice and then skip to the fourth. This is, in extreme synthesis, a scheme of what we can refer to as

‘heuristic’ in decision making.
It seems that the concept of heuristics refers only to a simplification of the task one faces. That is, our contention is that heuristics does not change *the way* we cope with a problem: it just helps us to have a general picture. In this sense, it is something like a *poorly detailed city map*. We can see the wide main streets and the railway station, for instance, but not the post office, the information center, or even shops, hotels, secondary streets, and so on. Indeed, even a poorly detailed map can be useful in many cases, however, the point is that heuristics does not provide an alternative behavioral model of decision-making, because it *essentially* remains based on the tree game, that oversimplifies reality. In this sense, the concept of heuristics is completely coherent to an *under-constrain* – or bounded – procedure of optimization.
However it is, the notion of heuristics that seems to introduce a radical and different perspective about how we make decisions and solve problems. As shown above, heuristics as an *ad hoc* argument is lacking, but it can be very useful in order to devise an alternative model: it can be considered as an anomaly that we must take into account (Kahneman, Knetsch, and Thaler, 1990; Camerer, 1988). The main reason to attribute such a role to it is that heuristics can be viewed as a *facilitator*. That is, it helps humans to manage complex tasks, and even *create* new valuable solutions.

The role of emotions

In the last part of his life, Simon placed increasing emphasis on the role played by various mechanisms, such as emotions, that help bounded rationality (Simon, 1983; Simon, 1947/1997). The argument is: humans can be partly rational because of their limits and the complexity of the environment. Therefore, they try to devise *alternative paths* to overcome all these constraints; that is connected to the idea of heuristics. As Simon put it: “emotion has particular importance because of its functions of selecting particular things in our environments as the focus of our attention.” (Simon, 1983: p. 29). Although Simon acknowledges the role of emotions in setting agenda for problem solving, he has never tried to integrate emotions, or other various external mechanisms, into bounded rationality (Hanoch, 2002). In contrast, the role of emotions in decision-making may help us to introduce the argument we will fully develop in the third section of this paper.
Several authors have recently opened up new and interesting perspectives on the cognitive role played by emotions. Favored theories mainly fall into two general categories (Thagard, 2005).
The first category considers emotions as judgments about a person’s general state (Oatley, 1992; Nussbaum, 2001; Scherer et al., 2001). Accordingly, an emotion, for instance, *fear*, can be viewed as a result of an *inference* that accounts for certain *clues* and *triggers* a certain response. In this sense, emotion is a *summary appraisal*.
Hanoch (2002), for example, pointed out that “emotions operate with rational thinking in two distinct ways: (i) they restrict the range of options contemplated and evaluated; (ii) they focus the agent’s attention on specific parameters or aspects of the information” (p. 3). Emotions, rather than being a mere constraint to rationality, are also an aid to rationality. To be more precise, they (a) “function as an information processing mechanism with their own internal logic, working in conjunction with rational calculation, […] *(b)* can function as a mechanism for establishing a hierarchy of goals by pressing us to pursue goals that have high survival value while setting aside less

urgent ones" (pp. 7-8; italics added), moreover, (c) emotions also let "individuals imagine what can happen" (p. 13; Shackle, 1961). Finally, the important issue to be noted here is that we cannot understand human behavior without analyzing the role that emotions play in conjunction to rationality.

Redefining Hanoch's argument, in order to address problem solving and decision-making more fully, emotions can be seen to play a very important role regarding four specific points. The first concerns paying attention: a strategy is needed that allows people to focus their attention on a selective set of information. The second point regards generating alternatives or improving those that the individual already has. The third is about gathering relevant facts to draw plausible inferences from them. Fourth, people need rules that tell them when to start searching for alternatives, but also when to stop. In each of these four stages emotions play a fundamental role.

The second category considers emotions as bodily reactions. Damasio (1994 and 1999) pointed out that emotions are *collections of chemical and neural responses* that use the body as their theatre. According to that, emotions serve two main purposes: first, the production of a certain reaction; for instance, *fear* may induce humans to run away, if facing danger. Second, emotions regulate internal states of the organism so that it can be ready to effect a certain reaction. Increasing blood flow and breathing rhythm are examples of this kind (Damasio, 1999).

Our claim is that these two views about the nature of emotions are not alternative, but rather complementary. As stated by the first category, we may argue that emotion is a kind of *representation* (or *cognitive state*) that can be considered a part of the cognitive process involved in decision-making. It helps humans to concentrate upon what matters, overcoming our limited computational resources. However, as argued in the second category, the cognitive relevance of emotions is not the one displayed by *cold reasoning*. In fact, emotions also involve a bodily reaction. In this sense, the representation we have of emotions is not something triggered within our conscious mind; in fact, physiological changes occur in terms of breathing rate, blood pressure, and so on. Accordingly, we may say that the body *is* the theatre of emotions (Damasio, 1999). Hence, the question is: what kind of representation is an emotion connected to? What is its nature?

Our contention is that emotion can be considered as a cognitive resource, although *distributed* across the human body. That is, the representation of an emotion is not (entirely) mirrored by an internal structure we can *verbally* or *consciously* access or induce. There are several empirical cases that support this conclusion. Let us quote a very interesting case-based study; that of *David* (Damasio and Tranel, 1993; Damasio, 1999). Since extensive brain damage to both temporal lobes and the region of amygdala, David has severe limitations in learning new facts and memory. Although these limitations do not allow him to name or even recognize any new person, he is able to make sound judgments about others. What puzzles us is that he can recognize whether a new person is trustworthy or not, if they are good or bad; but if asked, nothing comes to his mind about *why* he made that judgment, no images, no memories. The explanation provided by Damasio is that David's brain damage does not prevent emotions from doing their job. That is, emotions do not need any conscious state. This points to the conclusion that emotions are representations, that is to say, *cognitive states*, that are *external*, *bodily rooted*, and *unconsciously triggered*.

Regarding emotions as external representations suggests an alternative model of rationality and decision-making, since the notion of cognitive resources is somehow extended to domains such as that of emotion.

IV. De-bounding rationality: extending the model

The line of thought we are trying to pursue, leads us to point to a few relevant features of the original model of bounded rationality. In synthesis, the major claims are that bounded rationality (1) relies on computational capabilities only, (2) establishes a computational procedure to reach satisficing results, (3) doesn't recognize the role of internal and external variables not directly connected to computation. These points make the model out to be a static one.
In order to avoid these fallacies in understanding and describing human behavior, we present a model of rationality based on recent theories of *distributed cognition*.

Internal and external resources

Some of the critiques on the original bounded rationality model refer to the dichotomy between environmental and internal resources. Belonging to Todd and Gigerenzer (2003), the two spheres can be thought of as internal and external constraints to bounded rationality. In particular, different schools of economic thought emphasize the former or the latter element. Nevertheless, the two Authors insist on the fact that "there is another possibility regarding the bounds, external and internal, that surround our rationality: rather than being separate and unrelated, the two sets of bounds may be intimately linked" (2003, p. 144).
This is a sort of "third approach" to the issue of limits to rationality, as posed by the Authors. The merger seems to confer dynamics to the original BRM, as "the internal bounds comprising the capacities of the cognitive system can be shaped, for instance by evolution or development, to take advantage of the structure of the external environment" (2003: p. 144). That is to say that the two "bounds" are strictly interconnected, as the external ones modify (or "shape," as they put it) the internal ones. Thus, bounded rationality is the "positive outcome of the two types of bounds fitting together. In other words, humans exhibit *ecological rationality* – making good decisions with mental mechanisms whose internal structure can exploit the external information structures available in the environment" (2003, p. 144; italics in the text).
Todd and Gigerenzer's intuition is very original and is developed through a so-called "ecological rationality research program." It consists in defining heuristics – i.e. the way individuals gather and process data related to a specific problem – that match specific scenarios (pp. 148ff). Selected heuristics are very simple, and the Authors' thesis shows how effective behavior can also be explained by "fast and frugal" mechanisms. Following this framework, they find that "there are cases where cognitive limitations actually seem to be beneficial, enabling new functions that would be absent without them, rather than constraining possible behaviors of the system" (p. 160).
This approach to rationality, while providing useful concepts and a detailed research program, lacks consistency in two different points. The first is related to the way the program is developed, that is to say "heuristics can be instantiated as a testable computer program" (p. 149). This element gives to the approach a sort of rigidity that cannot be found so often in human thinking, as argued in the paper (see, for example, March, 1978 on tastes; Kaufman, 1999 on arousal; Hanoch, 2002; Franck 1988 on emotions). Moreover, the idea of testing human decision-making processes on the computer is still based on the original idea of Simon, Shaw and Newell, and has been

heavily sustained by artificial intelligence scientists. Nevertheless, the brain-computer metaphor doesn't find actual empirical evidence in recent neurological studies (Rose, 2005; Gazzaniga, 2005). To be more precise, our hardware (neuron structures) does change in relation to environmental exchanges, so that our cognitive capabilities strictly depend on "software-hardware" interrelations and modifications. Computer "instantiation" misleads on the real point: cognitive and rational bounds and capabilities.[7]

The second point is much more relevant and useful to introduce our approach. The merger between the external and internal resources leads to a new model where human bounded rationality "filters" the external variables and shapes its boundaries. However, this fundamental aspect is not integrated in the research program where schemes of heuristics remain fixed, and rationality concerns choosing the preferred scheme in relation to the environmental context. Where is cognitive re-shaping located? And, what kind of restructuring are we facing? Moreover, what is the real impact of external resources on rationality? Do we "move bounds" to rationality?

The distributed cognition approach and the role of external representation

Recent research in cognitive science fosters the role of external resources (exogenous variables for economists) in understanding how human cognitive capabilities work[8]. As a matter of fact, people constantly and heavily lean on external supports, and the quality of their performance would immediately drop without them (Clark and Chalmers, 1998). Humans constantly *delegate* cognitive functions to the environment: remembering and calculating, for instance, are heavily supported by the environment (Norman, 1993). Very simple artifacts, such as pen and paper allow us to accomplish tasks that otherwise we couldn't even think about (Donald, 2001; Magnani, 2001; Magnani, 2005a). And so forth.

The point we want to make here is that all these external objects are not mere approximating mechanisms, but they play a crucial role in *extending* the rationality of human behavior and decision-making. Bounded rationality theory and its basis fail to recognize the cognitive role exhibited by external objects. More precisely, since bounded rationality focuses only upon what goes on within the individual mind, it fails to account for the fact that external computational resources extend the rational capabilities of humans. Thus, we may claim that rationality is *un-bounded* from the confines of the limited individual brain by the exploitation of external resources.

In order to make this point, we shall deal with the concept of external representations that we briefly introduced in the last section. More precisely, we will show how external resources play a crucial cognitive role in extending the rational character of human decision-making; they encode computational resources that can be fruitfully exploited

[7] It is worth noting that differences between the words brain, mind, intelligence, rationality, and cognition need a precise and in depth explanation, as they maintain strictly divergent meanings.

[8] For a general account of the distributed cognition approach, see Norman, 1993; Salmon, 1993; Hutchins, 1995; Clark, 1997; Kirsh, 1999; Donald, 2001; Wilson, 2004. On the role of distributed cognition in science, see the concept of *construal* (Gooding, 1994; Gooding, 2004), and that of *epistemic mediator* (Magnani, 2001). For a general account of the *moral* role played by external resources, see the concept of *moral mediator* (Magnani et al, 2005; Magnani 2005b, Magnani and Bardone, 2005b). For a distributed cognition approach on the interaction between humans and computers (HCI), see Norman, 1999; Hollan et al, 2000; Susi and Ziemke, 2001, Calvi and Magnani, 2002; Kirsh, 2004; Perry, 2004; Magnani and Bardone, 2005.

by humans to overcome their cognitive limits.
Generally speaking, a problem can be defined by an *initial state*, a *goal state*, and a *set of operators* (or mediators) that allow transformation of the initial state into the goal state by a series of intermediate steps (Klahr and Simon, 1999).
These intermediate steps, that we will call hereafter *actions*, can be grouped into two main categories: *pragmatic* and *epistemic* (Kirsch and Maglio, 1994). By the term “pragmatic actions” we refer to all those intermediate steps that *alter* the world to achieve some physical goal or other physical intermediate stages. For example, if one has to be refunded for a certain *purchase*, he has to fax the receipt. The action of faxing the document is a pragmatic action because it brings one closer to the goal state, namely, being refunded. In contrast, *epistemic actions* are all those actions that alter the *representation* of the task one is facing. A child that *shakes* and *manipulates* their birthday present to guess what there is inside is a fair example of this kind; the action of shaking unearths additional information that makes *guessing* less blind. In this case, the world is not strictly changed: what is changed is the *representation* we have about the problem. Accordingly, epistemic actions can also be regarded as *task-transforming* representations (Hutchins, 1995).
That suggested above points to the conclusion that solving a problem means representing it so as to make the solution transparent. Hence, the question is: *how* can we make the solution of a problem more transparent? *What* can make the solution more transparent?
We claim that the cognitive role of *external resources* is precisely connected with *shaping* the representation of a task so as to transform difficult tasks into ones that can be easily carried out. Let us make an example. Consider, for instance, the following two medical prescriptions (Norman, 1993):

FIGURE 3
Two medical prescriptions

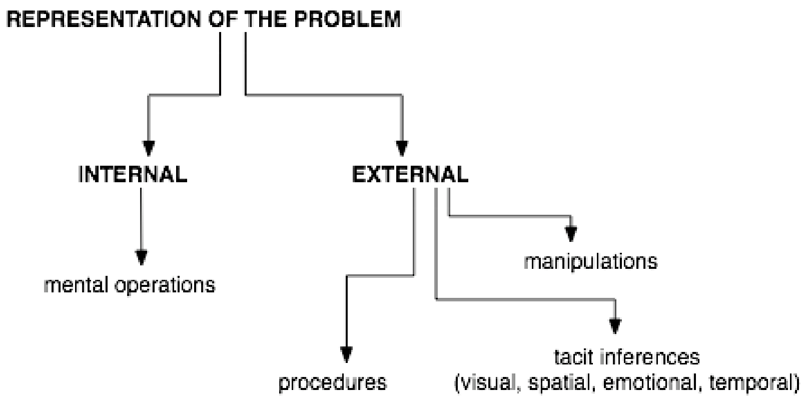
Inderal	-1 tablet 3 times a day
Lanoxin	-1 tablet every a.m.
Carafate	-1 tablet before meals and at bedtime
Zantac	-1 tablet every 12 hours (twice a day)
Quinaglute	-1 tablet 4 times a day
Coumadin	-1 tablet a day

	Br	**L**	**D**	**Bt**
Lanoxin	■			
Inderal	■	■	■	
Quinaglute	■	■	■	■
Carafate	■	■	■	■
Zantac		■		■
Coumadin				■

Now, suppose we should answer the question “how many pills should I take at lunch time?” Here we have two different ways of representing the problem. The first is a traditional medical prescription that simply tells us what kind of pills we should take, whereas the second is a matrix.
If we consider the two representations we immediately come up with the conclusion that the way the second represents the task is much easier than the first. The reason being the one suggested by Simon, that is, that matrix representation makes the solution more transparent. The medical prescription in figure X is far more complex. Already in the first line we need to think about what “1 tablet 3 times a day” means. Once we came up with the number of pills we should take, we have to write it down. Then pass to the

second line, and so forth. In contrast, the second representation is much simpler: answering the question simply means scanning down the lunch column "L" and counting the colored squares. We may even say that one gets the answer *at a glance*.[9]
The traditional notion of representation as a kind of *abstract mental structure* is misleading (cfr. Zhang and Norman, 1994; Gatti and Magnani, 2005; Knuutilla and Honkela, 2005). As the example shows, some cognitive performances can be viewed as the result of smart interplay between humans and the environment. The figure below illustrates our point.

FIGURE 4
Problem representation



The representation of the task we face is only partly internal. That is, when we try to accomplish a certain task, we exploit computational and cognitive resources embodied into external objects: for we are often engaged in such processes without holding an explicit and *internal* representation of them. In this case, an *external* representation is involved in terms of the actions, procedures and tacit inferences we are actually triggered to carry out. More generally, we may argue that external representations can be considered as *tacit procedures* that emerge from, and are prompted by, the interaction between humans and the environment. Therefore, internal representation does not *mirror* the entire representational task, because it is only a part of it.

Broad cognitive systems

In the last paragraph we pointed out how humans constantly lean on external resources to accomplish various tasks. We have outlined our approach relying on the notion of external representation. In our view, this notion plays a key role in understanding how external objects and symbols can enhance human capabilities. In this paragraph we shall detail some consequences that this approach brings about dealing with the notion of the *cognitive system*.
That the environment plays an active role in shaping decision-making activities is based on the assumption that a cognitive system goes beyond the confines of the *skull* (Clark, 2003). That is, the skull is not a "magic" boundary that clearly distinguishes what counts as cognitive and what does not (Wilson, 2004). There are several activities and performances that cannot be carried out only by the naked brain. External resources

[9] On the role of representation, see also Kahneman (2003), and Tverzky and Kahneman (1978).

actively *shape* cognitive performances that cannot be *taxonomized individually*, say, only referring to what happens within the brain (Wilson, 1994). Some cognitive processes that we attribute only to humans are the result of *smart interplay* between humans and the environment. According to that, cognitive systems can be viewed as a set of *packages of resources and operations* (Clark and Chalmers, 1998). This set is open to external upgrades and changes, and most of all is distributed. Indeed, the brain operates on a package of basic cognitive resources, but the reason why we praise it so much is because of its *portability* (Clark and Chalmers, 1998).

This conceptual branching leads to two main points. First of all, external resources can support pre-existing abilities such as memorizing or remembering. External symbols, that include rudimentary technologies, release humans from the limitations of the brain's biological memory systems (Donald, 2001).

Secondly, external objects can also bring into existence additional cognitive abilities that the naked brain could not exhibit by itself. For instance, there are several instances pointing to the conclusion that anthropomorphic thinking was brought about through the mediation of external objects that made it possible to integrate the separate intelligence of human and animal thought (Mithen, 1999; Magnani, 2005a). Upper Paleolithic cave paintings seemed to be fundamental aids to our ancestors in order to store information about animal location and behavior (Easthem & Easthem, 1991; D'Errico & Cacho, 1987; Mithen, 1988; Mithen 1996; Lewis-Williams, 2002). They were supposed to be models or maps for the specific terrain around the caves so that predictions about the natural world were improved and decision-making facilitated. Consciousness itself, namely thoughts about our thoughts, can be considered as a device that may, for instance, enhance social abilities; we explore and use our mind and consciousness to predict the behavior of another (Humphrey, 1976). That is, we reflect upon how we would act or behave in certain contexts and then *assume* or *infer* that another individual will do likewise.

The external resources approach broadens and deepens the original concept of rationality. Rationality is not referred to the decision-making process here while the result one obtains through the delegation of cognition to definite external resources is rational. It clearly appears then, that we do not refer merely to the computational capabilities but, more extensively, to the way human cognition is shaped and extended when getting in contact with external resources. Stating "when getting in contact to external resources" means in every circumstance, always; though, rationality is "expanded" by the way it depends on external resources and is enhanced by them.

Let us make another example following on from Simon. Simon recognizes the "gap between the real environment of a decision […] and the environment as the actors perceive it. […] Before the advent of the personal computer, for example, it was very difficult for managers in business organizations to pay attention to all the major variables affected by their decisions. Company treasurers frequently made decisions about working capital with little or no attention to their impact on inventory levels, while production and marketing executives made decisions about inventory without taking into account impacts on liquidity. The introduction of computers changed the ways in which executives were able to reach decisions; they could now view them in terms of a much wider set of interrelated consequences than before. The perception of the environment of a decision is a function of – among other things – the information sources and computational capabilities of the executives who make it" (Simon, 1978, p. 8).

This example is clear cut, since Simon – the other BRMs do not differ from the original on this point – treats environmental resources and computational capabilities as completely separate; the only link being perception. Therefore, the process of perception is the result of information, kept by human bounded rationality. This leads to a static relation between the information sources – the computer, in the example – and computational capabilities – of the executive. However, can we suppose that the executive changes his attitudes towards problem solving when the computer is introduced? Of course, we provide, as Simon does, a positive answer. But, has the computer-user executive enhanced her/his computational abilities in problem solving? Here answers begin to diverge: for Simon, there is no way to develop computational capabilities through external resources, while in our view the executive modifies her/his cognitive attitude. In fact, she/he delegates some computational cognitive functions to the computer, reaching higher results than already possible. The modification impacts on the executive's rationality in (1) redefining her/his way of approaching and representing (modeling) the problem, (2) giving the possibility to switch over variables other than mere computation (qualitative, relational, motivational, etc.), (3) changing the way itself of thinking about computation, and (4) exchanging data with the source (if you want a computer to give you some information, you must instruct it first!). The computer "changes the executive's mind," in a literal way.

Modeling Rationality on a Distributed Basis

The considerations made in the last two paragraphs might lead thinking that Simon's concept of rationality is a lighter version of what it actually is. Rationality as a computational resource can be defined as the under-esteemed version of the whole range of human rational capabilities. Thus, rationality is not bounded, while computational capabilities maybe.[10] More precisely, "computational capabilities" (I) partially represent human decision-making processes, and (II) change – together with the other human capabilities (psychological, ethical, political, economical, etc.) – on their own and in relation to external resources.

Following statement (I), we argue that *rationality is not limited to computational capabilities*, as we make decisions and obtain results also using not-entirely exploitable procedures. Then, following statement (II), we sustain that *rationality is not bounded*, neither in relation to the potential modifications of personal capabilities (think of the same individual as a child and as a Ph.D. laureate),[11] nor if we recognize the role of external resources (artifacts) in modifying our cognitive system.

In summary, indeed, we do have limitations, but these are always changing (the cognitive system is not stable by definition) and heavily dependent on external resources. In this way, it is clear that our model cannot be confused with the unbounded rationality model of the neoclassical approach.

Comparing the Three Models

In order to reach a better understanding of the differences between the three models and

[10] On this point, we completely agree with Langlois (1997) and Augier and Kreiner (2000), since what we claim to be limited is not rationality *per se.*

[11] It is not necessarily true that a Ph.D. laureate develops superior capabilities if compared to him/herself as a child; we are only trying todifferentiate.

to get a clearer picture of our model-building process, see Table 2. Here we try to express the main differences between the three models – neoclassical (NCM), bounded (BRM), and extended rationality model (ERM). In the paper, bounded rationality has been the starting point while the neoclassical approach remains on the background. Nevertheless, it is very interesting to show differences and similarities between the three as, in our view, bounded rationality maintains significant links to the traditional economic model.

TABLE 2.
The three models compared

	RESULT	PROCEDURE	COGNITIVE SYSTEM	COGNITIVE CAPABILITIES	CARRIER
NEOCLASSICAL MODEL	OPTIMAL	BRUTE FORCE	BRAIN-IN-ITS-BOX	UNBOUNDED	GOD-LIKE CREATURES
BOUNDED RATIONALITY	SUB-OPTIMAL	BRUTE FORCE	BRAIN-IN-ITS-BOX	BOUNDED	HUMANS
EXTENDED RATIONALITY	WORKABLE	EXPLOITATION OF EXTERNAL RESOURCES	BROAD / WIDE / DISTRIBUTED	EXTENDED / EXTERNALLY SHAPED	HUMANS

We find five variables for defining the models and make them comparable: (1) the kind of *result* (or solution) attained by each model; (2) the *procedure* leading to that result; (3) the hypotheses the models put forward on the human *cognitive system*; then, (4) the *cognitive capabilities* one is supposed to have; and, (5) the philosophical meaning attributed (mostly implicitly) to the acting entity, i.e. the *carrier*. The variables are not sorted by their importance. But, they can be organized thinking of the philosophical hypotheses on the individual (carrier), first and on the other variables as a subsequent consequence of that assumption. For example, the carrier has definite cognitive capabilities that are related to her/his cognitive system which uses a particular procedure in order to obtain the result. For a better explanation of the model's workings, it should be clearest to start from the first column. The major part of the issues here cited, are defined and criticized above.

The three models define in various ways the results their decision-maker obtains. The neoclassical model refers to optimal results, i.e. the best, while through the bounded rationality model we obtain only sub-optimal results. The extended model suggests that the individual gets results that usually fit a particular situation, and are not necessarily linked to the optimum result. They are *workable* in the sense that they allow us to manage definite situations and can be modified (or improved) when conditions change, both internal and external ones.

Our approach is based on the assumption that both the NCM and the BRM use computation (or brute force strategy) as the only rational goal-attainment procedure. In the ERM the procedure depends on the joint activity of internal and external resources, so that computation is only one possible procedure. Emotions, morality (in terms of personal values), ideas of justice and fairness, culture, etc. have to be integrated into the rational model of choice between alternatives. Moreover, the meaning here attributed to the *exploitation of external resources* is strictly linked to the cognitive meaning attributed. In other words, if all these elements occur in the decision-making process, it is clear that computation is a specific case, that cannot be considered in isolation. It can be prevalent or not, but it doesn't work as both NCM and BRM suppose it does.

In fact, the two models suppose the cognitive system to work without interrelation with external resources (i.e. the environment). In the first case (NCM), the system works in complete isolation; in the second case (BRM) the environment is a source of constraint to the "natural" and "static" human brain. So that, in the latter case, modifications do occur, but it is very similar to an input-output scheme. The extended model, on the contrary, is based on the *distributed* cognitive system, in the sense that external resources *define* our system and the way it works.

The main point here is that of limits to individuals' cognitive capabilities. The NCM hypothesis is that of individuals having no limits, we say they are *unbounded* (Shakun, 2001). On the contrary, BRM computational capabilities, as the only procedure to obtain results, are limited in individuals. In our approach, these rational bounds do exist as observed in actual human behavior; however, they are related (a) to the use and meanings of external resources, as (b) to the general social environment in which the individual behaves, and (c) to time-effect on this interaction (also reflected on means-end modifications). The individual here considered is clearly a god-like creature, for the NCM, while it is human for the other two. It is clear if we consider the normative flavor of the first and the behavioral intent of the other two.

V. Conclusion: Challenges and future developments

During the paper we used the term "rationality" with a particular meaning that is broader than that of computational capability. We never refer to cognitive capabilities using the word "intelligence." As Heims (1970) put it, intelligence can be defined as "the ability to grasp the essentials of situation and respond appropriately," and Humphrey (1976) suggests to "substitute 'adaptively' for 'appropriately' and the problem of the biological function of intellect is (tautologically) solved" (p. 304). The point is that problem solving is essential for every kind of animal, so that we cannot use the term without further specifications.

Defining intelligence is a very difficult task, however Humphrey thinks that "the following formula provides at least some kind of anchor: 'An animal displays intelligence when he modifies his behavior on the basis of valid inference from evidence.' The word valid is meant to imply only that the inference is logically sound" (1976: p. 304). Using the same scheme he uses for Heims' definition: substitute 'rational' for 'intelligence' and you find the meaning we give to "rationality."

Therefore, in order to avoid confusion, we recommend using rationality for human cognitive abilities, reflected both in behavior and thinking while intelligence is strictly connected to the self-consciousness that the individual has of her/his rationality. In this way we differ from the common use of the two terms and from the overlap of their meanings. Furthermore, we can say that animals are rational but, that strictly speaking, only humans can be intelligent.

The bounded rationality model, thus a very effective approach to analyze human decision-making, defines rationality as computational activity, emphasizing the use of brute force in problem solving. Therefore, it fails to recognize important variables such as the real impact of external resources, and the role emotions, morality, etc. do play in affecting the human cognitive system.

As we tried to show, recent cognitive studies underline that the way our mind operates is very different from what is supposed by that simple model. Instead of definition based on negative assumptions – those of bounded rationality, in the way it is based on a sort of neoclassical denial – we have to find out the positive attributes of human rationality.

We suggest using a broader approach to rationality, defined as the ability to make use of the human cognitive system. This is referred to the greater part of our cerebral activity, and it is not limited to decision making. However, most of this activity can be referred to as decision making and problem solving. This is the very reason why Simon's approach reached a broad impact in a huge number of different disciplinary domains.

Our cognitive system is distributed, in the sense that individuals cannot think or act rationally without the help of external resources, to which a sort of cognitive meaning is conferred. Thinking of human cognitive capability without implementing the role of external resources in its interactive processes, leads to a basic oversimplification of it. External resources can be materials, objects, and all kind of things (artifacts, in a technical meaning), but also, and primarily, other individuals. It is clear, then, that social, cultural, moral, political, and other variables referred to individual interactions must be included in the new model of rational choice.

In brief, the *extended model* defines rationality in a broad sense, including external variables into the human cognitive system, where bounds still remain in the actual process, but not in the potential exploitation of human resources.

The analysis of the model of rationality can take a number of roots. However, we are focusing the research on few but crucial elements.

First, we are studying the effect of the theory of distributed cognition on the process of decision-making. This research is of significant interest for economics, but it is developed on the basis of a broader approach, i.e. referring to other scientific domains such as psychology, sociology, and political science.

Secondly, we think that the most important contribution of the approach will be that of analyzing its impact in the organizational context. As Simon did with his model of bounded rationality, we are going to analyze the impact that the model has on motivation, creativity, leadership, staff-line relationships, etc. within the framework of organizational behavior studies. Moreover, the model should help in understanding decision-making processes, and provide us with new insights. Organizations are limited contexts where variables can be analyzed in greater depth way, so studies in this direction should lead to significant contributions. Last, but not least, our research program is devoted to empirical testing of the model. This part is not clearly separated from the other two, but serves to sustaining or even denying them. Both the study of decision-making in general and as it applies to organizations needs to be supported by data, in order to reach ever clearer and more useful models to enhance our understanding of human cognitive capabilities.

Finally, we started from the assumption that modern social sciences, and especially economics and management, need to be strongly rooted in actual behavior. The model of rationality based on the distributed cognition approach is basically an attempt to go further in direction: analyzing human rationality as it actually is.

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