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How to Cope With (New) Uncertainties: A Bounded Rationality Approach

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Abstract
A rigorous reconstruction of scenario-based real choice making reveals the incompleteness of decision-modeling and the practical prevalence of uncertainty. Theoretically complete models conceal it. As a remedy a scenario-based procedure of coping with uncertainty can prescribe how the boundedly rational decision-maker should proceed from her or his internal point of view. Though models of substantive rationality cannot serve as guidance for decision-making under uncertainty, we can improve prescriptions for coping with uncertainties in view of evidence of substantive success or failure. Decision theory should aim for a reflective equilibrium incorporating internalist-prescriptive and externalist-descriptive aspects to turn good into better practice.

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1. Introduction and overview

In theoretical contexts decisions concerning the acceptance or rejection of theories can be made without the urgency accompanying many practical decisions. Passing judgment can be confined to cases of statistical risk and withheld altogether as long as uncertainty prevails. As far as decision-urgency is concerned exposure to theoretical disciplines does not prepare well for coping with practical uncertainties. Practical disciplines like medicine, law, business administration claim to be better in this regard. They try to prepare their students for the necessities of passing clinical "judgment" in situations of uncertainty in which statistically tested empirical hypotheses are lacking but choices must nevertheless be made.[1]

Confronted with practical problems rigorously formulated and tested nomological hypotheses that reduce uncertainty to risk (with merely the residual uncertainty which derives from human fallibility per se) are not available for the "practitioner". The practical disciplines are not to be blamed for this lack of knowledge. What deserves criticism is raising claims to practical relevance that would allegedly be lost by more rigorous treatment.[2] That there is a loss of relevance by presenting arguments more rigorously is highly implausible. As a rule rigorous presentation of arguments and results will increase their relevance *provided* that there is relevant evidence at all.

If there are relevant results they can be formulated rigorously. Then there is no trade off between rigor and relevance. However, there is a risk coming along with rigor: if there are no relevant hypotheses that can be rigorously formulated and tested rigorous treatment may create the appearance of relevant argument when there is nothing behind it.

Psychologically it seems that the ascent of formal decision theoretic modeling in practical disciplines has nurtured the spurious belief that formal rigor can transform uncertainty into risk. Formal decision theoretic modeling of situations that are marred by ignorance and uncertainty *as if* they were situations of risk appeals to the human desire to "be in control". Yet it can be dangerous as has been illustrated recently again by examples from finance where it apparently created a serious "psychological model risk" by appealing to the human natural "will to believe" (see William James (1897/1956)). In view of this psychological proclivity, revealing and exposing our ignorance and uncertainty rather than concealing it should be the aim of decision-models. Only on this basis can we hope to develop models that can support boundedly rational human actors to deal with uncertainties in full awareness of their presence.

We start our discussion of how boundedly rational decision-makers with a glance at the foundational work of Blaise Pascal. This work embodies the achievements and problems not

[1] see Meehl (1954/2013) on the scope and limits of clinical vs. statistical judgment, Dawes et. al. (1989), Westen and Weinberger (2005), and on experts in politics, Tetlock (2009) and elsewhere Camerer and Johnson (1991).

[2] As claimed for instance in Viehweg (1998) and other treatises of topical reasoning that, widely off the mark in this, may often have interesting insights to contribute into practical reasoning processes.

only of past but of much present decision theoretic modeling at its very founding (2.). It is illustrated next how decision-theoretic standard models dress up uncertainty as if it were risk and thereby tend to lead (boundedly rational) decision-makers psychologically astray into "overconfidence and control illusions in the face of uncertainty" (3.). As an alternative to adapting the – in our view – practically misleading externalist theoretical model of substantively rational choice making we sketch an alternative. Doing so in ways that preserve the rational actor's focus on what can and what cannot be causally influenced by her or his interventions we first identify a fundamental source of uncertainty arising from the specifics of interactive decision-making (4.1). We then sketch in rigorous externalist terms how boundedly *rational* actors in fact cope with uncertainties (4.2). After this we strengthen the "normative" aspects implicitly present in good boundedly rational practice to yield prescriptions for "coping with uncertainties" (4.3). Finally we briefly discuss how prescriptions might be improved by boundedly rational decision-makers after observing substantive results (4.4). In conclusion we return to the relationship of theory and practice in a world in which boundedly rational actors have to cope with ever new uncertainties to which they have to respond despite a lack of experiental evidence (5.).

2. Modeling uncertainty and ignorance

The fallibility of all our conjectures concerning the real world is a fact of life. If there is a hypothesis that does make a claim about the world then formulating it more rigorously will contribute to refutability of the hypothesis. To the extent that uncertainty and ignorance amount to ignorance there is obviously nothing that can be made more refutable by rigorous formulation. Since the beginnings of decision theory in the work of Blaise Pascal (2003: § 184) scholars have nevertheless tried to rein uncertainty in through rigorous treatment. When Pascal worked out first mathematical analyses of risk in betting these were based on hypotheses with some empirical support. This straightforwardly led to statistical or actuarial models of risk. But Pascal also suggests that a Christian may cope with uncertainty concerning the existence of God in ways akin to his model of risk taking in a rigorous way. Why this to the present day influential way of modeling uncertainty may be misleading can be illustrated by focusing on Pascal's "(very) original sin".

2.1 The historical and present relevance of Pascal

Though among fallible human beings "residual uncertainty" of all knowledge claims will never be eliminated completely we need to clearly distinguish between uncertainties that became risks to the extent that we have empirical and analytical information on them and uncertainties for which such information is lacking. Pascal was well aware of the distinction. He was, on the one hand, calculating expectations concerning gambles in which frequencies of outcomes were known. On the other hand, he explored ways to cope with uncertainties in one-off situations in which information concerning probability distributions was lacking (see Knight 1921) and/or event spaces were genuinely unknown. The argument that became known as "Pascal's wager" is a paradigm case in point.

Despite the lack of evidence concerning the theistic hypothesis that God exists Pascal tried to present an a priori decision theoretic argument meant to show that even for vanishing probabilities in favor of the hypothesis it would be practically rational to believe in God's existence. Pascal makes the assumption that if God exists and if He rewards the believers, and only them, then this will bestow infinite bliss on those who believe while infinite desperation will accrue to those who do not believe. With this premise in hand, Pascal addresses the Christian who is facing what appears to her as a matter of existential and unavoidable choice. The *Christian* cannot postpone the decision until the hereafter. [3] At the same time all she knows in the here and now does not provide experiental (i.e. either empirical or experimental) evidence that God does (not) exist.[4] But since believing might lead to eternal bliss while non-believing might lead to hell or an eternity of no experience Christians have a good practical reason to believe in Him even for the smallest probability of His existence.

Somewhat more precisely, assume that all we know induces us to put a probability estimate of (1-q) on the negation of the theistic hypothesis. As long as 1-q<1, then for arbitrary low probability q>0 it would be subjectively preferable to decide on believing:

Pascal's Wager	God exists with **[q]**	God does not exist **[1-q]**
Become Believer	Some inconvenience here; eternal bliss hereafter **Value [A]**	Some inconvenience here; no hereafter. **Value: [B]**
Remain Non-Believer	Religiously unrestrained enjoyment here; eternal suffering hereafter. **Value: [X]**	Religiously unrestrained enjoyment here; no hereafter. **Value: [Y]**

Table 1

Assuming that a measure of value allowing for the appropriate algebraic operations exists the following inequality could be fulfilled for arbitrary small q and fixed Y-B if A-X becomes arbitrarily large:

$$q > \frac{Y - B}{A - X + Y - B}$$

To make the argument valid for "infinity" we need to cope with the formal problem of providing a consistent measure capturing the "overwhelming" desirability of eternal bliss. An axiomatic account of a utility function closely paralleling the original von Neumann-

[3] According to Hick (1963) there may be an "eschatological verification" of the theistic hypothesis by experiencing His presence in the hereafter though. No falsification will be possible since in case that God does not exist no experience of eternal bliss or hell will follow. See also Brams (1983).

[4] Sticking to natural rather than revealed religion, as in Hume (1779/1986).

Morgenstern utility conception can be provided and represent the implicitly assumed preferences in formally adequate ways.[5] Yet, what is lacking is an evidence-based rather than desire-based reason for restricting the possibility space to what Christian belief suggests.

For instance, that God will reward those who believe on insufficient grounds is uncertain. Dispositions like being credulous may be seen as vices rather than virtues – at least according to common views of what may be called the "ethics of belief" (see also Clifford's 1974/1879 classic on this). Still a will to believe when confronted with problems perceived as unavoidable seems deeply rooted. It is not restricted to religion and metaphysics. For situations for which judgment cannot be withheld since action or inaction will unavoidably take place it need not be maladaptive. Therefore Pascal's wager is of general importance as a paradigm case of what influences behavior when humans have to cope with uncertainty.

For instance in realms like finance problems though not matters of life and death have features akin to existential questions. Much is at stake and the will to believe is virulent. It seems therefore psychologically unsurprising, that human actors tended to adopt a broadly Pascalean strategy in coping with uncertainty in finance. For example, they and their regulators have been calculating "value at risk" by estimating how much would be at risk *at most* in, say, 98% of the cases *on which evidence exists*. Implicitly assuming that it was unnecessary to specify what could conceivably happen in the remaining 2% they used the risk they knew as guidance. Of course, they were not ignorant of the fact that unknown potential losses (and possibly gains) could occur in states of the world that they left unspecified. But knowing that complete models are impossible they were content with incorporating uncertainty into their models while leaving the nature of the beast unspecified.

The uncertainty must have been initially on the minds of practitioners in the field. But awareness slipped away from memory in the course of time. It seemed that a 98% chance that the uncertainty internal to the model would materialize was good enough for all practical purposes. The mathematical formulation lured many into a false belief that it was only risk they were dealing with. That they had a clear incentive to believe did not support a critically rational attitude either. Moreover, withholding judgment in a disinterested way was impossible since unavoidably inaction with respect to financial assets is a form action as well – after all the decision "not to invest" in assets amounts to an investment choice, too.

Uncertainty as well as action in the face of it may be unavoidable in particular in situations in which what we regard as inaction in one sense amounts to a choice in another sense as well. No way of modeling can change this feature of the world itself. It is, to put it slightly bombastically, part of the "conditio humana". Yet we need to avoid wistful thinking and any self-deception that can invite its workings. The latently fatal role of a Pascalean approach to

[5] See lucid and close to the present context Herzberg (2009, 2011) and also the early work by Hernstein and Milnor (1953) on broader utility conceptions.

modeling uncertainty in this regard can be brought forward by looking at its incarnation in what has become the standard model of rational decision-making.

2.2 The standard model of rational decision making

The most fundamental aspect of human practical rationality is the faculty to distinguish between what is and what is not causally influenced through interventions of a human actor. This leads to a minimal characterization of rationality: An actor who is *instrumentally rational* tries to build – to the extent that this is viable with "acceptable" effort – a model of the action situation that distinguishes between what is and what is not subject to her causal influence.

The focus on the causal structure is a crucial aspect of all rational-choice modeling simply because representations of causal relations underlie all decision-making on purposefully rational intervention into the course of the world. There are

(i)	plans, s,	functions – comprised in a set S
(ii)	states, z,	of the world – comprised in a set Z
(iii)	results, r,	that emerge - comprised in a set R
(iv)	technologies[6], f,	described by functions $f: S \times Z \rightarrow R$

The standard decision model as represented by table 2 below lists as rows the results f(s_i, z_k) that emerge through mechanism f when alternative plans s_i of the decision-maker and *k=1, 2, …, l* states of the world $Z = \{z_k \mid k = 1,2,\ldots,l\}$ „become real". To each of the states, *k*, corresponds a column of the table listing the results that may emerge in state *k* under all alternative plans s_i.

	z_1	z_2	…	z_k	…	z_{l-1}	z_l
plan s_1	f(s_1 , z_1)			f(s_1, z_k)			f(s_1, z_l)
…							
plan s_i				f(s_i , z_k)			
…							
plan s_m	f(s_m, z_1)						f(s_m, z_l)

Table 2

The standard model assumes that the set Z of states of the world and a probability distribution *p* on *Z* are known. Rational choice behavior complies with axioms that guarantee the existence of values that can be assigned such that preferences over lotteries can be *represented* by expected value formation relying on the assigned values without distortion of the preferences over the set of all lotteries.

[6] see for the critical rationalist use of "technology" Albert (1985).

Though the residual general uncertainty that arises from the fallibility of all human knowledge may be acknowledged as a background premise, there is no systematic place for uncertainty *in* the standard model. Still following the lead of Pascal one might try to represent uncertainty by providing a place for it *within* the model.

3. Uncertainty as risk?

Assume that the probabilities that are known are aggregated to yield a mass (1-q) for the known and of 1-(1-q)=q for the unknown state. Though there is no knowledge concerning the nature of what is contained in the "state-else" the clause *represents* the uncertainty and ignorance as if it were a risk. Again the tabular decision model may serve as an illustration:

	z_1	z_2	…	z_k	…	z_l	z_{else}
plan s_1	$f(s_1, z_1)$			$f(s_1, z_k)$			$f(s_1, z_{else})$
…							
plan s_i				$f(s_i, z_k)$			
…							
plan s_m	$f(s_m, z_1)$						$f(s_m, z_{else})$

Table 3

If "state z_{else}" is one of which the choice-maker assumes that she may neglect it in view of her pursuits then she implicitly assumes that the neglected state will not "relevantly" affect her rankings even though she has no empirical information on it. To put it slightly otherwise, if "something else" as non-anticipated result after choosing one of the plans (which are functions, too) occurs, this will not affect her *global* ranking of plans. If she would not implicitly make that assumption and base the ranking on all states except the "else" state the model would be wrongly specified. It would present something as representable by a "closed" model without a reason for assuming closure.

We do not criticize standard models of decision-making for not transforming uncertainty into risk. No formal model can do this as a model. Yet, that formal models latently suggest that they can accomplish this is what we are warning against in this paper. Since the models merely can represent but not create empirical information, only better information can transform uncertainty into risk.

To present uncertainty in a model as a residual risk-category amounts to stopping further scrutiny of the elements of that category without openly admitting it. To stop somewhere is a practical necessity but to present the "else category" as if it were on a par with what is explicitly specified according to empirical evidence is not. It is a distortion since it represents the "untamed" type of uncertainty – not hedged in by some empirical knowledge that is – as if it were a "risk". Though decision-makers could be warned of the "misspecification", the representation of uncertainty as if it were risk tends to make them psychologically less aware of the limit between what is and what is not evidence-based in their mental models.

In short, to the extent that real individuals must make a decision without actuarial (statistical) or other empirical evidence the fiction of a complete model loses its practical usefulness and becomes a risk factor itself. A more realistic representation of decision behavior in situations of uncertainty can acknowledge the bounds of knowledge explicitly and prepare the ground for more adequate decision models and more adequate models of "decision-support" to be based on them. The models to which we turn next do not assume away uncertainty and the fact that the decision-makers have merely limited intellectual resources to cope with it.

4. Practices of coping with uncertainty in interactive decision-making

Simple decision models can be used in two ways: first from the external point of view of an onlooker who observes decision-maker behavior, second, as reconstructing the internal point of view of the decision- or choice-*maker* who intentionally does something herself to bring about effects by her action. In the first case the outside observer represents the situation in which decision-makers make their decisions with the theoretical aim of describing, explaining and predicting what *they* do. The results of this kind of research are typically meant to be communicated to fellow theorists. In the second case the decision-theorist emulates the position of a "doer", that is, an actor who does *not predict* but *makes* decisions and executes them in choices in response to the question "what *should I do*?".

Most economic models of choice making do *not* answer the practical question of "what should I do?" nor are they helpful for that purpose at all. In particular those based on revealed preference conceptions start from representing *overt choices* rather than from the desires and beliefs generating the overt choice behavior. If they care about processes generating the overt choice behavior at all they counterfactually *ascribe* to the choice makers the externalist theory of substantive rationality and claim that the behavior is "as if" the externalist model was guiding the internal process of decision-making.[7] Though there is a role for externalist modeling of human choice behavior it is typically widely off the mark as far as processes of real decision-making are concerned. Beyond the simplest situations the models of substantive rationality in overt behavior will not be of any help in actually finding a decision from the perspective internal to a decision-maker.

In our stylized – and, as we think in view of empirical evidence, more realistic – external characterization of how boundedly rational decision-makers as a matter of fact try to cope with uncertainties in interactive situations we first sketch how and why the presence of

[7] Often this otherwise stunningly unrealistic assumption is justified by the argument that in competition only those who behave *as if* guided by full rationality would survive. This „evolutionary" argument, elegant as it may be, cannot tell actors what they *should do* from their internal point of view; see for a classical statement of the argument Alchian (1950). In particular it is useless for developing models of decision-support that would actually tell boundedly rational actors how to go about decision-making.

"other minds" may be a and presumably often that most important source of uncertainty (4.1). We then present – still from an external point of view – boundedly rational choice making in situations of interactive uncertainty (4.2). Refining this reconstruction leads to the prescriptive flow-chart of a decision support procedure that can be used by the decision maker herself from her internal point of view (4.3). How this procedure can be evaluated and improved in view of substantive results is briefly illustrated (4.4).

4.1 Other minds as a source of uncertainty

Human beings are part of nature. In this sense interactive decision-making in a group of human actors can be reduced to as many "games against nature" as there are actors; that is, if there is a set of n>1 decision makers *j=1, 2, 3, …, n* each *j* is facing *n-1* other decision-makers $i \in \{1,2,3,\ldots,n\} \setminus \{j\}$. The planner j can plan on exerting control by choosing a plan $s_j \in S_j$.[8] He does so without being able to control or to know the plans of other actors $S_{-j} := \{s_{-j} \mid s_{-j} := (s_1, s_2, \ldots, s_{j-1}, s_{j-1} \ldots, s_{n-1}, s_n) \mid s_i \in S_i, i \neq j, i = 1,2,\ldots,n\}$.[9] The strategic representation of a game is defined on the Cartesian product of the strategy sets S_j of the *j=1,2, …, n* interacting individuals

$$S := \times_{j=1}^{n} S_j = \{(s_1, s_2, s_3, \ldots, s_{n-1}, s_n) \mid s_j \in S_j, j = 1.2,\ldots,n\}$$

and the states of the world Z, yielding: $S \times Z$.

Each strategy is a full *plan* specifying an action ("move") for all information sets that can conceivably be reached as part of some play of the game. It is obviously viable to construct for each individual decision-maker j a table that pits j "against" $\{1,2,3,\ldots,n\} \setminus \{j\}$. The actor j chooses a plan $s_j \in S_j$ knowing that he has no control over $s_{-j} \in S_{-j}$. For each strategy $s_j \in S_j$ of actor j the results that j expects to emerge according to her mental (causal) model f^j form rows $f^j(s_j, s_{-j}, z)\ for\ (s_{-j}, z) \in S_{-j} \times Z$ of j's decision table.

Human actors as well as their minds are "part of nature". This speaks in favor of forming as many separate games against nature as there are individuals treating the states of other individuals as states of nature. They are as much beyond the control of actor *j* as other states of nature. Yet it is also obvious that human beings are a special part of nature. That part of nature "contains" representations of states of nature, i.e. what is "on other minds". The familiar problem of representing mental models of other individuals in mental models of still

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[8] To reduce notational clutter we drop the upper index „j" in what should be $s_i^j \in S_j$ and simply write $s_i \in S_j$ for the i-th plan of the j-th individual assuming that it is clear from context in each case j.

[9] He clearly cannot perform the actions of others as his own. Likewise distinguishing between what is and what is not under the direct causal influence of the actor through his own actions thinking in terms of collective action is beside the point.

others who again have mental models etc. emerges (including the need of an initial fixed point of the modeling dynamics).

Whether the uncontrollable S_{-j} can be classified as "risk" or should be conceived as "uncertainty" by the individual j is open. Note first, that the rational actor who – qua rationality – can distinguish between what is and what is not among the causal influences of acts that he can choose has no *causal power* to *fix* a sequence of acts "in one act" unless there is an option to do just this.[10] He can plan on exerting a certain kind of influence by making a specific move but he cannot make the move beforehand. He cannot exert a causal influence until the occasion for the influence arises (i.e. he remains uncommitted unless there is an option to commit).

The fact that, opposed to choosing a fixed program, strategies as plans have to be put into action sequentially confronts the boundedly rational actor with commitment problems. It also adds to the difficulty of foreseeing future states of the world as brought about by actions of others. Being rational other boundedly rational actors can distinguish between what is and what is not a causal effect of their actions. They will take opportunities on the basis of their knowledge and against the background of their idiosyncratic experience and memory at any action opportunity (information set). This adds another layer to the causal structure of the world.

That the ignorance concerning this layer is not plausibly classified as "risk" can be illustrated by taking a closer look at the seemingly simple concept of a mixed strategies. According to the standard view, so-called mixed behavioral strategies are probability distributions over choices of an actor that describe not the randomness of *her* choices – after all, as an actor she must subjectively "do" something[11] – but rather the *ignorance of other* actors. Accordingly, if participants – not external (omniscient) onlookers – of an interaction ascribe probabilities to the behavior of other participants of an interaction they sum up their own ignorance of what others might do. This is very similar to constructing uncertainty as a residual category (as in case of table 3 above) or as if it were an ordinary risk on which evidence exists. As in case of treating residual uncertainty as if it were a known risk it seems strange to treat the behavior of other individuals as if it were a known risk.

That other individuals despite the complexity of their mental models seem predictable to us is related to the presence of institutions. Institutions like for instance markets, auctions etc. can create incentives that channel individual behavior in repeat interactive situations and

[10] Even boundedly rational actors understand this quite well. They often use tricks like having no chocolate/cigarettes/liqor in the house to commit themselves to certain options.

[11] In fact, if the actor could let her the act be chosen by rolling a die or make it contingent on some other random event from Z then this would be another choice option that the actor would choose deterministically. „Active" mixing of choices is a reasonable strategy only if the actor has in fact the power to commit to following the outcome of the random experiment. Otherwise he can only plan on doing so and then has subjectively the option of deviating from the plan or executing it in a fully deterministic manner.

make it more predictable. Yet in view of the fact that human actors can always decide on the basis of their own idiosyncratic models of the future it seems that this will not work in cases that are "new" in the sense that no (institutional) rules for these cases yet exist.

For participants of interaction the strategy sets, the states of knowledge and the likelihood of actions they cannot control will more often than not be such that the situation should be modeled as one of uncertainty rather than risk. In particular a Bayesian risk model approach with "given subjective probabilistic beliefs cum utility representations", though adequate for *ideal* game theory, will be inadequate for describing what is actually going on among real boundedly rational decision- and choice-makers.

4.2 Scenario-based practices of coping with complex decision-problems[12]

Starting from the full set $S \times Z$ and common knowledge of some closed model describing all plans $s_j \in S_j$ and all $S_{-j} := \left\{ s_{-j} \mid s_{-j} := \left(s_1, s_2, ..., s_{j-1}, s_{j-1} ..., s_{n-1}, s_n \right) \mid s_i \in S_i, i \neq j, i = 1,2,...,n \right\}$, seems an outrageously far-fetched assumption (except for some illustrative simple "toy" games)[13]. Depending on their idiosyncratic experiences and their memory, boundedly rational actors will focus on a select (rather "thin") belief set $B_j \subseteq S_{-j} \times Z$. A boundedly rational actor can focus merely on a few $s_j \in S_j^{'} \subset S_j$ along with exemplary scenarios $\left(s_{-j}, z \right) \in B_j \subseteq S_{-j} \times Z$ to form potential case solutions $\left(s_j, \left(s_{-j}, z \right) \right)$.[14]

Relying on the fiction of unlimited rational capacities is useless from the internal point of view of a boundedly rational decision-maker who actually needs to make choices. She could not handle the complete information even if she had access to it. She selects scenarios $\left(s_{-j}, z \right) \in B_j$ to form scenario-specific aspirations $A_j \left(s_{-j}, z \right)$ of goal achievement (she deems fulfillment important in view of her broader aims, ends or values). Aspirations and belief sets may be revised if it turns out that they cannot be fulfilled at all or can be fulfilled to a higher degree than initially assumed. Likewise some $s_j \in S_j^{'}$ may be excluded or another may be included to yield a modified set $S_j^{''}$. If the modified $S_j^{''}$ emerges because an additional element is considered the mental modeling process will take place for the additional element only to yield $f^j(s_j, s_{-j}, z)\ for\ (s_{-j}, z) \in S_{-j} \times Z$. Only for select $\left(s_j, \left(s_{-j}, z \right) \right)$ the

[12] To make clear where we stand, in our next step we shall characterize what real choice-makers who are boundedly rational as a matter of fact seem to do when confronted with uncertainty. On the basis of this slightly idealized descriptive account of what broadly speaking rational actors do we shall then present a slightly refined prescriptive suggestion of what they should do in coping with uncertainties. We finally address the issue of evaluating the procedure in terms of substantive feedback.

[13] In the previous cases of a single actor even a full list all options seemed unrealistic.

[14] Akin to the concept of „case" used in Gilboa and Schmeidler (2010) who also allow for selective mental models in their externalist characterization of case based decision-making.

effort of gathering evidence to construct $f^j(s_j, s_{-j}, z)$ is made. Adaptations may take place also if the underlying aims, ends or values change or new information is gathered.

Properly speaking the $A_i(s_{-i}, z)$ will be a list of dimensions of value $A_i^k(s_{-i}, z), k = 1,2,...,l$ or *action goals* rather than a single scalar; i.e. $A_i(s_{-i}, z) = \left(A_i^1(s_{-i}, z), A_i^2(s_{-i}, z), ..., A_i^l(s_{-i}, z)\right)$. The aspiration levels of the *k=1, 2, …, l* action goals are scenario specific. The boundedly rational actor will generate these scenario specific levels along with the scenarios and then evaluate her options $s_i \in S_i^{'} \subset S_i$ for each scenario $(s_{-i}, z) \in B_i$.

If an option satisfies her aspirations for all scenarios this can be a stopping point. If no $s_i \in S_i^{'} \subset S_i$ yields results that satisfy all goals of the list $A_i^k(s_{-i}, z), k = 1,2,...,l$ in all scenarios considered then the actor *i* may adapt her aspirations (action goals) at least for some scenarios (for an early account of aspiration adaptation see Sauermann and Selten 1962).

To repeat, the assumption that the full set S_i may be checked is unrealistic in all but in unrealistically simple cases. The mental modeling effort that creates $f^j(s_j, s_{-j}, z)$ for options $s_j \in S_j^{'}$ and scenarios $(s_{-j}, z) \in B_j$ will be undertaken merely selectively. This is necessary to economize on scarce mental resources. From the perspective ideal externalist modeling that assume way all such costs to form ideal models on theoretically complete spaces this may seem unsatisfactory. Yet from a practical point of view it has the immense advantage of openly acknowledging that a boundedly rational decision-maker has to cope with uncertainty.

In all realistically complex situations of uncertainty the boundedness constraint will be binding and an instrumentally rational actor has – in view of his aims, ends or values good reason to proceed selectively. It will be more or less a process of systematic trial and error in which the pursuit of aspirations will as a rule consist in successive search and adaptation of all aspects of decision-making and the process of mental modeling underlying it. In a theoretical context this search could in principle be open ended whereas in cases in which action must come forward (the James/Pascal case of “life options”, see above, 2) search must end at some point and action must be taken in view of uncertainty.

Up to now the argument was conceptual. It was more to the descriptive than to the prescriptive side. The analysis of what boundedly rational actors in fact do is, however, not all we are interested in. Ultimately the aim is to improve procedures of boundedly rational decision-making rather than to reconstruct them. A reconstruction often already contains some idealization. It is stylized and in itself embodies hypotheses and (value) judgments concerning the relevance of certain aspects of what is reconstructed. Therefore such a stylized account can “naturally” serve as a step towards the explicitly normative realm of creating rules of how an actor herself *should* go about decision problems. To put it slightly otherwise the reconstruction of the previous two sections can assure that normative

suggestions are sufficiently close to what real human individuals can in fact do. On this basis then something akin to the following flow-chart may sum up the search process through which an instrumentally but boundedly rational actor *should* go.

4.3 An outline of a decision procedure for coping with uncertainties

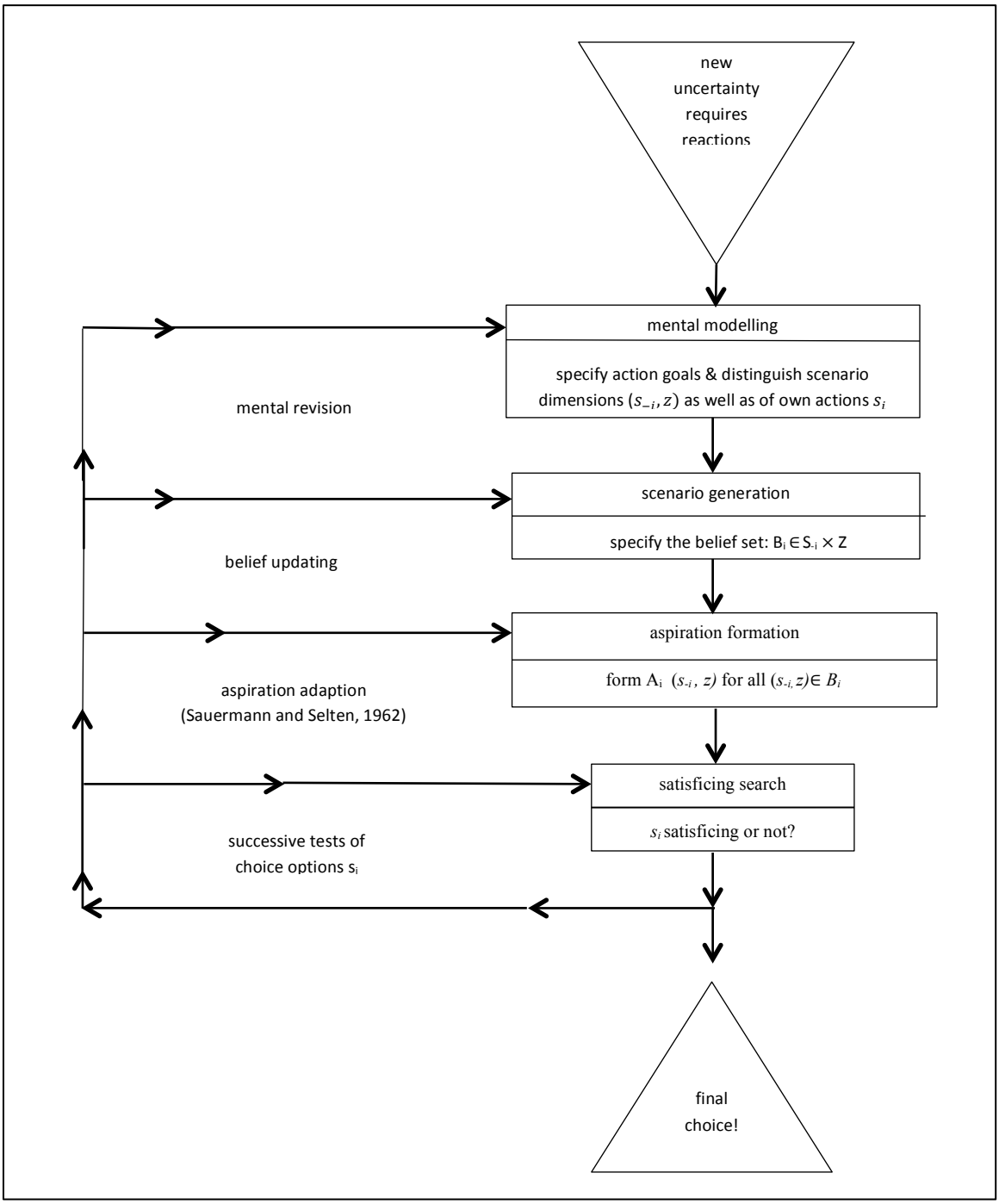

Figure 1

The individual *i* must answer questions concerning the relationship between action goals which can be achieved by excerting causal influence directly and the aspirations that can be reached only in a deferred way by a *sequence* of such actions or "moves". Since the instrumentally rational actor is also boundedly rational she is not able to form a full plan for

everything she might learn in a sequence of decisions. Yet, she can adopt a process in which she would adapt her choices to information that might become available after examining and testing some acts of a sequence of acts.

To prepare the ground for learning from scenarios and interventions into the course of the world a boundedly rational actor needs to have some hypotheses concerning the evaluation of steps (moves, actions) she is making. In short, she has to select which variables are to be used in her mental modeling as short-term indicators of long-term success. We will not go over the details of this rather crucial process of finding indicators for the fulfillment of the underlying larger aspirations. We can emphasize merely that the quality of end point results will crucially depend on making the right choices on the level of "intermediate" variables.

4.4 Evaluating the decision procedure for coping with uncertainties

Most conventional decision-theoretic approaches model behavior from the external point of view of an "observer of choices" rather than the internal point of view of a "maker of choices". The preceding flow-chart is meant to be used by the decision-maker herself as guidance or prescription of how to proceed in view of uncertainty.

Within the external perspective it is sufficient to observe overt behavior. As long as acyclicity – of the strong part of the ordering allegedly "revealed" in choices – and some auxiliary axioms are fulfilled behavior can indeed be represented as if it were maximizing the expected value of a function as derived from a pair of utility and probability measures. For theorists who intend to describe from an external point of view the behavior generated by internal mental processes and to evaluate its substantive success in terms of end points or final outcomes this is useful. For those who as participants of interaction actually have to generate the behavior the externalist stenographical representation of behavior is practically useless. After all the choice-representing measures (utility cum probability) do *not* represent reasons for making choices from alternatives. Which action from the *internal* point of view of the decision-maker *should* be chosen cannot be justified by utility and probability expectations that (after the fact) merely represent the choices made.

The deliberations of a choice maker must rely on evaluations of causal effects of action that are brought about for a reason. A motive must be operative from the internal point of view of the decision-maker. It is effective within his or her cognitive processes rather than representing the overt behavior resulting from such processes. In this realm rationality must be procedural. It is about the rules that generate choices that is about their procedural and not about their so-called substantive rationality.

Still, there are links between the two levels or points of view. First of all, if a choice maker learns that her choices violate acyclicity in that she – in some indirect way or other – prefers some alternative A to B then B to C and then C to A she has good reason to change her internal processes of generating choices. In this sense substantive result-oriented rationality criteria can – one level up so to say – feed back on the procedures themselves and contribute to their improvement. Secondly, procedures like the one represented in the

preceding flow-chart can be tested for substantive success according to some measure like, in biology, number of offspring or in economics profit (or firm growth or whatever).

Applying the preceding remarks on the relation between procedure and substantive success to the issue of how to cope with (new) uncertainties is straightforward. Competing flow-charts standardizing competing procedures should be tested for substantive success. A good setting for this could be the experimental economics laboratory provided that aspects of the flow-chart are properly embedded in incentive structures.

For instance, participants of an experiment can be induced to generate explicit scenarios. Likewise one can elicit aspiration levels and incentivize their explicit formulation by paying according to the aspirations if actual success is satisfying them. This can be compared to informal decision making without incentives to reason and plan according to a decision support system as characterized by the chart.

First experiments concerning such matters can be found on the homepage of the former Max Planck Institute for economics in Jena http://www.econ.mpg.de/english/staff/esi/gueth

Certainly many more experiments should be run. If our basic implicit empirical hypothesis is correct all successful kinds of decision support that might be charted out should be "prescriptive extrapolations of good practice" as characterized here. The prescriptions derived will always incorporate the distinction between what is and what is not controlled by the decision maker, beliefs, aspirations, and action variables. The focus on causality structures (see Pearl (2000)) based on hypotheses linking plans/actions, scenarios and goal achievement should be essential across the board. As long as we are dealing with one off decisions not much more can be said about how exactly the degrees of freedom in detail can be reigned in. Yet, since the broader procedure is present in all decisions it is itself not one-off and we can gather statistical evidence on its workings that reduces the uncertainty attached to explicating the rationality concept in procedural terms.

5. Conclusion

After reflecting on procedures of cased based decision-making many researchers tend to endorse some concept of inductive reasoning (see Gilboa and Schmeidler (2010)). Leaning towards the fallibilist view that in a fundamental sense to err is human and residual uncertainty will never go away we tend to reject a foundationalist role of induction. The basic view that an established human practice per se has normative force when it comes to extrapolating into the future and to improve practices seems reasonable to us. Accordingly we reconstructed the observable practices of boundedly rational decision-makers first. The normative proposal at improving the practices was based on the prevailing practices of real people. We started from where they are and from there on tried to critically reflect on our practices and to critically assess them in view of how we evaluate the results of such practices.

There are degrees of freedom in improving and adapting practices. At the same time, since epistemologically speaking we are also merely boundedly rational, we should not trust in any kind of claim to know a priori what the standards of good practice should be. Foundational uncertainty cannot be eliminated by a priori arguments. Yet we can act as good empiricists and try to form and test hypotheses on good practice. The aim is to collect evidence on what works and what does not work with the proviso that we may have to revise our views as we go along. We believe that much more piece meal research is necessary to gather evidence on how to cope better with uncertainties. From our point of view there is a role for feedback derived from substantive externalist considerations but in the end procedures come first and substantive evaluation comes second. Fictitious models are closed merely fictitiously. Assuming that real boundedly rational decision-makers could make any good use of ideal theoretical models is empirically outrageously unlikely. Starting from probabilistic expectations and utility functions representing preferences conceals the uncertainty that we face in realistically complex one-off decision problems. This being said it needs to be emphasized that whenever possible decision-making should be evidence based and the formulation of the problem as rigorous as possible. If mathematical language is used correctly it should make us alert of what we do not know rather than conceal it from our views as many models of full rationality tend to do.

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