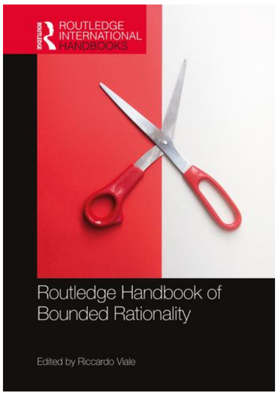

Routledge Handbook of Bounded Rationality

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BOUNDED RATIONALITY AND ORGANIZATIONAL DECISION MAKING

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Introduction

Rational choice and human decision making are two different processes. The distinction between the two became more and more apparent as the notion of bounded rationality was proposed and developed. By the 1950s, rational choice was fully formalized, thanks to the foundational work on Expected Utility Theory carried out by Von Neumann and Morgenstern (1947), as well as that of Jimmy Savage (1954). Rational choice assumes that all conditions surrounding a risky choice are given and known by the decision maker, who links means and ends in a coherent choice among the acts at her disposal. Human decision-making, on the other hand, investigates whether and how these conditions can be established, and how individuals make decisions when they are not established, i.e., when data are not fully available, or not fully processed, or preferences are ill-defined. In these cases, processes widely different from rational choice are active: Decision framing, decision setting, search, categorization, representation are all notions developed to try and capture the subtleties and intricacies of human decision making. Such notions allow the understanding of the processes behind choice, and reveal the limits and bounds of human decision-making abilities. Thus, the endpoints of both human and organizational decision making are not rational, but rather boundedly rational choices.

Are managers rational?

Simon developed the idea of *bounded rationality* in his PhD dissertation,[1] later published in the book, *Administrative Behavior* (Simon, 1947). The book opened up the "black box" of the internal mechanisms of organizations. Simon identified the main characteristics of *managerial decision making* by analyzing the structure of the organizational process. He recognized that the core of every organization is the pattern of the division of tasks and their coordination. The organization is thought of as a goal-oriented structure based on internal tasks that must be coordinated in order to achieve the organization's overall objectives. Behavior within organizations is thus goal-oriented, and goals are by and large complex and hierarchically structured, as many intermediate sub-goals need to be realized, often in a specific order, for the final goal to be achieved. The dynamics of organizational decision-making may therefore be very complex, presenting two main aspects. First, goals are often defined in very general and ambiguous terms, thus necessitating continuous revising of the sub-goals' hierarchy. Second, hidden conflicting objectives can be unearthed during various organizational decisions, and this may, again, make it necessary to revise both sub-goals and their hierarchy.

Rationality in organizations

The complexity of the organizational environment is a perfect arena for evaluating the complexity of decision making and the feasibility of the standard model of rational decision making. Indeed, in this context the rich variety of elements characterizing our decision processes becomes more apparent, illuminating the fact that standard "rationality," conceived as means-ends consistency, is only the final element of a more intricate decision process. Decisions, in a nutshell, are the result of several operations, such as searching and selecting relevant information, framing the context of decision, providing an appropriate categorization of its elements, attempting to reduce uncertainty, and so on. Such operations are prerequisites of choice requiring the activation of complex mental activities, well beyond mere means-end consistency.

In particular, according to Simon, the search for relevant information, knowledge acquisition, and learning are the most important processes for achieving a good or rational decision in complex conditions. In the organizational context, the classic processes of division of labor and subsequent coordination are pervasive, and decision-making conditions present themselves highly unstructured or ill-defined. This, as we shall see, makes standard Expected Utility Theory (EUT) inadequate as a model of choice. Indeed, during the 1950s, when EUT was the standard tool for the market theory of both consumer and production (and hence of economic equilibrium), we see that no attempts were made to extend this approach to the internal mechanisms of organizations. By describing the entrepreneur's production decision as an optimal, utility-maximizing choice, the model was assuming as a matter of fact all internal organizational processes as fixed, since the production function was supposed to fully represent a given technology and organizational form.

Besides Simon, the only approach to the problem of rationality in organizational and evolutionary settings that suggested the need for new analytical tools (other than EUT-based approaches), was due to Schumpeter. His analysis presupposes limits of individuals' rationality both in economics and politics. These limits are clarified and explored under the label "conscious rationality," that is, rationality characterized by individual volition leading to purposeful action. In his view, individuals may have different degrees of conscious rationality, depending on how familiar they are with the domain of a given decision, and on how deliberate is the decision they make.[2] Schumpeter's views are strikingly close to Herbert Simon's models of bounded rationality. Despite a successful acceptance of many of his analytic positions,[3] the attempts to formalize Schumpeter's ideas have been relatively limited, due to the difficulties in applying the standard theory of rational decision to conditions of innovation. Later in this chapter, we will argue also through an example that Simon's bounded rationality approach, sharing several crucial elements with Schumpeter's approach to rationality, is key to a deeper understanding of decision making in contexts of *organizational* innovation.

Rationality, psychology, economics

To fully appreciate the relevance of the idea of bounded rationality in the context of organization, it is useful to consider it in the light of the intellectual endeavors to produce a "pure" theory of human reasoning carried over in various contexts (probability theory, logic, decision theory) during the nineteenth and twentieth centuries. In the words of Reinhardt Selten:

> 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. This view of economics is not based on empirical evidence, but rather on the simultaneous axiomatization 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.[4]

Selten's quote highlights two main issues. The first issue is that ideal rationality, as defined by the axioms of rational choice in their more widely accepted version—EUT—requires both logical consistency and coherence with probability theory. Moreover, ideal rationality also requires unlimited computing capacity, as the procedure to discover the optimal choice may necessitate an astronomically vast number of calculations while ideal agents would be able to perform them subject to no limitations.

The second issue raised by Selten pertains to the nature and available evidence of the discrepancy between real and ideal behavior. Such discrepancies had been spotted and discussed during the creation and development of logic, of probability theory, and of rational choice, independently from one another. For instance, probability theory was first developed by and large in order to answer normative questions about gambling, and it was soon apparent that gamblers' behavior deviated significantly from the rules of probability calculus. Laplace maintains[5] that probability theory may help individuals to rationally correct the misleading illusions generated by the "sensorium" (what today we would call the cognitive system).[5] In logic, too, during the nineteenth century and in particular with the work of Gottlob Frege, it was apparent that there is a great distance between the psychology of human reasoning, on the one hand, and the laws on which logic was based, on the other.[6] In economics, the formalization of rational choice culminating in EUT followed the same anti-psychologistic stance, and when the theory was found descriptively wanting by the experimental work of Maurice Allais (1953) showing that human decision-makers violate the axioms of rational choice, a natural response to his results was to create more sophisticated versions of EUT by weakening or dropping some of its axioms.

During the same years in which Allais performed his experiments, Herbert Simon began pioneering his bounded rationality approach, shedding light on the limits of rationality and exploring decision mechanisms from the vantage point of the cognitive processes involved in them. Simon's approach is orthogonal to attempts of mending EUT by tinkering with its axioms. Simon, along with many other scholars, chose to follow a different route altogether, one in which human decision making was modeled on the basis of the complexity of the underlying psychological mechanisms.

Bounded rationality and problem solving

If rational choice theory is removed from the reality of human reasoning, a theory originating from empirical observations might offer better insights to identify the main mechanisms undergirding human decision making. Indeed, in 1956, Cyert, Simon, and Trow carried out an empirical analysis of managerial decision contexts that highlighted how search and learning were at the core of human rationality.[7] The study revealed an evident "dualism" of behavior: On the one hand, there is behavior guided by a coherent choice among alternatives typical of structured and repetitive conditions; on the other, behavior characterized by highly uncertain and ill-defined conditions, where the predominant role was played by problem-solving activities.

The dualism between repetitive and well-known decision contexts and ill-defined decision contexts proved to be a key distinction for our understanding of decision processes. In situations of the former kind, it highlights the process of decision-making routinization. In the latter, the necessary conditions for applying standard rational choice theory are lacking, and the most important decision process is the ability of the subjects to formulate and solve problems.[8] This suggests that the real restrictions on rational decisions happen during the process of construction of the context of the decision, leading to the working representation of the decision problem. The notion of bounded rationality refers mostly to these conditions, and hence it is implicitly intertwined with the notion of problem solving.

The dual process account of reasoning

The 1960s were 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 for comprehending human bounded rationality, and hence producing more realistic models of economic and organizational phenomena.

One of the components of the discovery of the cognitive limits of rationality was originated by Luchins (1942), and Luchins and Luchins (1950), who performed experiments on "mechanization of thought." They conducted experiments with subjects exposed to mathematical problems that had solutions at different levels of efficiency. The authors showed that subjects, having identified a simple solution to a task in a given (repetitive) context, may automatically and systematically apply the solution to other contexts, even if it proves to be suboptimal. The 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 mechanized. Mechanization enables individuals to pass from deliberate effortful mental activity to partially automatic, unconscious, and effortless mental operations.

This phenomenon has been further explored by psychologists, and our understanding deepened through a great deal of experiments. Among these, the experiments on chess by Simon and colleagues provided important new findings. Simon maintains that, in the course of acquiring their skill, chess players store chunks in long-term memory corresponding to patterns of pieces. Their recalling such patterns from long-term memory, during the match, is fast and automatic, and forms the basis for the conscious process of symbolic manipulation of the recalled mental items.

> One key to understanding chess mastery ... seems to lie in the immediate perceptual processing, for it is here that the game is structured, and it is here in the static analysis that the good moves are generated for subsequent processing. Behind this perceptual analysis, as with all skills ... lies an extensive cognitive apparatus amassed through years of constant practice. What was once accomplished by slow, conscious deductive reasoning is now arrived at by fast, unconscious perceptual processing. It is no mistake of language for the chess master to say that he 'sees' the right move.[9]

The experiments made by Simon and colleagues then led to the discovery that the architecture of thinking is characterized by a complex interaction between the automatic and fast recall of the elements stored in the long-term memory and the conscious process of symbolic manipulation over the mental items. This dualism between unconscious and deliberate aspects of the process of thinking has been further explored over the past years, also outside of the context of chess, by many authors, for instance, in Schneider and Shiffrin (1977), Hogarth (2001), Evans (2003), Evans and Frankish (2009), Stanovich (1999), Stanovich and West (2000) and many others. While in Simon and in the subsequent literature the use of chunks was to show how to construct a decision strategy, Kahneman adopts the dual system theory functionally to introduce accessibility as the main theoretical concept at work in the explanation of rational choice relative to the problem at hand.[10]

Organizations and routines

Routinized and not routinized behavior

As we have seen, the observation of managerial decisions within large organizations made clear the dualism between repetitive decisions in stationary conditions and innovative decisions in ill-defined and evolving environment. The latter (which Simon and March analyze preponderantly) is the extreme case of decisions (much more likely to happen) made in complex situations in which it is too costly or unfeasible to compute a strategy to achieve an optimal solution. In *Organizations*, March and Simon expand on this observation, and provide a definition of "routinized behaviors":

> We will regard a set of activities as routinized, [then,] to the degree that choice has been simplified by the development of a fixed response to defined stimuli. If search has been eliminated, but a choice remains in the form of clearly defined and systematic computing routine, we will say that the activities are routinized.[11]

A part of this definition should be highlighted: Routinized behaviors take place when "search has been eliminated," i.e., when the individual learning and problem-solving process stops.[12] The reference to the process of mechanization of thought previously studied in chess players is evident in the quote above, where it is considered in the context of a multiplicity of individuals. When *individual* behaviors are routinized, as suggested in the literature, the mental load required to decide is reduced and choice becomes an automatic and familiar process. March and Simon suggest that this process happens also in the minds of individuals while they are cooperating to achieve a shared, common goal. Cooperation, reciprocal adaptability, and the shared belief in common goals are the most important requirements for individuals participating in the same *program* within an organization. Moreover, they assume the differentiation among members according to their roles and to the knowledge required to perform tasks, as well as their interdependence.[13] By extending to group (or team) behavior the properties of Simon's chunking theory, we can tackle the question of how prior knowledge automatically recalled from the long-term memory of different individuals must be re-composed, as if it were a puzzle, and how the collective decision process must be simplified and reduced to automatic and habitual process.[14] March and Simon suggest that this kind of process occurs. They do so by claiming that if all participants in a program become familiar and expert in their specific role and do not search for new solutions any further, then a routine is established as a collection of repetitive *organizational procedures*. At the same time, they offer a "micro-individual" definition of *routinized behaviors* of the individuals involved into the same organizational procedure:[15]

> Problem-solving activities can generally be identified by the extent to which they involve *search;* search aimed at discovering alternatives of action or consequences of action. "Discovering" alternatives may involve inventing and elaborating whole *performance programs* where these are not already available in the problem solver's repertory.[16]

Problem-solving activity is then the core process within organizations, searching for better results and higher efficiency. This search is performed in every area in which more efficient goals might be achieved (aspiration levels). A process ends up when the search leads to a satisficing result, i.e., a new "performance program, or simply a program, has been discovered." A "performance program" is intended as an *organizational procedure*, i.e., it consists of a *repository of rules*, that, in response to organizational conditions, prescribe the appropriate behavior for each of the individuals collaborating to achieve a shared goal.[17] The main characteristics of these rules, is that they are *prescriptions* that originate during problem solving and that come to be used again when the same conditions apply. Such procedures have basic analogies with computer programs as both consist in prescriptions about what is to be done (*action*) when a given *condition* applies. However, unlike computer programs in which prescriptions must be explicitly and specifically given in an artificial language, in human procedures, prescriptions can be largely implicit. In general, not all contents of a procedure involving humans need to be conceptually and verbally specified. A large part of the verbal prescriptions may be very general and synthetic,[18] assuming that individuals will have sufficient competence to activate it correctly. This aspect has a fundamental importance because humans, while putting into effect a procedure, are supposed to retain large discretionary power, enabling them to specify and realize prescriptions even when they are generic or unclear, or even pushing them to discover new alternatives:

> A program may specify only general goals, and leave unspecified the exact activities to be used in reaching them. Moreover, knowledge of the means-ends connections may be sufficiently incomplete and inexact that these cannot be very well specified in advance. Then "discretion" refers to the development and modification of the *performance program* through problem-solving and learning processes.[19]

A procedure then can be *not fully specified*, and in this case the individuals who put it in effect must have competences *to autonomously construct the parts which are not specified*. This shows that individual micro-creativity is a necessary component of the process of realizing a procedure.

The "discretionary" character of large parts of a program presupposes the "creative" ability of individuals to fill the gaps of imperfectly specified programs.[20]

Further evolutions of the notion of organizational routine

The notion of routine was revisited 30 years after *Organization* by Nelson and Winter's *Evolutionary Theory of Economic Change*.[21] In their approach to organizations, they consider routines as the basic elements of an organization's life, and innovation as the engine of routine creation. One relevant element on which they focus attention is the role and transmission of tacit knowledge.[22] Routines may consist of actions that are often not verbalized, and need not be transmitted in the form of messages. Routines, or better *organizational* routines, are not formally defined and are implicitly treated as behavioral patterns. Expanding March and Simon's notion, Nelson and Winter attribute to organizational routines the role of basic units in the evolutionary process of organizational change. This perspective slightly changes the original meaning of "routinized programs" in March and Simon's approach, as the evolutionary approach ends up attributing to the "organizational routine" more properties than March and Simon do in their problem-solving context.[23] Many definitions of organizational routines have been proposed in these years, with slight differences intended to capture different properties. The attempt to unify and operationalize these requirements is still ongoing after many decades.[24]

Besides there being a repository of a stored collective knowledge (as we have seen above, an idea already present *in nuce* in March and Simon), an issue often debated in the literature pertains to how to understand routines both as stable entities (especially in relation to internal conflicts) and simultaneously as a source of change. We suggest that going back to the original Simon and March approach solves this apparent contradiction. In fact, as we have previously remarked a (human) routine is never *fully specified*, presupposing therefore that the individuals effecting it need to possess the competences necessary to autonomously supply the underspecified parts of the routines, hence expressing micro-creativity. This implies that micro search processes are still active also when an organization has produced a certain set of stable routines. Thus, micro-innovations (mutations) can still emerge.[25] This way, the apparent contradictory property of being stable while also potentially a source of change can be categorized and modeled.

Of course, more radical innovations can happen within organizations through the introduction of new top-down programs. The distinction between micro-innovations (mutations) and radical innovations can be treated by using the properties of complex systems, and in particular the decomposability features of the rules system. In fact, according to the original meaning of "routinized programs" in March and Simon, routines can be modeled as systems of if-then rules (Holland et al., 1986) that evolve through learning and adaptation. A system of condition-action rules embeds a representation of the problem(s) the organization faces. The condition part of the rules refers to the set of states (both of the world and internal) that are considered as equivalent or indistinguishable and therefore activate the same course of action. The action parts instead prescribe what ought to be done for each of these perceived situations.[26]

Marengo (2015) presents a simple model of organizational problem-solving where the generation of solutions is constrained by the representation of the problem and, in particular, by the conjectural decomposition of the problem it embeds. Routines are temporary solutions and may undergo small local changes which are reinforced as long as the routine keeps being functional or even improves. By adding up a number of these small local changes, the initial routine may finally evolve into a considerably different one. Two elements play a key role in this evolutionary dynamics of routines: The decomposition of the problem and the selection mechanism. The former sets the constraints to the generation of variations, in the sense that small local changes can only take place within the given decomposition (or division of labor). The latter defines the set of routines which are considered at least equally functional to the current one and therefore the set of variants which are acceptable. When such a set is small, i.e., small changes in a functional routine tend to damage its functionality, most variations will not be viable and routines will tend to be rigid and persistent. When, on the contrary, the set is relatively large, a routine will more easily evolve into a new one.[27]

Empirical evidence: switching from routinization to exploration

We select, among many others, three examples of experimental evidence related to routines and bounded rationality. Two are laboratory experiments, and the third is a field experiment.

The experiments illustrate some of the crucial issues in organizational bounded rationality described above: Routinization of behavior, switching from routinized to exploratory behavior, and whether routinization hinders creativity.

Target the Two (TTT) is a card game introduced by Cohen and Bacdayan (1994). Pairs of participants to the experiment need to cooperate in order to achieve a common goal. They are rewarded according to the success of the cooperative strategy they apply, rather than according to individual performances. Thus, participants must discover a good strategy *jointly*, and then follow it cooperatively in order to achieve their goal. Cohen and Bacdayan observe a laboratory tournament of pairs of players to study the emergence of routinized behavior involving coordination and cooperation. They make the first relevant attempt to explore in laboratory the emergence of rules of coordination, or *organizational routines*.

Egidi and Narduzzo (1997) find that *Target the Two* admits of two different strategies, whose efficiency depends upon the card distribution. In the lab, players who are trained to play one strategy continue to use it more frequently also in contexts in which the alternative strategy would be more efficient. This phenomenon shows that the *Einstellung* effect may happen also in a cooperative context.[28] Most players' performances become automatic, their prior knowledge triggering automatic reactions that direct attention toward the cards relevant to the more familiar strategy. In this way, they do not search for cards relevant to the strategy that would be more efficient given the current card distribution on the board, and automatically select familiar cards instead.[29] In terms of Simon's definitions, each of the two groups of players discovers a different organizational routine and persists in using it even when it becomes not efficient. Indeed, in this game only a limited subset of players explore more deeply the space of possible actions and use the routine performing best in the current conditions. They are fully rational, in the sense that their behavior is not routinized and they rationally select the more efficient between the two available routines. In TTT the attention of routinized players is strictly driven by the familiar strategy (analogously to situations of confirmation bias). Here the question arises, whether routinization of behavior may prevent the discovery of a new strategy. An answer comes from a field study by Ohly, Sonnentag, and Pluntke (2006). The authors examine the relationship between routinization and creativity in a randomly selected sample of 278 employees of a German high-tech company. They look at four characteristics (job control, job complexity, time pressure, and supervisor support) and a range of other creative and proactive behaviors. Regression analyses reveal that in addition to work characteristics, routinization is generally positively related to creative and proactive behaviors due to available resources that can be used to develop new ideas while working.

The problem of the switch from routinized to exploratory behavior has been studied also at the level of neural activity. Schuck et al. (2015) show through multivariate neuroimaging analyses that, in the classification task described below, before subjects spontaneously change to an alternative strategy, the medial prefrontal cortex (MPFC) encodes information irrelevant for the current strategy but necessary for the new one. Thus, they indicate that behavioral changes, the realization of the existence of a "better" strategy, and the decision to implement the new strategy, all lag significantly behind changes in cerebral activity that indicate brain sensitivity to the new strategy. Preceding the shift to a new strategy there is therefore a largely unconscious process. For this reason, the shift from exploitation to exploration strategies does not seem to be the outcome of a conscious, optimal response to a problem-solving procedure, as neural changes correlated with the (reported) change in the decision method (hence in representation) happen *before* the actual behavior change. The medial prefrontal cortex functions in this situation as a "planning and evaluation" unit for exploration of new strategies. Furthermore, Schuck et al. (2015) also establish that the categorization strategy yielding the current representation linked to the problem-solving method becomes entrenched at the physiological level, as it is accompanied by inhibition of alternative categorizations of the problem at hand. In other words, once a given strategy has become established, the MPFC tends to inhibit those elements that could bring about an alternative categorization of the problem, making it more difficult for the agent to adopt an innovative strategy. Exploration is hindered by our own devices, yet when we adopt exploratory behavior, we do so before we become conscious of its adoption.

Creativity and innovation

The cognitive limits of human reasoning were fundamental pillars in the Schumpeterian analysis scheme, both for the theory of innovation and the theory of democracy.[30] Schumpeter considers the innovative activity as a "*creative response*" to external changes. He claims that this activity can be understood *ex post*, but cannot be predicted "*ex ante*." It is illuminating to interpret Schumpeter's description of the capacity for innovative activity (or "seeing things in a way which afterwards proves to be true, even though it cannot be established at the moment") through the theory of bounded rationality.

As we have seen, according to Simon, solving a problem requires a selective search that presupposes automatic recollection from long-term memory prior to conscious deliberation. In this context, the interaction between automatic and deliberate thinking explains, as we know, the chess master's superiority over a novice. The master has the advantage of automatically using heuristics accumulated through years of constant practice.[31] In the same vein, the more a novice learns and memorizes new strategies, the less mental effort he needs to play.[32] Now imagine a chess club where members organize a tournament with a grand master as opponent. Suppose all of the participants have an average level of competence: During the tournament, players will be mostly unable to predict the grand master's moves because he draws upon a vastly wider repertoire of strategies and can explore in much greater depth than his opponent the possible sequences of moves and countermoves at her disposal. To the eyes of the club players, the master's strategy is *unpredictable*, and exhibits precisely the characteristics that Schumpeter attributes to an innovator:

> From the standpoint of the observer who is in full possession of all relevant facts, it can always be understood *ex post;* but it can practically never be understood *ex ante;* that is to say, it cannot be predicted by applying the ordinary rules of inference from the pre-existing facts.[33]

Then, we could explain innovation purely on the basis of the *competence gap*[34] between the innovator and other individuals. This shows that there are possible analytical tools that can help to decodify innovative behaviors, while a direct application of standard expected utility theory to this context does not seem to be appropriate.

Conclusion

We conclude by highlighting the momentous impulse that bounded rationality has given to organizational science. The discovery of the dual nature of decisions within organizations (routine and search) led March and Simon to completely redefine the definition and analysis of the notion of "planning." Planning ceases to be a static and mechanical activity based on rational decisions immersed in a world of complete information, and becomes instead based on "organizational learning." Search, therefore, becomes a key activity in organizations, and as such becomes possible to differential improvement, giving rise to differentiation in organizational performances. Adaptation is now the crucial element generating differentiation and sub-optimalities. A relevant conceptual improvement is that not only organizations learn, but they also make errors during the learning process, and – as March's behavioral description shows – because adaptation may easily lead to sub-optimal organizational configurations, errors may be systematic and stable in the long run. Both of these developments have spawned a vast literature.

We have argued that bounded rationality is a component of the theory of problem solving, assuming that individuals are natural problem solvers and that their *central ability is thinking*. This implies that behind the bounds of rationality there lie the same cognitive processes generating creativity: problem framing, problem solving, searching, categorizing, memorizing, etc. Simon's theory incorporates problem solving into the process of rational decision. In the bounded rationality approach, requisites of consistency were relaxed, but at the same time new elements (knowledge acquisition and creativity) became of the essence. Moreover, while empirically based, the theory of problem solving has developed into a highly abstract setting foundational of Artificial Intelligence. In their seminal *Human Problem Solving*, Newell and Simon (1972) establish a formal theory of problem solving: The goal was to uncover the secrets of human cognition and transfer it into formal representation. They 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 artifacts mimicking human cognitive skills. The artificial reproduction of certain aspects of human problem solving was a new strategy with which to understand the human mind. Simon worked in parallel on giving strong impetus to the empirical analysis of cognitive processes. As we have remarked, the starting point was analysis of the game of chess, from which he moved beyond the notion of calculation by first introducing the idea of "symbolic manipulation" and then directly considering the determinants of cognitive processes in order to transfer to formal artificial tools.

The nineteenth-century view considered logic and probability as theories representing the "laws" of human thought.[35] To some extent the development of Artificial Intelligence started with Simon's theory of problem solving, under the assumption of bounded rationality, representing a modern version of the same idea that Turing was explicitly supporting. This opened up a deep unsolved question of the limits of constructing formal models of intelligence (or, in the words of Turing, building a mechanical intelligence). A question tackled by Turing himself and later by Gödel, with the discovery of the limits of computability. Whatever the opinion we can express on the "great perspective" of discovery of the "laws" of human thought, the approach of bounded rationality has opened the doors for the study of the mental processes involved in search and reasoning and started with the formal representation of these processes, both in the individual and organizational context.

Notes

1 "The dissertation contains the foundation and much of the superstructure of the theory of bounded rationality that has been my lodestar for nearly fifty years" (Simon 1996, p. 86).
2 Schumpeter (1942, p. 363).
3 The contemporary theory of representative democracy is founded on Schumpeter's theory of democracy (see, for example, Held, 2006). Contemporary theories of innovation also draw widely on Schumpeter's ideas.
4 Cf. Selten (2001 p. 13).
5 Laplace ([1825] 1995).
6 See, for instance, Frege ([1884] 1934).
7 Cyert et al. (1956, p. 238).

8 Of course, much exists in between the two extremes (e.g., well-structured analytical problems such as logical or mathematical problems, or opaque problems tackled intuitively).
9 Chase and Simon (1973, p. 56).
10 See Kahneman's Nobel Prize Lecture, delivered on December 8, 2002, revised in Kahneman (2003). Dual process theory has been criticized (notably by Gigerenzer and the ABC Research Group), see, for instance, Viale (2018, 2019), where it is argued that there is a continuum rather than a dichotomy.
11 March and Simon (1958, p. 142).
12 It is not the case that individual learning always fully resolves and stops problem-solving processes, rather, the problem at hand is transformed as new problem-solving processes may arise.
13 See e.g., Orasanu and Salas (1993).
14 See e.g., Orasanu (1990), Glickman et al. (1987).
15 A relatively restricted literature has been dedicated to the development of this point (see Orasanu and Salas 1993).
16 March and Simon (1958, pp. 160–161).
17 Hereinafter. we will use the word *procedure* instead of *program*, to distinguish computer programs from human programs.
18 A possibly relevant part of the search can be entirely unconscious; see, for instance, Macchi et al. (2016).
19 March and Simon (1958, p. 170).
20 The discretionary processes emerging in routines are well illustrated in a field experiment by Narduzzo, Rocco, and Warglien (2002).
21 Nelson and Winter (1982).
22 See Polanyi (1958).
23 Among the most relevant, the role of tacit knowledge, memory, distributed authority structure, and conflict are deepened.
24 As well described in Becker (2002) and further developed in Becker (2008). See also Feldman (2000).
25 See Ohly, Sonnentag, and Pluntke (2006).
26 Actions can operate on the environment or simply generate new "internal" states which in turn activate other rules. Therefore, a system of condition-action rule can be interpreted as a kind of organizational mental model (Johnson-Laird, 1983) and a memory of the organization (Dosi et al., 2017).
27 In both cases simple heuristics may serve the decision maker well, in the former case, by rigidly designing a specific routinized solution to a stable problem, in the latter, or when the environment is in flux, by suggesting different possible solutions.
28 See Luchins (1942).
29 This suggests that the automatic recall depends on the accessibility that the different strategies have in the player's mind. See Egidi (2016, pp. 199–201).
30 See Egidi (2017b).
31 Chase and Simon (1973, p. 56).
32 See Egidi (2017a).
33 Schumpeter (1947, p. 150).
34 See Heiner (1983, p. 562), in which a competence gap arises through the differential abilities of agents relative to mapping informational signals to true events.
35 The expression "laws of thought" gained prominence after the publication of *An Investigation of the Laws of Thought on Which are Founded the Mathematical Theories of Logic and Probabilities* by George Boole (1854). Today the distinction between psychology (as a study of mental phenomena) and logic (as a study of valid inference) is widely accepted even though the links between the two areas are debated by many authors.

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