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EDITORIAL ARTICLE

Special Issue 'Expanding the boundaries of rationality: Towards new models of decision making for radical uncertainty'

The quest for non-Bayesian decision-making heuristics : towards a logic of imagination.

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INTRODUCTION

In this special issue, papers explore different trends of non-Bayesian decision heuristics. They all address, to some extent, the challenges of managing in the *unknown* i.e., in contexts where surprises, discoveries and innovations are frequent events. After a brief reminding and synthesizing of four main conceptual assumptions of Bayesian decision making (Savage 1954, 1972), we will develop a quick overview of non-Bayesian heuristics that we classify according to the Bayesian and Savagean assumptions they selectively reject. This approach hopefully captures the management issues and world views that each trend tries to address.

The development of Bayesian decision making in the 50's has been a major achievement both for theory and for practice (Wald 1950a, b; Savage 1951; Savage 1972; Raiffa and Schlaifer 1961) in deep interaction with management science (Erickson et al. 2013; Giocoli 2013). In theory, utility functions for probabilistic lotteries allowed to compare decision alternatives facing uncertainties; in addition, the introduction of- so called subjective- *prior* probabilities of uncertain events made possible to compute, through Bayes's conditional probabilities theorem, the value of a new information about these events. Bayesian theory is still highly influential in several fields (statistics, medical science, finance, cognitive psychology, AI...) but also in industrial practice when investment policies face costly uncertainties like in pharma or oil and gas explorations.

However, Bayesian probability and logic have been also a highly controversial topic in statistical and management science (see in particular Shackle 1972, 1983, Lachman, 1990, Hey, 1990). It was often argued (see for instance two recent special issues in *European Management Review* (Elmqvist et al. 2019) and *Academy of Management Review* (Alvarez and Porac 2020)) that the assumptions underlying the Savagean model were not adapted to major aspects of organizational life that are now commonplace for companies, states and consumers, namely:

- i) Contexts where fast and unpredictable changes occur and where unknown situations emerge and not only known- yet uncertain- events
- ii) the routinized mobilization of entrepreneurship, research, design and innovation which forces to recognize that unknown events are also proactively sought and provoked by organizations.

Actually, criticism of the Bayesian model also indicates directions of investigation and potential progress. As often in science, research tends to keep existing models as much as possible, while attempting to reject the most unrealistic assumptions (Ehrig and Foss 2022; Grandori and Cholakova 2013) and research has explored new families of heuristics that extends Bayesian decision framework (Feduzi et al. 2020; Ehrig and Schmidt 2022). Such endeavors are expected to, hopefully, offer tractable alternatives to the standard approach.

THE MAIN CONCEPTUAL ASSUMPTIONS OF BAYESIAN DECISION MAKING.

Bayesian Decision theory (Savage 1951, 1972) was built by combining conceptual and technical axioms coming from rational choice theory and from Bayesian probability theory. These axioms can be synthesized through four conceptual major assumptions that we remind broadly below, avoiding unnecessary mathematical details.

Assumption 1: uncertainty in a closed and known world. The Bayesian decision model assumes i) a fixed list of decision alternatives D that are operational and actionable ; ii) a fixed set of events E that are all “uncertain” : meaning that the decision maker ignores which one will happen ; yet, it must be mentioned that the events that are elements of E are perfectly known, only their occurrence is uncertain. No lack of precision or incompleteness in the definitions of D and E are assumed (Shackle 1972; Hey 1990; Loch et al. 2008).

Assumption 2: measurability of decision utility with uncertain events. Coming from classic rational choice this assumption means that it is possible to measure (and compare) the utility (or costs, or consequences) of a decision alternative in D *when any event in E occurs*. Thanks to this measure, the decision maker can evaluate *the variations* of the utility of each alternative when the uncertainty of events in E is changed. For, instance when some new information about E is obtained. It is worth mentioning that this assumption does not mean that the measure is “objective”. Both probabilities and utilities are subjective evaluations of the decision maker. Yet, once these values are accepted the Savagian decision making axioms require that the decision maker adopts all rational and consistent consequences of these values (Savage 1951). Thus measurability demands an “objective” continuity in conduct that fits with the assumptions of the model – This assumption was discussed by Maurice Allais, Economics Nobel prize winner, and this discussion is famously reported in Savage’s following books (Savage 1972).

Assumption 3: the uncertainty of events E can be measured by Bayesian probabilities. This assumption is technically demanding but it has important consequences on the learning model that is central in Bayesian decision making. It allows to calculate the Bayesian utility of a new information that may change the so called “prior” or “subjective” probabilities of events E . In practice, the possibility of such calculations determined the wide adoption of Bayesian decision making in several domains.

Assumption 4: the decision maker cannot change E . This assumption means that decisions do not influence the set E but only the probabilities of the elements of E . Simply put, the model takes for granted some events that are beyond the action of the decision maker. Technically, this means that decision alternatives and events are independent variables.

NON-BAYESIAN WORLDS : DISTINGUISHING BETWEEN THE UNCERTAIN AND THE UNKNOWN

All these assumptions correspond to several mathematical structures and properties (Savage 1951, 1954) that we cannot describe here. However, the four assumptions portray the type of managerial and economic world view that fits with the model : classical investments with commercial uncertainties, financial policies in stable markets, diversification and make or buy strategies,...In such contexts, uncertainty may be important, but the stability of techniques and assets and the measurability of consequences are sufficient to justify the acceptance of the four schemes of assumptions.

Contrasting with this first world, we all recognize contexts where technology changes occur with accelerated pace, start-ups can grow or die very fast, human agency is key, social and environmental issues disrupt performance and responsibility and so on. In such contexts the assumptions of the Bayesian model are clearly non valid.

In economics, Frank Knight (see Nicolai Foss' 2023, this SI) is well known for having introduced the idea of non-probabilistic situations, called "Knightian uncertainty" where "judgment" is necessary for decision making. Recently, Hatchuel and Segrestin (2019) remarked that, in 1916, before Knight, Henri Fayol, the founder of administrative science acknowledged unpredictable futures and introduced "the unknown" as a key element of any management "program" (Fayol 1916). Actually, Fayol was both a manager and an accomplished scientist. Discoveries made in his laboratory contributed to the 1920 Nobel Prize in physics of Charles-Edouard Guillaume and to the business success of his company (Hatchuel and Segrestin 2019). Thus, one of the first modern management thinkers was already facing a non-Bayesian world.

Are Knightian uncertainty or the popular "radical uncertainty" or "the Fayolian unknown" different expressions for the same notion ? It is clear that speaking of "uncertainty" when the situation includes future "surprises" or "discoveries" requires additional images and periphrasis. On the contrary, these traits are common sense attributes of the "unknown" simply understood as acknowledged ignorance. Scientific reasoning needs a sharp distinction between uncertain and unknown: the age of the sun is known with uncertainties (that can be high); the nature of "dark matter", if it exists, is unknown; a universal and quick cure of all cancers is unknown and uncertainty has no meaning about these entities.

This remark has direct consequences for non-Bayesian heuristics. It allows to distinguish among Savagian assumptions those that describe a closed world (ie. all actions and events are known even if they are uncertain) from those which describe beliefs or probabilities (or any other quantities) associated to the realization of these known events. Let's summarize these notions through an example: one acknowledges that she may be affected by a well-known disease: this is an *uncertain* event. Yet, she can reject any probability value of that event: the uncertainty of the event is seen as not *measurable*.

Unfortunately the treatment for such well known disease may be *unknown* to day. Research is active but no one knows if some good news may be heard in the future.

To date, it seems that a non-Bayesian heuristics for rational decision making that would reject all four assumptions is not explored in the literature. For sure, authors, including those that appear in this issue may *in principle* reject all these assumptions. But when they elaborate a heuristic, researchers tend to prioritize the rejection of some of these assumptions according to some decisional context. Thus in the following, and for the sake of clarity, we describe some trends and emerging propositions of non-Bayesian heuristics by focusing on the assumptions that are explicitly rejected in the heuristics. Note that the same heuristic may appear in more than one trend.

Rejecting the measure of utility and its improvement (Assumption 2).

This statement not only means that indicators of utility are controversial or weak, it accounts also for the belief that utility evaluations cannot be made better by some additional information, i.e. learning itself is rejected. This direction of work is explored by the paper by Frey, Osterloh and Rust (2023, this SI) on the rationality of qualified lotteries. Such extreme heuristics target situations which may appear in human resources management or when there is the need to select important executives while acknowledging that, after a first shortlisting, judgment about the future behavior of remaining candidates is difficult and controversial. Authors revisit the old tradition of randomly choosing among qualified candidates and argue that such apparently “blind” decision is “locally” the best possible choice. They also claim that such heuristic contributes to avoid political coalitions and biases during the final step of selection. Theoretically, this heuristic stands at the frontier between non-Bayesian and Bayesian decision making. It still can be interpreted as a Bayesian decision making with uniform prior probability on the future performance of selected candidates, yet without any possible learning. It is assumed that no additional information or expertise would significantly modify the uniform prior probability. Hence it is a border line situation where Bayesian inference is possible but has no decisional value.

Rejecting the assumption that uncertainty can be measured by probabilities (Assumption 3)

It is worth mentioning that this line of criticism goes beyond the traditional epistemological debate about objective and subjective (prior) probabilities that has flourished in statistical theory and philosophy of science (Taper and Lele 2004). In management and connected areas, since the seminal work of Kahneman and Tversky (1974), authors reject the idea that human cognition and beliefs obey to the consistency axioms that are requested by probability theory. The notion of *belief* is not rejected per se; but the way people build or changes their beliefs is not seen as universal or consistent. Thus, authors look for heuristics that adjust the notion of “belief” to the type of consequences and risks involved by the situation.

Bearing on the notion of “evidential weight” that has been early proposed by Keynes, Derbyshire, Feduzi and Runde (2023, this SI) suggest a heuristic that focuses on the parameters with the weakest “evidential weight” and the biggest impact. These two factors may be identified, for example, through the building of different scenarios for a complex investment. Scenarios are not prediction of the future, they only allow to enact the evidential weight/impact evaluation. These parameters should guide the decision maker towards a strategic monitoring process. Yet no Bayesian learning is assumed or warranted for the evolution of “evidential weights”. With this trend of research non-Bayesian decision making contributes to the larger class of risk management heuristics which traditionally relied on the assumption that one can evaluate the probability of critical events.

Rejecting the closed world assumption (Assumption 1).

This trend also often includes the rejection of assumption 4 by introducing the capacity of the decision maker to transform both E and D. Actually, this trend opens a wide range of research possibilities. For two reasons :

- it embeds the Bayesian logic in a larger process where the sets D and E are no more fixed and can evolve in surprising and diverse ways. This means acknowledging the existence of an expandable “unknown” world (the “large world” in Foss’ introductory note, 2023, this issue).
- Surprising events or disruptions can be imposed by this outside world or can *be voluntarily provoked* by the decision maker (entrepreneurship, design, research, innovation..). The latter case requires “expandable rationality” (Hatchuel 2001) that fits with the unknown world.

Facing such unknown world, Knightian “judgment” is still helpful. The “evidential weight” can be seen as a type of “judgment” ; while “qualified lotteries” deal with a situation where judgment leads to stop seeking increased information. Yet, judgment has also to *evolve reflexively* with the dynamics of events that reveals parts of the unknown world and may generate also new unknowns. And when judgment is about some imagined and desirable entities new heuristics are proposed .

Heuristics for reflexive and dynamic judgment.

In management and entrepreneurship literature, “adaptive management”, “strategic flexibility”, “agility”, “effectuation” (Sarasvathy 2003) are well known topics that also aim to capture dynamic decision making. However, in spite of their attractivity, such notions also need well-grounded and rational heuristic development (Gigerenzer and Gaissmaier 2010). Obviously, not all agility or flexibility are efficient or relevant per se and the requested scope of adaptation depends on the departure situation. Hence, one should expect from a class of non-Bayesian heuristics that aim to revise D and E that they channel the generation of new D and new E towards an improvement of the value and relevance for the decision maker. Any such heuristic would offer an operational process for flexible or agile management and entrepreneurship. Scenario building for instance (see Derbyshire et al 2023, this SI) can be used not only to predict but also to help making

robust and consistent judgments when new events appear. Likewise a scientific model is used to detect anomalies and organize the minimal revision that fits with the surprising data. Thus scientific heuristics (hypothesis, experimentation, modelling,) that aim at detecting new causes and anomalies (see Grandori 2023, this SI) are possible guides for reflexive judgment and for navigating in the unknown.

Heuristics for imaginative exploration

Judgment may also require "imagination" (see also Foss 2023 and Grandori 2023, this SI). This idea was already in Simon (Simon 1978) when he discussed "creative" problem solving and design. But what type of rational heuristics include "imagination" safely, without creating nonsense?

The "logic" of imagination is a strange one. If one looks for a rational use of imagination, several thought models are possible. In Science, imagination can help building new hypothesis and new models, yet they have to be testable *and controlled* by experiments. These imaginative models may enrich a Bayesian exploration by extending causalities and events.

In mathematics, imagination plays a different role, it is used to elaborate a *controlled extension* (like in the design of complex numbers or non-euclidean geometries) where an imaginary entity is designed with no possibility to test its existence. Rather it is expected that it may help discovering previously unknown mathematical worlds. Yet, this design could create nonsense and contradictions. Therefore, it is submitted to tight controls of consistency and value of the new worlds. Can we find similar imaginative heuristics for decision making ? Hatchuel et al. (2013) showed the correspondence between a formal logic of design and the theory of mathematical extensions, called *Forcing*. Forcing describes how one can create new sets, new numbers or new families of sets with a controlled heuristic.

Thus imagination can be *safely* used, not only to anticipate real observations like in science but also to "force" the generation of new worlds. Hence, there exists a class of non-Bayesian heuristics that can guide "creative" decision-making when required.

In this special issue, the paper on *Chimera heuristics* (Gilain et al 2023, this issue) follows Le Masson et al. (2018) and uses a design logic - namely, concept-knowledge theory (Hatchuel and Weil 2003, 2007; Sharif Ullah et al. 2010) - to build a controlled non-Bayesian extension of D and E. This heuristic introduces imaginary decision alternatives or events (d^* or e^*) that have the form of desirable "chimeras" : a mixture of alternatives and events that does not exist, but would have a greater value than existing alternatives : for instance, a new robot that would perform better than all known robots . These chimeras have no warranted existence at present or in the future and need no notion of evidence or probability. The final aim of this heuristic is not the realization of these chimeras (that may never occur) but to systematically provoke a knowledge expansion in both D and E until some satisfactory and improved stage (D' , E')

has been reached, even if (d^*, e^*) is not part of it. Such heuristic does not aim at transforming “what is” (D, E) into what “ought to be” (d^*, e^*) , like in classic design projects (Le Masson et al. 2011), but to reach a new, yet unpredictable “is” (D', E') where new decision alternatives and new events have a higher value. Thus, in this heuristic learning does not only change the uncertainty of some events like in Bayesian logic. Learning reveals the value of ignored unknowns. At the end of the process, chimeras may remain chimeras, but the impact for the decision maker could be real and worth the journey. The decision maker has jumped “out of the box” of Bayesian thinking. It is interesting to remark that chimeras may be generated either by imaginative judgment, or by creating a chimeral scenario departing (ie. “jumping out”) from a classic scenario building or from a standard Savagean model. What counts is controlling the process of generating new knowledge and new decision alternatives.

CONCLUSION : THE RATIONALITY OF NON-BAYESIAN WORLDS

Managerial worlds are not all alike. Some look Bayesian, others no. Thus, the rationality of non-Bayesian decision heuristics do not deny the rationality of Bayesian assumptions, it only reminds that their validity has to be restricted to some stable contexts of action and uncertainty. In such contexts Bayesian decision making is highly relevant and will remain so.

Non-Bayesian heuristics are necessary when the world becomes dominated by processes that generate unpredictability and unknownness. Their rationality is different : it still has boundaries, however it is an expandable rationality (Hatchuel 2001) : it calls for reflexive judgments, scientific inquiry and expanding the decision world rather than optimize it.

Interestingly, the papers appearing in this special issue suggest, although through different heuristics, that rationality in the unknown cannot be limited to exploration and reactive agility. There are cases where exploration has no sense and where random choices are better. Agility needs reflexive judgment on critical unknowns in non-probabilistic worlds. Such reflexivity may become transformative by introducing chimeras that may “force” knowledge expansion and extend the scope of decision alternatives. Hence, even if the class of non-Bayesian heuristics is still open to further research, the papers of this issue offer operational advances and food for thought on what rationality means in highly unknown situations.

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