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ADEQUATE MOODS FOR NON-EU DECISION MAKING
IN A SEQUENTIAL FRAMEWORK

A Synthetic Discussion

Nathalie Etchart

ABSTRACT

In a dynamic (sequential) framework, departures from the independence axiom (IND) are reputed to induce violations of dynamic consistency (DC), which may in turn have undesirable normative consequences. This result thus questions the normative acceptability of non expected-utility (non-EU) models, which precisely relax IND. This paper pursues a twofold objective. The main one is to discuss the normative conclusion: we show that usual arguments linking violations of DC to departures from IND are actually based on specific (but usually remaining implicit) assumptions which may rightfully be released, so that it is actually possible for a non-EU maximizer to be dynamically consistent and thus avoid normative difficulties. Our second objective is to introduce a kind of 'reality principle' (through two other evaluation criteria) in order to mitigate the normative requirement when examining adequate moods for non-EU decision making.

KEYWORDS: Non-expected utility, sequential choice, dynamic consistency, money pump, consequentialism.

1. INTRODUCTION

The modern theory of utility under risk stems from von Neumann and Morgenstern (1944)'s seminal work. The essence of this theory is a set of restrictions imposed to the preference relations over lotteries, allowing their representation by the mathematical expectation of a real-valued function on the set of outcomes (utility function) – from which the name of 'expected utility theory' (EU). Let \mathcal{P} be a convex set of probability distributions over a non-empty set of outcomes $X \subset \mathbb{R}$. The decision maker's preferences on \mathcal{P} are represented through a binary relation \succeq . We define the three following axioms (Karni and Schmeidler, 1991b):

- (a) vNM₁: \succeq is a weak order on \mathcal{P} (\succeq complete and transitive).
- (b) vNM₂: \succeq satisfies the independence axiom (IND). For all lotteries $P, Q, R \in \mathcal{P}$, and all $\alpha \in [0, 1]$, if $P \succeq Q$ then $\alpha P + (1-\alpha)R \succeq \alpha Q + (1-\alpha)R$.
- (c) vNM₃: \succeq satisfies the Archimedean continuity axiom. For all $P, Q, R \in \mathcal{P}$ such that $P \succeq Q$ and $Q \succeq R$, there exists $\alpha, \beta \in [0, 1]$ such that $\alpha P + (1-\alpha)R \succeq Q \succeq \beta P + (1-\beta)R$.

Then, the two following conditions are equivalent:

- (i) vNM₁, vNM₂ and vNM₃ hold;
- (ii) there exists a function $U: \mathcal{P} \rightarrow \mathbb{R}$ (utility function) such that U represents \succeq on \mathcal{P} , i. e.

for all $P, Q \in \mathcal{P}$, $P \succeq Q \Leftrightarrow U(P) \succeq U(Q)$, and U is affine, i. e. for all $P, Q \in \mathcal{P}$ and all

$\alpha \in [0, 1]$, $U(\alpha P + (1-\alpha) Q) = \alpha U(P) + (1-\alpha) U(Q)$. U is unique up to a positive affine transformation and $U(P)$ has an expected-utility form.

Thus, preferences that satisfy vNM_1 and vNM_3 but depart from vNM_2 (IND) cannot be represented by the EU functional. In the following, we precisely call non-EU preferences (resp. models) which violate (resp. relax) IND but preserve vNM_1 and vNM_3 .

Von Neumann and Morgenstern's axiomatics rather relates to static choice situations, in which "all decisions are irrevocably made before the resolution of any uncertainty" (Machina, 1989, p. 1633). Still, it is worth investigating dynamic choice situations, in which decisions are implemented successively, some of them being implemented after the resolution of some uncertainty (see Machina, 1989, pp. 1632-1633). The rationale for this is twofold. First, most real-life situations involve dynamic decisions. Secondly (and crucially here), dynamic decision making rises specific normative stakes. Indeed, departures from IND in a dynamic framework apparently result in violations of another axiom, called dynamic consistency (DC), which may in turn entail undesirable normative consequences, such as violations of first-order stochastic dominance (FOSD), aversion to free information (Wakker, 1988; Schlee, 1990) and vulnerability to money pumpⁱ. Under the legitimate claim that "economists are responsible for the logical implications of their behavioral models when embedded in social settings" (Machina, 1989, p. 1623), a theory should not be retained unless it shelters the decision maker (DM) from basic irrationality. This is why DC has been used to draw the normative line between the only (irreproachable) theory which preserves it (EU) and those which allow it to be violated and thus look normatively unacceptable (non-EU).

This paper pursues a twofold objective. First, we aim to show that the normative conclusion above is not unquestionable: the apparently tight link between IND and DC actually depends on peculiar but usually hidden assumptions, which may rightfully be released. If they are, it becomes possible to satisfy DC, thus be rational, without being a EU maximizer. Secondly, we think the debate should not be confined to the normative level and some other requirements ought to be introduced for a more comprehensive evaluation of non-EU decision

making. What we especially plead for here is a kind of 'reality principle' (one should not only consider what ought to be done, but also what is actually done and what can be done), which will find expression in the introduction of two other criteria: a descriptive one, which will essentially boil down to psychological feasibility here, since empirical and experimental studies involving dynamic choices are still rather scarce (specific methodological difficulties make results difficult to obtain and interpret, see Cubitt et al., 1998 or Busemeyer et al., 2000 for instance), and a 'pragmatic'ⁱⁱ (in the sense of computational tractability) one. We will then try to reexamine the global performance of non-EU decision making in the light of these three criteria, within a certain class of dynamic choice situations, called sequential, in which the consequence obtains at the end of the decision process only. Lapses of time between decisions are thus irrelevant to the DM and time reduces to a mere chronology of decisions and events (contrary to the other class of dynamic choices, called intertemporal, where the sequence of decisions progressively determines a sequence of consequences, for instance a consumption stream, so that the time at which each consequence obtains is crucially relevant to the DM).

The paper is organized as follows. Section 2 introduces an operational definition of dynamic consistency, allowing its violations to be detected. Section 3 explores the link between IND and DC and highlights three (two of which preserving DC) axiomatic ways of being a non-EU maximizer. The following two sections (4 and 5) evaluate the associated rules of behaviour with respect to the three former criteria. The last section (6) discusses the results and concludes.

2. TOWARDS AN OPERATIONAL DEFINITION OF DYNAMIC CONSISTENCY

A sequential decision problem can be described through a decision tree A_1 (e.g. [Figure 1]), where one (circle) chance node at least is followed by a (square) decision node n_i , $i = 0, 1, \dots$, so that some decisions be implemented after the resolution of an uncertainty (Machina, 1989, p. 1633). We define a strategy as a sequence of decisions taking all ex-ante contingencies into

account, thus prescribing a choice at each decision node throughout the tree (given that some nodes will actually not be reached ex-post)ⁱⁱⁱ. Facing all available strategies at the outset of the tree, the DM determines the one she prefers according to her evaluation at this point, that is to say her optimal strategy.

[Figure 1]

Now, let us examine the consistency between this initially preferred strategy and the choices actually made by the DM at each decision node she actually reaches. Logically, the two should coincide: (1) at the outset of the tree, the DM should implement the strategy she judges optimal at this point, (2) since the initially chosen strategy stipulates what to do in any state of nature, the DM should behave at node n_i as she initially decided to do if she ever came to this node. Still, we could imagine that the DM (1) does not implement at node n_0 the strategy she prefers or (2) does no longer consider it optimal at node n_i to behave as stipulated by the initially optimal strategy, so that she deviates from it. In both cases, actual choices contradict the initially optimal strategy. Any such deviation is called dynamic inconsistency.

The problem with this definition is that it is not operational, since the initial strategy is neither observable (it is in the DM's mind only) nor even revealable. According to the usual convention indeed, people behave in compliance with their preferences, so that we can infer from their behaviour their underlying (but non observable) preferences. Since dynamic choice situations precisely raise the possibility that the DM does not behave according to her preferences (if she eventually does not implement her optimal strategy), this convention cannot apply here. We thus need another procedure for revealing the initially optimal strategy in dynamic choice situations, so that we be able to detect potential deviations from it.

Still, the former convention can be fruitfully exploited here: since there is (by definition) no hiatus between preferences and behaviour in static choice situations, the idea is to transform the dynamic problem into its static equivalent, by deriving from the original tree A_1 another

tree A'_1 (see [Figure 2]) such that: (1) all decisions in A'_1 are made and implemented before the resolution of uncertainty (static choice situation), so that we can apply the usual convention and assume that the DM's behaviour in A'_1 reveals her preferences (thus optimal strategy) in A'_1 , (2) A'_1 preserves A_1 's sequence of events and thus the information on the very dynamic nature of the situation accounted for by tree A_1 (Sarin and Wakker, 1998), so that the DM at the root of A_1 is deemed to be facing the same strategies as in A'_1 . Consequently, the DM's behaviour in A'_1 (revealing the strategy she prefers in A'_1) is also assumed to reveal her optimal strategy at the outset of A_1 .

[Figure 2]

For any given tree A_1 and its static analog A'_1 , it is now possible to give an operational definition of dynamic consistency, by comparing the DM's behaviour in A'_1 (revealing her initially optimal strategy in A_1) with her behaviour (actual choices) in A_1 .

DEFINITION 1: The DM satisfies dynamic consistency (DC) if her choices (behaviour) in A_1 and in A'_1 coincide.

3. DYNAMIC CONSISTENCY AND CONSEQUENTIALISM

We now present two classical arguments which link up violations of DC to departures from IND. Since they are a cornerstone in the debate concerning the normative acceptability of non-EU theories, they deserve a detailed presentation.

THE BASIC ARGUMENT: MYOPIA AND DYNAMIC INCONSISTENCY: Assume that, at every node she comes to, the DM chooses the strategy she prefers at this node, irrespective of what she did before and of what she will do at subsequent nodes. We call myopic (or selfish, or naive, depending on the psychological interpretation) such a short-sighted behaviour, allowing the DM to reconsider her decision at each decision node (Strotz, 1956; Hammond, 1976). Myopia appears to be a strong psychological inclination (for a broader presentation in the intertemporal context, see Asheim, 1997), the most typical manifestations of which are

procrastination (people tend to continually postpone unpleasant tasks; Strotz, 1956; O'Donoghue and Rabin, 1999) and addiction (Hammond, 1976; Orphanides and Zervos, 1998). We call de novo the strategy which is chosen at each node by such a myopic DM, and examine whether de novo strategies are substrategies of the initially optimal strategy or not: if they are, DC is satisfied (since actual choices and initial strategy coincide); if they are not, DC is violated. We also define the reduction of compound lotteries (RCL) axiom, which is a necessary technical assumption for the argument. RCL requires that a two-stage lottery be reduceable to the corresponding single-stage one through probability calculus. Under RCL, it can easily be shown^{iv} that, for a myopic EU maximizer, de novo strategies are always substrategies of the initial strategy : locally optimal decisions are also globally optimal so that DC is de facto satisfied. On the contrary, for a myopic satisfying RCL non-EU maximizer, de novo strategies may deviate from the initial strategy and DC be violated. Thus:

RESULT 1: Under RCL (technical assumption) and myopia (psychological assumption), any non-EU individual may violate DC.

The former two assumptions ought not to be forgotten. First, due to its embarrassing psychological features and normative implications, myopia has been serving as a foil and has incited advocates of non-EU theories to think of better rules of behaviour (see *infra*, sections 4 and 5). Secondly, it seems somewhat fallacious to reject non-EU decision making on the ground of this argument solely, without considering what would happen to a non-myopic or violating RCL non-EU DM: at this stage, no absolute normative conclusion is possible. This is why we now turn to a more general and formal argument.

CONSEQUENTIALISM AND THE INCOMPATIBILITY BETWEEN NON-EU PREFERENCES AND DC: We owe to Hammond (1988a, 1988b, 1989) a theory known as consequentialism (from its eponym main axiom), which axiomatically establishes and strengthens the previous link

between IND and DC. However, we will see that Hammond's argument paradoxically (and unvoluntarily) opens the possibility of dissociating these axioms.

We first introduce a reformulated version of the theorem (for the original one, see Hammond, 1988a, p. 43 for instance) through Karni and Schmeidler (1991a, 1991b)'s and Wakker (1999)'s more usual formalism (since Hammond's terminology is rather specific; see Wakker, 1999). We define a third dynamic axiom, the consequentialist (CONS) one, as follows: "at any point in time we can focus on the consequences from now on (choices, states, probabilities and outcomes), and we do not need to know where we've come from or what other probability or choice branches were previously available" (Keller, 1992). Then we get the following result:

THEOREM 1: Under vNM_1 and vNM_3 , if RCL and CONS are satisfied, then DC is satisfied if and only if IND (vNM_2) is satisfied.

This theorem has a direct logical implication: if CONS is retained as a rationality principle (as for Hammond), and RCL as a necessary calculus tool (as for most authors), then DC cannot be preserved unless IND is. The former incompatibility between non-EU preferences and DC arises again:

COROLLARY 1: Under vNM_1 and vNM_3 , a non-EU DM satisfying CONS and RCL cannot universally satisfy DC.

In this framework, the normative conclusion is straightforward: non-EU decision making is inadequate. Besides, since myopia is a particular case of $CONS^v$, Result 1 appears to be a particular case of Corollary 1. This remark is crucial. It implies that normative troubles concern all (satisfying RCL) consequentialist non-EU DMs – not only myopic ones.

However, the above interpretation of Theorem 1 is only a peculiar one, based on the preservation of both CONS and RCL. It could actually be read the opposite way: in order to release the equivalence between IND and DC and allow the preservation of DC in a non-EU

framework, one only need relax either CONS or RCL. Finally, three^{vi} possibilities arise for modeling non-EU preferences, two of which allowing the DM to satisfy DC and thus to be rather rational [Table 1]. Note that the [preserving CONS-violating DC] DM is called sophisticated, while her symmetrical fellow is called resolute, in accordance with the (moral) philosophical terminology (see McClennen, 1988b, 1990, 1997).

[Table 1]

In the following, we try to put our 'reality principle' into practice, which will lead us to mitigate the normative evaluation. For instance, the relaxation of RCL (Segal, 1990, 1992) raises embarrassing pragmatic difficulties (concerning probability calculus in decision trees), which may explain why this solution has not been extensively studied yet, despite its stimulating originality, normative immunity (see Segal, 1992) and descriptive interest (since RCL appears to be frequently violated; see Bernasconi, 1994 for instance). The remainder of the paper will thus be devoted to the more popular other two possibilities. These are axiomatically 'dual', since they are based on the necessary trade-off between CONS and DC when preferences are non-EU and satisfy RCL. Sophistication preserves CONS so that DC may be violated. It thus meets normative difficulties, while its descriptive and pragmatic performance is rather good. Resolution offers dual virtues and drawbacks. But beside their 'duality', these two solutions share a common feature: they both are behavioural rules which attempt to offer a better alternative to myopia for non-EU decision making^{vii}.

4. THE SOPHISTICATED RULE OF BEHAVIOUR

Sophistication is most generally introduced as a behavioural rule, so that its axiomatic components rather appear to be incidental features – except for Ghirardato (1997) whose starting point is axiomatic. A non-EU DM is said to be sophisticated when she anticipates her potential myopic deviations from the initial strategy and provides against them by initially choosing a strategy she is sure she will be able to carry out. Consistent planning and

precommitment are two apparently distinct techniques for sophisticated behaviour; actually, precommitment is just a complementary device which may help the DM to ensure her consistent planning.

CONSISTENT PLANNING: A sophisticated DM makes a consistent planning (Strotz, 1956; Pollak, 1968; Hammond, 1976^{viii}) when she avoids the myopic betrayal of her initial strategy by: (1) removing from the set of available strategies those she has anticipated not to be feasible, i.e. those she knows she will not be able to carry out. Note that she de facto satisfies CONS – since she only contemplates future consequences – so that she can solve her decision problem backward, through backward induction (BI); (2) choosing among the remaining feasible strategies the one she prefers. So, consistent planning amounts for the DM to "restrict [her] choice to courses of action that [she] know[s] [she] will actually follow" (Dardadoni, 1990, p. 392) and then "to find the best plan among [them]" (Strotz, 1956, p. 173). It is obviously a second-best procedure, since the strategy the DM prefers among feasible ones may not be the strategy she absolutely prefers: by removing sources of deviation, she also eliminates possibly better alternatives. Her behaviour is consistent, since she precisely chooses a strategy she knows she will be able to abide by; but she may be dynamically inconsistent if she does not choose her optimal strategy at the outset of the decision tree. We thus define behavioural consistency as a weaker condition of consistency, applying to behaviour only (Karni and Safra, 1988, 1989, 1990; Dardadoni, 1990).

Although this example does not involve any uncertainty, Hammond (1976)'s famous potential addict (PA) may help us to grasp the differences as well as the common feature (DC violated) between myopic and sophisticated behaviour. A PA is a person who is able not to drink at all, but unable to stop drinking if she starts to. She initially has to choose between three possibilities: (1) drink but stop drinking when alcohol turns out to be harmful to her health; (2) drink until she becomes an addict (with the associated harmful consequences); (3) refuse

any glass of alcohol. The DM's optimal strategy is obviously to drink without becoming an addict (1). Can she implement it ? If she is consequentialist and myopic (so that she does not anticipate her potential deviations from the initial strategy^{ix}), she will start to drink. Because of her addiction, she will then no longer be able to stop drinking. She will finally deviate from her optimal strategy and exhibit dynamic inconsistency. Now, if she is sophisticated, she anticipates she will not be able to stop drinking if she starts to. The optimal drink-and-stop strategy is actually not feasible, so she removes it from the set of strategies and decides not to drink at all. Doing so, she also violates DC, but in a different way: she naturally does not deviate from her initial strategy, but this strategy is not the optimal one.

PRECOMMITMENT: Precommitment is always associated with consistent planning, so it is not very interesting in itself. But it actually refers to two conceptually different ideas (Asheim, 1997; Wakker, 1999) which are worth clarifying. On the one hand, the DM precommits when she makes a consistent planning but needs an extraneous help to be able to implement the sophisticated strategy. For instance, the PA makes a consistent planning when she chooses not to drink. She will also precommit if she throws her bottles away or tells everybody that she does not want to drink any longer (relying on social pressure). This is what we call sophisticated precommitment. On the other hand, the DM also precommits when she chooses the strategy she really prefers (drink-and-stop for instance) but resorts to an extraneous help to be able to abide by this decision. We are no longer in the sophisticated case here; we will see further (section 5) that this kind of precommitment actually belongs to the resolute approach, so we shall call it resolute precommitment.

Still, these two kinds of precommitment share three common features: first, they both are related to weakness of will, since people resort to them when they do not feel strong enough to implement without help the strategy they have chosen. Secondly, since weakness of will is rather widespread in real-life situations, they both are usual attitudes. Thirdly, they raise the

same conceptual problem: since they introduce new opportunities / strategies (not to drink with an extraneous help, or drink then stop drinking with an extraneous help), they imply a change in the context of the choice situation and / or in the decision tree (Asheim, 1997). Strictly speaking thus, we should not take any kind of precommitment into account here (but we will actually do, because we think this may help to both clarify and enrich the matter).

THE DESCRIPTIVE AND PRAGMATIC EVALUATION OF SOPHISTICATION: We lack empirical and experimental data concerning sophisticated decision making in itself, but real-life situations provide some evidence for it. For instance, various institutions exist which aim to help people to ensure such decisions as not to drink (AA), not to eat (Weight Watchers), not to spend money (Christmas Clubs in the United States, Thaler and Shefrin, 1981). This indirectly proves the extent of both consistent planning and precommitment. As we said before, sophisticated precommitment can be psychologically accounted for by weakness of will. The same remark applies to consistent planning itself, which constitutes a rather radical 'defence mechanism' against one's potential weakmindedness and myopic temptations. Still, we shall go further and investigate psychological mechanisms that underlie weakness of will. The previous remark about "myopic temptations" precisely opens the way to a promising interpretation in terms of intrapersonal conflict. A very natural framework for this exploring appears to be the more general multi-selves approach, in which the ego (the conscience) of the individual is not monolithic but consists of – or can be captured through – the succession (Schelling, 1984) or cohabitation (Thaler and Shefrin, 1981) of selves^x. This idea is intuitively grasped through the phrase 'the multiple facets of personality', that everyone might have personally experienced. If we further assume that selves are in conflict with each other, then we get a more accurate interpretation of consistent planning. In Thaler and Shefrin (1981)'s approach, two conflicting selves (the planner and the doer) cohabit at a given time. The 'planner' has a long term view and is concerned with collective well-being (on the whole life

duration), since the 'doer' lives one period only and is totally selfish or myopic. This is a static analysis, but it can easily be transposed into a dynamic context, where the planner will anticipate myopic dispositions of all successive doers and make a consistent planning to guard against them. This is closely related to Ainslie (1986)'s description of two competing principles of decision making within the individual: a 'short-term' (myopic and impulsive) interest based on the preference for the nearest (possibly poor) reward, and a 'long-term' (rational) interest based on the preference for the best (possibly far in the future) reward. Schelling (1984)'s approach is more directly dynamic than the former two, since it assumes that the individual is the receptacle for several sets of values following each other (or for a unique set of values, the hierarchy of which varies in the course of life) so that each self may consider that her interests are threatened by her successors' own goals.

Beside its psychological feasibility, sophisticated decision making offers a pragmatic advantage as well, since backward induction (BI) makes the 'consistent planned' strategy easy to determine^{xi}. Moreover, the multi-selves interpretation of sophistication offers a very natural ground for applying game theoretical methods and results: given that to each decision node in the tree corresponds a selfish self, the originally intra-personal decision problem turns out to be closely analogous to a non cooperative inter-personal game. The concept of behavioural consistency is thus equivalent in spirit to Selten's subgame-perfect Nash equilibrium concept (Karni and Safra, 1988, 1989, 1990).

THE NORMATIVE EVALUATION OF SOPHISTICATION: Sophistication looks normatively more questionable^{xii}. Since the sophisticated DM has consequentialist but non-EU preferences, the recourse to BI is technically possible but it may lead to the selection of a non-optimal, or even stochastically dominated, strategy^{xiii} (Machina, 1989; Wakker, 1996). Because of the necessary trade-off between CONS and DC, the reason why the sophisticated DM can resort to BI (CONS being preserved) is precisely the reason why she may violate DC, implement a

dominated strategy and be vulnerable to money pump. Note that two kinds of money pump are worth distinguishing here: the usual one (insofar as the sophisticated DM may violate DC) and a more subtle one, resulting from precommitment and involving either monetary or symbolic fees (when you enter a Weight Watchers club for instance, you have to pay a subscription; when you throw all your wines and spirits away not to be tempted, you may get the socially unpleasant reputation of a inhospitable person).

Besides, we think that sophisticated psychology itself is normatively questionable. Let alone addiction situations (alcoholism, bulimia, spendthriftness...) which are even more disputable (see below, footnote 9), sophistication may be viewed as a manifestation of imperfect rationality (McClennen, 1997). Two arguments can be put forward. First, just as the myopic DM, the sophisticated one is liable to weakness of will. The very difference is that she is aware of it and tries to guard against it, but her strategy for that (consistent planning) may be so radical and disadvantageous that it is akin to a headlong flight. Secondly, the 'sophisticated' multi-selves approach, based on hostile and almost stranger selves, amounts to reject any kind of psychological unity and thus to deny the basic requirement of 'internal consistency'.

Finally, despite her lucidity, and even though she may not implement the same strategy as the myopic DM, the sophisticated DM does not really do better than the myopic one: both of them may violate DC and meet normative difficulties. Weak (behavioural) consistency is obviously not sufficient to avoid irrationality. This is why it is important to strictly distinguish between dynamic and behavioural consistency.

5. THE RESOLUTE RULE OF BEHAVIOUR

In all respects, resolution can be viewed as symmetrical about sophistication. Behaviourally, the resolute DM implements her best strategy (instead of a second-best one) at the outset of the tree, and she then carries it out. She thus satisfies DC. Since her abiding requires that she remembers what to abide by, she by definition does not only look into the future but also into

the past. CONS is thus relaxed. More exactly, the reason why the non-EU DM is able to be dynamically consistent is precisely the reason why she cannot be consequentialist. The most typical approaches to resolution are McClennen (1988b, 1990)'s and Machina (1989)'s ones. Their starting point is rather different. McClennen starts from the psychological and normative drawbacks of sophistication and aims to find a psychologically and normatively better rule of behaviour, based on (mental) resolution. On the contrary, Machina (1989) argues that a peculiar property of non-EU preferences makes it natural to give up CONS, which allows for the preservation of DC without any psychological requirement.

COMMITMENT AND RESOLUTE PRECOMMITMENT: Just as sophistication, resolution includes two complementary techniques: commitment (Machina, 1989; McClennen, 1990) and (resolute) precommitment (Strotz, 1956; Laibson, 1997). Resolute precommitment raises the same problems as sophisticated precommitment (see above, section 4); moreover, since the word 'resolution' indicates a certain strength of will that any kind of precommitment denies, we think it conceptually does not really belong to resolution.

Elster (1979)'s interpretation of Ulysses and the Sirens' mythical tale illustrates the difference between commitment and resolute precommitment and allows us to compare the features of resolute, myopic and sophisticated behaviour. In the tale, Ulysses' ship is about to sail along the rockbound coast of the Sirens, whose beautiful singing is well-known for irresistibly attracting sailors whose ships finally crash onto the rocks. Before getting closer to the coast, Ulysses has to choose between four^{xiv} strategies: (1) listen to the songs and get closer to the coast until the ship crashes: this is the myopic strategy; (2) leave straightaway without sailing along the coast: this is the sophisticated strategy; (3) listen to the songs for a while, and then leave: this is the committing resolute strategy, which requires strength of will; (4) resort to an extraneous help in order to be still able to leave after listening to the songs: this is the precommitting resolute strategy, that Ulysses actually implements in the tale (he gets himself

tied up to the mast so that he can listen to the music without being attracted !). Now, let us compare the resolute behaviour with the myopic and sophisticated ones. First, at the initial node, the resolute DM makes the same decision as the myopic one, as they both choose the optimal strategy. The difference is that the resolute DM does not deviate from this strategy and implements it throughout the tree. Secondly, just as the sophisticated DM, the resolute one is able to implement the same strategy all along the tree. The difference is that the 'resolute' strategy is always the optimal one, whereas the 'sophisticated' strategy may be a second-best (and even stochastically dominated) one.

THE NORMATIVE EVALUATION OF RESOLUTION AND A TYPOLOGY OF NON-EU BEHAVIOURAL RULES: The normative conclusion is unambiguous. First, since she satisfies DC, the resolute DM does not suffer from basic irrationality. Secondly, since resolution "involves a special capacity to relate to the future" and requires "a more holistic view of the decision problem", it is close to "perfect rationality" (McClennen, 1997, p. 235). Thirdly, resolution is based on a normatively more acceptable psychological assumption than sophistication (strength of will). Consequently, human beings should be resolute rather than sophisticated. Still, note that the resolute precommitting DM is vulnerable to the second kind of money pump (the cost of any extraneous device): she has to pay a monetary or symbolic fee to a third person (who might be an institution) whereas she could have obtained the same outcome without spending anything, had she been truly resolute. This is another reason why we think resolute precommitment should not be assimilated to resolution.

We can now [Table 2] draw a typology of behaviours (Machina, 1989; Dardadoni, 1990), based on the necessary trade-off between CONS and DC when IND is relaxed and RCL is preserved, and its normative implications: the upholding of CONS implies potential deviations from DC, thus normative difficulties, whereas its relaxation allows the preservation of DC, thus normative immunity.

[Table 2]

THE PRAGMATIC AND DESCRIPTIVE EVALUATION OF RESOLUTION: Since it violates CONS, the resolute solution does not allow for BI. Thus, it requires a separate evaluation and comparison of a potentially tremendous number of strategies, which may be cognitively hard. Still, it seems possible to get round this difficulty. The first way out is to find a systematic method for updating preferences, i.e. for evaluating substrategies at each decision node: this is Machina (1989)'s proposal, eventually discussed and improved by Wakker (1996) (for some other features and limits of Machina's updating method, see also Border and Segal, 1994; Segal, 1997; Wakker, 1996). The second approach is based on the idea that BI need not be universally abandoned, provided a new consistency condition is satisfied (Sarin and Wakker, 1998) or the DM's preferences are consequentialist even though her behaviour is not (Jaffray, 1999; Nielsen and Jaffray, 2001).

The psychological feasibility of resolution may be more questionable. Indeed, resolution implies that sources of inconsistency remain and that the DM be able to resist them, whereas sophistication allows for their removal – which also removes the difficulty ! So resolution may require strength of will and mental effort. No doubt resolution is normatively better than sophistication (people should be resolute), but the descriptive question is still to be solved: are people resolute ? The answer is obviously not trivial. Since her globally optimal strategy may be locally sub-optimal, we need examine the reasons why a non-EU DM would pursue a global optimum at the expense of local satisfaction – in other words, what prevents her from yielding to myopic temptation at subsequent decision nodes.

This question has received different answers. Machina (1989)'s approach is rather original, since it actually bypasses the previous question ! His starting point is the non separability^{xv} of non-EU preferences. Preferences are said to be separable if, at any node of the decision tree, they are influenced neither by past decisions nor by counterfactual facts (events that could

have occurred but did not) so that the preceding part of the tree can be snipped off. Being non linear in the probabilities, non-EU preferences are non separable by construction (see Machina, 1989, p. 1627, for a proof). When she makes a decision at a given decision node, a non-EU DM does not forget why and how she came to it (see also Munier, 1994). Thus, she by definition departs from CONS, which "is essentially a dynamic version of the very separability that non-EU maximizers reject." (Machina, 1989, p. 1642). Moreover, since her current preferences depend on past decisions and events, she still finds it optimal at subsequent nodes to abide by the initial strategy, so that she satisfies DC. The dilemma between local and global optimality does not exist here.

Machina (1989) resorts to several examples to make this idea clear, the most famous one being Mom's story. Mom has a single gift and two children, Benjamin (B) and Abigail (A). It is all the same to her whether Benjamin or Abigail receives the gift, but she prefers that one of them receives it (rather than none of them), and she also prefers to throw a coin than to give the present to one of the children directly ($0.5 A + 0.5 B \succ A$ and $A \sim B$). The rule is that Abigail receives the gift if heads come out, otherwise Benjamin gets it. After the throw of the coin, Benjamin, who has lost, asks his mother to throw the coin again. Actually, he would like his mother to behave in a consequentialist way, that is to say to forget that the coin has already been thrown and to apply her original preferences (for the throw of the coin) at the current point. Answering that he has already got his chance, Mom reveals that she takes the former part of the tree – the previous throw of the coin and especially the initial probability 0.5 of B – into account: she acknowledges she is not consequentialist and refuses to be so !

Significantly, Machina does not use the term 'resolution' here, and this is rather natural, since there is no need for mental resolution in his framework. Indeed, beyond their peculiar underlying motives (ethic considerations; satiation...), all Machina's stories (Mom; pizza

eating; movie watching...) are based on the same feature, namely the conditionality of preferences, which makes resolution effortless.

Still, we think that, in more general cases, resolution is not so easy to reach. This is why we now turn to real resolution (demanding real mental effort). Symmetrically to sophistication, we may either simply assume strength of will or try to better understand it with the help of the multi-selves approach. Since will-power is psychologically more demanding than weakness, it seems rather ad hoc to merely assume it: this actually does not solve our feasibility problem ! It is then worth exploring the second approach, which has been introduced by McClennen (1990, 1997)^{xvi} and is based on the idea that resolution is feasible provided "both the ex ante self and the ex post self can reasonably expect to benefit from such a policy" (1990, pp. 212-213). To be more precise, when they become aware that (1) "there are mutual gains to be realized by aligning their choices to each other" (1997, p. 233) and that (2) these "benefits will have to be forgone if the self cannot act resolutely" (1990, p. 212), selves are prepared to give up a certain amount of selfish (local) satisfaction and to cooperate with each other in order to carry out the best collective strategy, namely resolution. Thus, whereas sophistication considers that selves are selfish (or even hostile to each other) and pursue their own interest, resolution is based on the assumption that selves are aware of the best collective strategy and prepared to implement it so that a satisfactory consensus be attainable and a collectively disadvantageous situation be avoided. From a more philosophical point of view, note that McClennen does not adhere to the 'Kantian' conception of a metaphysically continuing self (1997, p. 243) which he moreover considers to be superfluous for resolution. Actually, the only required presupposition is the existence of a certain "community of interests" between selves (1990, p. 217). In this context, the two-step implementation of a resolute behaviour raises no real difficulty: first, selves become aware that resolution is the best collective

strategy; secondly, their mutual desire to implement the resolute behaviour is sufficient to ensure its fulfilment.

We unreservedly hold to the first step of the reasoning. Insofar as cooperation is collectively more profitable than non-cooperation, it is all the more plausible in this context as (1) selves "are all part of the same mind and cannot hide intentions from each other, [which] rules out bluff and betrayal and should therefore facilitate cooperation" (Nielsen and Jaffray, 2001) and (2) it is rather unlikely that 'intrapersonal' cooperation be less prevalent than 'interpersonal' cooperation, which precisely frequently emerges in real-life situations.

The second step of the reasoning is more questionable perhaps. Two lines of argument have been put forward. The first one is based on the idea that the intention to be resolute may not be sufficient to reach resolution if one lacks a good reason to act in a resolute way – which could actually be the case since the globally optimal strategy may be locally sub-optimal. This is one of the main lessons of the famous 'toxin puzzle' (Kavka, 1983)^{xvii}, which has precisely become a cornerstone in the debate between defenders of sophistication (who consider that resolution cannot be attained) and advocates of resolution (see Bratman, 1992 for instance). A parallel can be drawn between the former idea and so-called residual states (Elster, 1983), which offer a second line of argument against resolution. 'Residual states' are states of mind that cannot be reached intentionally (the more you try to reach them, the less you can) but only as non-expected consequences of other actions. For instance, one cannot decide to sleep, to laugh, to be spontaneous. Here, this feature leads to an unexpected as well as stimulating conclusion: someone intending to be resolute cannot be, while it is possible to be resolute when not trying to. This is why Elster (1983)'s conclusion about the feasibility of resolution is rather pessimistic; he finally concentrates on sophistication and resolute precommitment, which he thinks are less glorious but more feasible.

Still, we think that both previous arguments are too strong. Convincing counterarguments can be found in Ainslie (1986) and Vergnaud (1994). Both analyses are based on what we should call 'internal credibility'. Ainslie (1986)'s idea is that people intending to ensure a resolute commitment make 'private (mental) rules', the main characteristic of which is to psychologically hold (and be efficient as a rule !) as long as they are strictly complied with, since any violation would create a precedent and allow for subsequent succumbings. Otherwise speaking, there is a 'bright line' not to be crossed. This is the very meaning of Vergnaud (1994)'s multi-selves analysis in terms of 'exemplarity'. Each self reasons as follows: "If I deviate from the initial strategy, subsequent selves will have a good reason to deviate too; if I do not, they may feel morally constrained not to deviate either. It would certainly be in my selfish interest to deviate, provided other selves be resolute; but why should they make such an effort if I do not ?" Everyone may have personally experienced that it is all the more difficult to be resolute since one has not been resolute before. When you have started to transgress the rule (i.e. to cross the 'bright line') you have created a precedent that will make it hard not to transgress again and again. And conversely, it is easier to keep on being resolute since you have been constantly resolute until now: each victory over selfish temptation helps to ensure strength of will, and a virtuous circle is initiated (you cannot give up 'so close to the end'). This is why "the person making a private rule tests the rule against each successive temptation." (Ainslie, 1986). In this framework, will-power can thus be defined as the "tactic of staking the credibility of a long-term goal on each choice that threatens it". As it is, ability to resolution appears to be a deep and strong human feature.

Still, previous investigation of psychological feasibility is not sufficient to conclude. First, there is also much real-life evidence that people tend to be myopic or sophisticated rather than resolute. Second, though rather scarce, experimental studies (Cubitt et al., 1998; Busemeyer et al., 2000) come to the same conclusion: CONS appears to be rather satisfied, while DC is

systematically violated. Finally, it seems that the axiomatic duality of sophistication and resolution leads to a necessary trade-off between the normative and descriptive requirements.

6. CONCLUSION

We now try to answer our guiding questions. On the one hand, the normative conclusion appears to be less clear-cut than it used to be through the usual consequentialist argument. Since a non-EU (satisfying RCL) DM will not violate DC provided she is resolute, non-EU decision making is no longer universally condemned to irrationality. On the other hand, the taking into account of our other two criteria highlights the potential conflict between the normative and descriptive requirements. Indeed, the descriptive power and computational tractability of resolution are at least questionable, whereas sophistication, though normatively unsatisfactory, may fit human psychology better and be easier to implement. Finally, there is no clear-cut global answer concerning adequate non-EU decision making in dynamic contexts, but only contingent ones, depending on one's epistemological position.

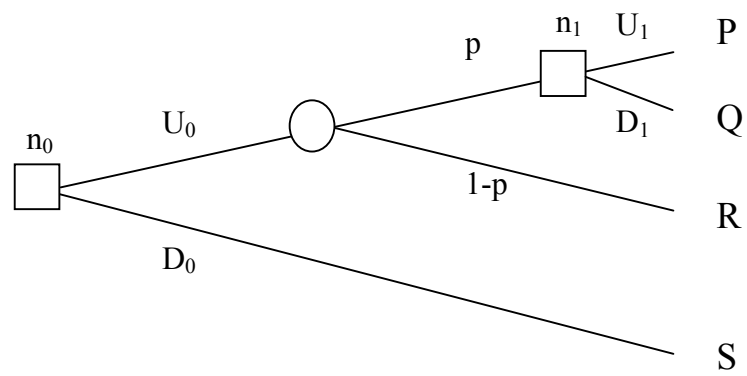
We now briefly discuss the money pump argument and the analogy between sequential and intertemporal approaches.

THE MONEY PUMP ARGUMENT: Vulnerability to money pump is a usual normative argument. Though, we think it is questionable. Indeed: (1) most people are dynamically inconsistent, so we might expect that they would not subject others to what they would not like to undergo from them; (2) if the number of potential manipulators is infinite (free entry on a competitive market), competition among them guarantees that manipulation will not involve large amounts of money: at the equilibrium, the wrung amount should be very close to zero; (3) people are very unlikely to be money pumped into ruin (when they become aware of the danger, they may break the deal). The conclusion of these three arguments is the same: money pump may not be such a serious problem.

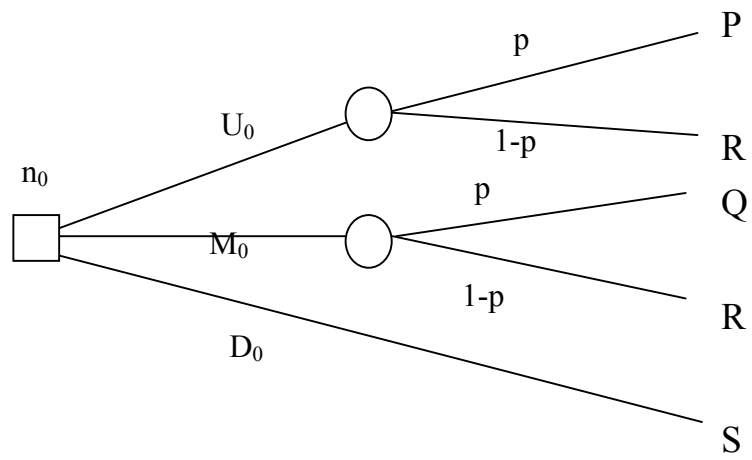
A PROMISING COMPARISON BETWEEN THE SEQUENTIAL AND INTERTEMPORAL FRAMEWORKS: As a dynamic issue, dynamic consistency does not only concern sequential, but also intertemporal, choices. Do theoretical results obtained for the former apply to the latter too ? There is no clear-cut answer. Actually, some real analogies exist between sequential and intertemporal choices, and some interesting phenomena, such as addictive behaviour and myopia, can be fruitfully examined in both fields (see Orphanides and Zervos, 1998 for instance). Still, most results depend on whether the timing of the resolution of uncertainty plays or not a role in the process (Karni and Schmeidler, 1991b; Paradiso and Hey, 1999). For instance, normative conclusions might be less restrictive when people are not indifferent to how uncertainty resolves (see Epstein and Le Breton (1993)'s brief remark p. 18).

FIGURES AND TABLES

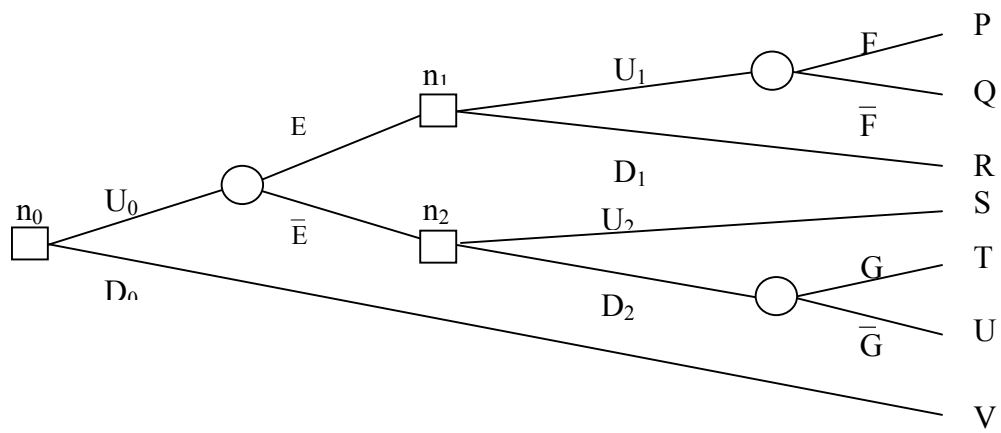
[Figure 1] : The decision tree A_1 : a simple dynamic choice situation



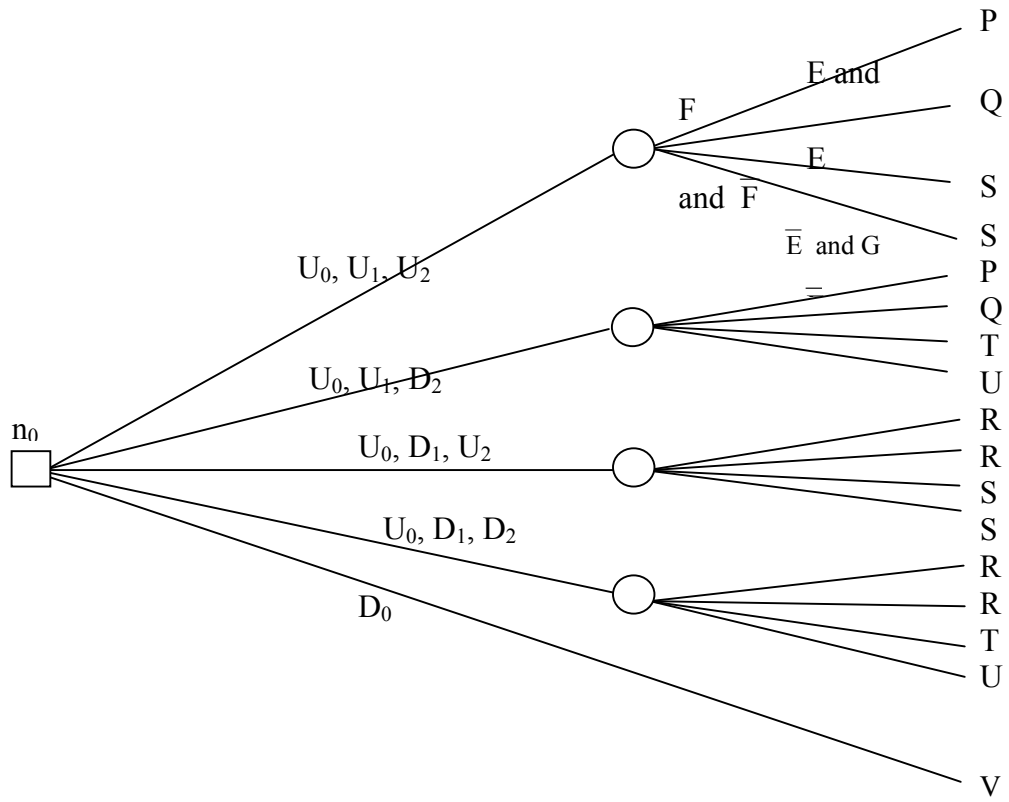
[Figure 2] : The decision tree A'_1 : the static equivalent of A_1



[Figure 1] : Example of a decision tree (A_1) representing a typical dynamic choice problem



[Figure 2] : The static equivalent (A'_1) of former dynamic tree A_1



[Table 1] : The three conceivable axiomatic combinations for non-EU preferences and the corresponding contributions

<div>Axiomatic combinations</div> <div>Contributions</div>	RCL	DC	CONS
Segal (1990, 1992)	No	Yes	Yes
<div><u>Sophisticated decision maker</u></div> <div>Strotz (1956), Pollak (1968), Hammond (1976)</div> <div>Thaler & Shefrin (1981), Schelling (1984)</div> <div>Karni & Safra (1988, 1989, 1990), Dardadoni (1990)</div>	Yes	No	Yes
<div><u>Resolute decision maker</u></div> <div>Machina (1989), McClennen (1988, 1990),</div> <div>Wakker (1996), Jaffray (1998)</div>	Yes	Yes	No

[Table 2] : A typology of EU and non-EU (satisfying RCL) decision makers

DM	Type	Axiomatic features	Normative difficulties
EU	<u>α type</u>	IND is satisfied. CONS and DC are de facto satisfied.	No
Non-EU	<u>β type</u> (myopic)	IND is relaxed, and CONS is preserved. DC may thus be violated.	Yes
	<u>δ type</u> (sophisticated)		Yes (in this respect, being sophisticated does not change anything)
	<u>γ type</u> (resolute)	IND is relaxed, and CONS is relaxed too. Thus, it is now possible to preserve DC.	No

NOTES

ⁱ A greedy and smart person could take advantage of the DM's dynamic inconsistency and offer him a transaction such that, whatever happens, the DM loses with certainty a given amount of money; such a money pump, applied several times, may even lead the DM to ruin.

² This word is given a peculiar meaning here – different from McClennen (1988b, 1990)'s for instance.

ⁱⁱⁱ In A_1 , there are 5 strategies: $[U_0, U_1, U_2]$, $[U_0, U_1, D_2]$, $[U_0, D_1, U_2]$, $[U_0, D_1, D_2]$, $[D_0]$.

^{iv} See Etchart (1999) for a broader presentation.

^v A consequentialist DM can avoid being myopic (if she is long-sighted), but a myopic DM is always consequentialist (since she just considers the future and not the past).

^{vi} Naturally, two of the axioms, or even all of them, could logically be relaxed. But the resulting behaviour would not be very interesting !

^{vii} We will not develop Rabinowicz (1995)'s conciliatory solution of wise choice, which amounts to "the sophisticated approach minus separability" (see p. 606 and sequ.).

^{viii} Hammond (1976) does not use the expression 'consistent planning'. Still, what he calls sophistication is actually a consistent planning.

^{ix} Still, the story of the PA (and all addiction stories, actually !) is questionable: myopia should allow a minimal ability to analysis that the myopic PA does not even have, since she is ruled by her addiction (at subsequent nodes, she does not decide any longer whether to drink or not, she cannot help drinking !). From which McClennen (1990, 1997)'s legitimate claim: "My concern is with agents who are liable to being disadvantaged by the 'Sirens' Song' of incremental reasoning, rather than those who expect their deliberative powers to be overwhelmed by external forces". (McClennen, 1997, p. 217, footnote 14)

^x This approach has resulted in a new domain of investigation in economics: picoeconomics (Ainslie, 1993). "It is not a new idea that the self is multiple. [...] If the parts of the self can be clearly articulated, they may be suitable material for a model more microscopic than microeconomics, 'picoeconomics' perhaps." (Ainslie, 1986)

^{xi} We consider the recourse to BI as a pragmatic advantage, but it might on the contrary be considered as problematic (see Rabinowicz, 1995, pp. 596-597).

^{xii} Space constraints preclude my reporting of the series of exchanges that started in 1988 between Seidenfeld (1988a) and McClennen (1988a, 1990), went on between Seidenfeld (1988b) and Rabinowicz (1995, 1997) and focuses on the point whether the sophisticated DM violates crucial 'coherence' principles or not. See for instance Rabinowicz (1995) pp. 615-616.

^{xiii} Actually, BI is technically possible and results in the optimal strategy when CONS and DC are satisfied (thus in the EU framework). Otherwise: (1) if CONS is satisfied, then BI is technically possible, but, since DC cannot be universally satisfied, it may lead to the implementation of sub-optimal or even dominated strategies (sophisticated case); (2) if DC is preserved, then CONS is necessarily relaxed so that BI cannot be used (resolute case).

^{xiv} To be exhaustive, we should have also introduced the precommitting sophisticated strategy, allowing Ulysses to resort to an extraneous help to leave straightaway. But it is not really crucial here, since our concern is to compare resolution with sophistication and myopia.

¹⁶ Note that this term is not universally accepted in this meaning, since it refers to a well-established mathematical property. We have nevertheless chosen to abide by Machina's terminology. See Rabinowicz (1995) p. 605, footnote 15, for a discussion.

^{xvi} McClennen's terminology may have led to some misinterpretation of his argument. His claim that resolution consists in "disciplining ex post choice to ex ante choice" (1988b, p. 526) or in "regimenting future choice to the originally adopted plan" (McClennen, 1997, p.

231), as well as the idea that "one's present concerns and interests can effectively tyrannize over the concerns one subsequently comes to have" inevitably lead to the following question: why would subsequent selves accept such a dictatorial rule ? Naturally, this kind of resolution lacks genuine psychological foundations, which makes it look rather ad hoc !

^{xvii} "You cannot intend to act as you have no reason to act. [...] When we have good reasons to intend but not to act, conflicting standards of evaluation come into play and something has to give way." (Kavka, 1983, p. 35).

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