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ARTICLE

Behavioural and heuristic models are as-if models too – and that's ok

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Abstract
I examine some behavioural and heuristic models of individual decision-making and argue that the diverse psychological mechanisms these models posit are too demanding to be implemented, either consciously or unconsciously, by actual decision makers. Accordingly, and contrary to what their advocates typically claim, behavioural and heuristic models are best understood as 'as-if' models. I then sketch a version of scientific antirealism that justifies the practice of as-if modelling in decision theory but goes beyond traditional instrumentalism. Finally, I relate my account of decision models to the recent controversy about mentalism versus behaviourism, reject both positions, and offer an alternative view.

Keywords: Neoclassical decision models; behavioural decision models; heuristic decision models; scientific antirealism; mechanistic explanation

1. Introduction

1.1. Neoclassical, behavioural and heuristic models

In the economic theory of individual decision-making, the models on offer can be divided into three main groups: neoclassical, behavioural and heuristic.

By neoclassical models I refer to traditional, mainstream models such as Expected Utility theory for risky decisions (Bernoulli 1954 [1738]; von Neumann and Morgenstern 1953 [1944]) or the Discounted Utility model for intertemporal decisions (Samuelson 1937; Koopmans 1960). These models dominated decision theory until the late 20th century, are still taught in most economics courses, and are widely used in applied economics. Neoclassical models conceptualize choice as the result of preference or utility maximization.

By behavioural models I broadly refer to the models that began to be advanced in the late 1970s to account for behaviours that were repeatedly recorded in choice experiments and violate neoclassical models. Popular behavioural models include Prospect Theory (Kahneman and Tversky 1979), Rank Dependent Utility theory

(Quiggin 1982) and the Quasi-Hyperbolic model (Laibson 1997). Behavioural models extend and modify neoclassical models in different ways, but they maintain the neoclassical conceptualization of choice as the result of preference or utility maximization.[1]

The third group of decision models is constituted by heuristic models, which adopt the heuristic-based approach inaugurated by Simon (1955) and developed, among others, by Gigerenzer and his research associates (see e.g. Gigerenzer 1999). Like behavioural models, heuristic models aim at accounting for a wide array of choice behaviours, including those violating neoclassical theories. However, in the heuristic approach preference and utility maximization are absent from the explicit model, and choice is conceived of as the result of the application of simple heuristic rules on the part of the decision maker.[2]

1.2. As-if models, and their discontents

In a seminal article on Expected Utility theory (henceforth EU), Friedman and Savage (1948) interpreted EU as an 'as-if model' of individual decision-making under risk. Friedman (1953) refined the as-if interpretation of EU and extended it to other economic models.[3]

Broadly speaking, as-if models attempt to account for the observable choices that individuals make, but do not pretend to capture the underlying psychological mechanisms that might generate those choices. Some underlying choice-generating mechanism, such as utility maximization, is attached to the model. However, in the as-if approach the decision theorist is agnostic about whether this mechanism actually operates in the mind of the decision maker. She may even deem, and explicitly acknowledge, that the posited mechanism and its components (such as the utility function, the preference relation or the heuristic rules), are only fictional constructs. Nonetheless, the decision theorist explains, describes or predicts the decision maker's choices *as if* they were generated by the posited psychological mechanism at issue. Insofar as the as-if model is capable of accounting for the decision maker's choice behaviour or indicating

[1]Among behavioural models, it is possible to further distinguish between models in the 'heuristics & biases' program, which extend neoclassical models by modifying the form of the utility function or adding new constructs, such as a weighting function $w(p)$ or an impulsivity factor β (e.g. Kahneman and Tversky 1979; Laibson 1997), and 'decision-theoretic models', which modify the assumptions about the preference relation (e.g. Quiggin 1982). For the purposes of the present article, however, this distinction is immaterial. We will briefly return to it in the conclusions.

[2]Heuristic models *à la* Simon–Gigerenzer are often labelled as models belonging to the 'fast-and-frugal-heuristics' programme and are opposed to behavioural models in the 'heuristics & biases' programme (see footnote 1). In this article I employ the expression 'heuristic' only in relation to the Simon–Gigerenzer approach.

[3]Friedman's 1953 essay has generated an enormous debate in the philosophy of economics and has been interpreted in several contrasting ways, ranging from instrumentalism to realism (see Mäki 2009a for an overview of the interpretations until the early 2000s, and Galbács 2019 and Hoyningen-Huene 2021 for more recent accounts). Here I do not engage with the controversies about Friedman's essay, as I believe that the broad characterization of the as-if approach offered below suffices for the present paper's purposes. For a more fine-grained analysis of as-if claims, see Lehtinen (2013).

ways to effectively control it for economic policy purposes, the model is considered scientifically valid.

To better illustrate the as-if account of decision models, some quotations may be useful. In their article, Friedman and Savage (1948: 298) argued that EU theory 'does not assert that individuals explicitly or consciously calculate and compare expected utilities. … The hypothesis asserts rather that, in making a particular class of decisions, individuals behave *as if* they calculated and compared expected utility.' Accordingly, the validity of EU 'does not depend on whether individuals … say that they calculate and compare expected utilities … or whether psychologists can uncover any evidence that they do'. Moving from the late 1940s to the early 2020s, in a recent paper Gilboa *et al.* (2021: 96) note that neoclassical consumer theory 'does not assume that a mental process of maximization actually takes place. … While many writers have commented on the fact that a literal interpretation of the theory does not appear very plausible, economic theory generally adopts the "as if" interpretation of constrained utility maximization, thus rendering the … point largely irrelevant.'[4]

While decision theorists of all camps tend to understand neoclassical models such as EU and consumer theory as as-if models, the interpretation of the status of behavioural and heuristic models is more controversial. Behavioural economists have often criticized the as-if approach to economic modelling and have argued that decision models should figure out correctly the underlying psychological processes that generate individual choice behaviour. They have also claimed that their behavioural models fulfil this requirement and that this is the reason why behavioural models account for choice behaviour better than neoclassical models (see e.g. Thaler 1980; Rabin 1998; Starmer 2000; Diecidue and Wakker 2001; Wakker 2010; Thaler 2016). For instance, Camerer and Loewenstein (2004: 3) argue that 'at the core of behavioral economics is the conviction that increasing the realism of the psychological underpinnings of economic analysis will improve the field of economics'. In opposition to the as-if approach to economic modelling, they add that 'the ultimate test of a theory is the accuracy with which it identifies the actual causes of behavior' (2004: 4).

In the decision-theoretic literature, models that capture, or at least pretend to capture, the actual psychological processes generating individual choice behaviour have been called 'homeomorphic models' (Wakker 2010), 'procedural models' (Starmer 2000) or, to use the name I adopt here, 'process models' (Berg and Gigerenzer 2010).

Like behavioural economists, decision theorists who advocate heuristic models have also criticized the as-if approach to economic modelling and have argued that decision models should be process models. However, for these decision theorists not only neoclassical models, but also behavioural models, are mere as-if models. This is because behavioural models maintain the neoclassical conceptualization of choice as the result of preference or utility maximization, which is considered psychologically unrealistic by decision theorists following

[4]As-if models have also been called 'paramorphic models' (Wakker 2010) or, with a range of slightly different connotations, 'stories' (Dekel and Lipman 2010), 'analogies' (Gilboa *et al.* 2014) or 'fables' (Rubinstein 2012). Here I stick to the traditional expression 'as-if models'.

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the heuristic approach. For them, only models that frame choice as deriving from the application of some simple heuristic on the part of the decision maker are genuine process models that capture actual psychological mechanisms (see e.g. Brandstätter *et al.* 2006; Güth 2008; Katsikopoulos 2014; Pachur *et al.* 2017). For example, Berg and Gigerenzer (2010: 133) argue that 'behavioral economics appears indistinguishable from neoclassical economics in its reliance on "as-if" arguments'.

1.3. This article

My first claim here is that the models currently used in decision theory, be they neoclassical, behavioural or heuristic, are best understood as as-if models. The main argument in support of this claim is that the psychological mechanisms posited by current decision models are cognitively too demanding to be implemented, consciously or unconsciously, by actual decision makers. This argument is reinforced by the consideration that, outside economics, human decision making is often modelled by referring to psychological constructs different from those used in decision theory.

The claim that neoclassical models such as EU or consumer theory are best understood as as-if models may appear trivial since decision theorists of all camps tend to interpret them in this way, as the previous quotations also suggest. However, for behavioural and heuristic models the claim is far from trivial, for their advocates are typically adamant in presenting them as process models that correctly portray the psychological mechanisms generating individual choice behaviour.

My second and more philosophical claim is that, contrary to what advocates of behavioural and heuristic models usually assert, as-if modelling in the theory of decision-making is not an illegitimate scientific practice but an epistemologically justified approach that can be rationalized by some form of scientific antirealism. In particular, the version of antirealism I advance in this article emphasizes the role that mechanistic explanations play in decision theory and therefore goes beyond traditional instrumentalism. With respect to the recent controversy in the philosophy of economics about the mentalist versus the behaviourist interpretation of preferences and other decision-theoretic constructs (for a review, see Moscati 2021), my account of decision models opposes both mentalism and behaviourism and offers an alternative interpretation of those constructs.

Note that the validity of the first claim, i.e. that behavioural and heuristic models are as-if models too, is independent of the validity of the second claim, i.e. that this state of affairs is epistemologically – as the title of the article says – ok. Although I hope to persuade the reader that both claims are valid, I can imagine readers who accept the first claim but not the version of scientific antirealism that backs the second. Even in this case, I submit, this article provides a novel contribution to the philosophical understanding of behavioural and heuristic models of decision-making.

I make my case in three steps. Initially, I focus on three prominent models for decisions in situations of risk, that is, situations where decision makers are supposed

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to know the objective probabilities of the uncertain outcomes. I first consider Expected Utility theory (EU), distinguishing between Bernoulli's and von Neumann–Morgenstern's versions of EU. I then move to Cumulative Prospect Theory (CPT), which over the years has become the leading behavioural model for risk, and the Priority Heuristic model (PH), which is a widely discussed heuristic model for risk. In section 2, I quickly review EU, CPT and PH. Next, in sections 3–6, I expound my arguments in support of the claim that not only EU but also CPT and PH are best understood as as-if models. Lastly, in section 7 I extend the claim made for these three decision models to other neoclassical, behavioural and heuristic models for decision-making under risk or uncertainty, and over time.

In the second part of the article I connect the debate about the as-if account of decision theories to the time-honoured debate between realist and antirealist accounts of scientific theories. In section 8, I sketch a version of scientific antirealism that offers an epistemological rationalization of as-if modelling practices in decision theory. This version of antirealism goes beyond traditional instrumentalism, in that it attempts to capture the important role that explanations play in decision theory. Moreover, the antirealism on offer is local in both a disciplinary sense (it applies to decision theory but might not hold for other areas of economics) and a temporal sense (it concerns the current state of decision theory but might not hold for future developments in the discipline). In section 9, I relate my antirealist account of decision models to the controversy about mentalism and behaviourism in decision theory, and to the realist accounts of decision models advanced by Dietrich and List (2016) and Mäki (2009b, 2012). In particular, I reject behaviourism and defend the use of psychological constructs in decision theory. However, I also argue that the rejection of behaviourism does not imply a commitment to either a realist or a mentalist interpretation of these psychological constructs. A possible and apparently oxymoronic label for my position is 'as-if mentalism'. Section 10 concludes.

A few final remarks about the goals and scope of the article are in order. First, this is not at all a paper against behavioural or heuristic models of decision-making (if anything, it is just the opposite of that). I do not criticize the scientific validity of behavioural or heuristic models of decision-making, but only their interpretation as process models. I do not take issue with the scientific practices of behavioural economists and decision theorists who advocate heuristic models, but only with the way they interpret their own practices. Second, although I also discuss the epistemological status of the single components of the decision mechanisms featured in the models under consideration (e.g. the utility function or the preference relation), my focus here is on how the models use or combine these components in order to explain choice behaviour; that is, the focus is on the decision mechanisms as a whole. Third, I focus on decision theories as descriptive rather than normative models of human decision-making and do not explore the implications of my as-if account of decision models for the normative use of these models; although the latter is certainly an important topic, discussing it in some detail would require another paper. Finally, I do not consider models in consumer theory, nor models in game theory. I deem that the arguments advanced in this article extend to these other models, but I do not have room to discuss them here.[5]

2. EU, CPT and PH: A Review

2.1. Bernoulli's EU

Expected Utility theory was originally advanced by Daniel Bernoulli (1954 [1738]) to model decision-making in situations of risk. In these situations, the decision maker chooses between alternative options of the form $\left[x_1, p_1; x_2, p_2; \ldots; x_N, p_N\right]$ that are called prospects or lotteries. A lottery yields outcome x_i with objective probability p_i, which is supposed to be known by the decision maker.

In Bernoulli's EU the primitive element of the analysis, besides the probabilities p_i of the outcomes, is a function $u(x)$ which is defined over the set of outcomes and expresses the utility that each possible outcome x_i would give the decision maker if he eventually obtains that outcome. Interpreted as a model that portrays actual psychological processes, Bernoulli's EU posits the following five-step decision mechanism, which I shall call the Bernoullian mechanism:

(1) For each possible outcome x_i, the decision maker determines the utility $u(x_i)$ that he would obtain from outcome x_i.
(2) He weights the utility $u(x_i)$ of each outcome by multiplying it by the objective probability of the outcome, that is, he calculates the N values $u(x_1)p_1, \ldots, u(x_N)p_N$.
(3) He adds the weighted utilities calculated in step 2, that is, he computes the expected utility $\sum_{i=1}^{N} u(x_i)p_i$ of the lottery.
(4) He repeats steps 1–3 for all lotteries in his choice set.
(5) Finally, he chooses the lottery associated with the highest value of $\sum_{i=1}^{N} u(x_i)p_i$.

The Bernoullian mechanism is the prototype of a class of mechanisms that is featured in many other decision-theoretic models, which I shall call 'multiply-and-add mechanisms'. In these mechanisms the utility function $u(x)$ is a primitive element of the analysis and the decision maker is supposed to multiply utility values, i.e. utilities, by some factor, add the multiplied utilities, and choose the option associated with the highest sum of the multiplied utilities.

2.2. Von Neumann and Morgenstern's EU

Bernoulli's EU underwent alternate fortunes in economics. From the 1730s to the 1870s, it passed almost unnoticed in the discipline. Beginning in the 1870s, it was rediscovered and accepted by most economists of the period, although with some reservations. In the 1920s and 1930s, further criticisms against the theory were raised and by the early 1940s the supporters of it were few. The fortunes of EU

[5]Regarding game theory, Vromen (2022) makes a point similar to the one I make here for decision theory, namely that behavioural game-theoretic models featuring inequality aversion and other social preferences are as-if models, just like the neoclassical game-theoretic models they intend to supplant.

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recovered in the 1950s, after von Neumann and Morgenstern (1953 [1944]) provided an alternative version of the theory (on the fortunes of EU in economics, see Schlee 1992 and Moscati 2018). Bernoulli's EU and von Neumann and Morgenstern's EU are often taken to be one and the same theory, and for many purposes this identification is satisfactory. However, for our purposes here it is important to keep the two versions of EU distinct because they feature different primitive notions and different decision mechanisms.[6]

In von Neumann and Morgenstern's EU the primitive element of the analysis is not a utility function defined over the set of outcomes, but a binary relation indicated by the symbol $\succcurlyeq$, defined over the set of lotteries and interpreted as representing the decision maker's preferences between lotteries. Concerning the decision mechanism, the decision maker is supposed to rank all lotteries available to him from the least preferred to the most preferred, and to choose the most preferred one.

Since von Neumann and Morgenstern's preference-based decision mechanism does not require complicated calculations, from a cognitive viewpoint it may appear far less demanding than the Bernoullian multiply-and-add mechanism. However, as discussed in section 5, to ensure that the preference-based mechanism works properly, the preference relation $\succcurlyeq$ should display a number of unplausible properties.

Von Neumann-Morgenstern showed that if (and only if) the preference relation $\succcurlyeq$ satisfies these properties, there exists a function $\tilde{u}(x)$, termed the von Neumann-Morgenstern utility function and defined over the lotteries' outcomes, such that the decision maker prefers the lottery associated with the maximum value of the weighted sum $\sum_{i=1}^{N} \tilde{u}(x_i)p_i$. As the discussions of the 1950's on EU made clear (see in particular Ellsberg 1954; Luce and Raiffa 1957), the von Neumann-Morgenstern utility function $\tilde{u}(x)$ and the Bernoulli utility function $u(x)$ are not equivalent, neither analytically (for instance, one can be concave and the other convex), nor conceptually (if interpreted as psychological factors, they express different factors).[7]

At any rate, in the preference-based version of EU, the function $\tilde{u}(x)$ does not play any decisional role: the only components of the decision mechanism are the decision maker's preferences, and they operate by selecting the most preferred lottery, which is the lottery the decision maker will choose. In other terms, in von Neumann–Morgenstern's preference-based version of EU, the decision maker's choices between lotteries do not result from the combination of his desires for the outcomes (captured by a utility function) and his beliefs about the likelihood of events (captured by a probability function), but directly from his preferences

[6]Another difference between the two versions of EU is that von Neumann and Morgenstern presented their version of the theory in axiomatic terms while Bernoulli did not. But this difference is not essential for the purposes of this article and, besides, axiomatic versions of Bernoulli's EU do exist; see Peterson (2004).

[7]The von Neumann-Morgenstern function $\tilde{u}(x)$ expresses the decision maker's preferences between lotteries and therefore reflects and conflates all possible factors that may influence his preferences between uncertain options. One of these factors can certainly be his desire for the outcomes of the lotteries, and this is the factor captured by Bernoulli's utility function $u(x)$. But $\tilde{u}(x)$ may reflect also other factors, such as the decision maker's attitude toward risk. For more on the distinction between $\tilde{u}(x)$ and $u(x)$, see Schoemaker (1982); Abdellaoui *et al.* (2007); for a historical reconstruction of the discussions on $\tilde{u}(x)$ and $u(x)$, see Moscati (2018: Chs 10–12).

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between lotteries. The desire-belief interpretation of EU can be attached to Bernoulli's version of the theory not von Neumann–Morgenstern's.[8]

2.3. Cumulative Prospect Theory

In order to account for choice behaviours that violate EU, in the late 1970s Kahneman and Tversky (1979) put forward Prospect Theory. Cumulative Prospect Theory (Tversky and Kahneman 1992) is a modified version of Prospect Theory that fixes certain shortcomings of the original theory. The components of CPT are a 'value function', $v(x)$, and two 'weighting functions', $w^{+}(p)$ and $w^{-}(p)$.

The value function $v(x)$ is analogous to the Bernoullian utility function $u(x)$: it expresses the subjective valuation that the decision maker attaches to outcomes. However, for $v(x)$ the outcomes are defined as gains or losses with respect to some reference point, such as the decision maker's initial wealth, rather than as absolute payoff levels.

The weighting function $w^{+}(p)$ expresses how the decision maker subjectively perceives the objective probability p of obtaining an outcome that he regards as a gain. The decision maker overrates or underrates the objective probability p by assigning it a decision weight $w^{+}(p)$ that is different from p. For instance, if $w^{+}(p) = p^2$ and $p = 0.5$, the decision maker perceives this objective probability as if it were $0.5^2 = 0.25$. Analogously, $w^{-}(p)$ expresses how the decision maker subjectively perceives the objective probability p of a loss.

In CPT the outcomes of the prospect or lottery are reordered from the worst (x_1) to the best (x_N). In particular, it will be assumed that outcomes from x_1 to x_k are losses and outcomes from x_{k+1} to x_N are gains. Correspondingly, probabilities from p_1 to p_k are the probabilities of losses and probabilities from p_{k+1} to p_N are the probabilities of gains. This reordering allows us to identify 'cumulative probabilities'. For gains, $(p_i + \ldots + p_N)$ is the cumulative probability of gaining at least x_i. For losses, $(p_1 + \ldots + p_i)$ is the cumulative probability of losing x_i or more than x_i. Finally, for gains, the function $w^{+}(p_i + \ldots + p_N)$ expresses the decision weight that the decision maker assigns to the objective probability of gaining at least x_i. For losses, $w^{-}(p_1 + \ldots + p_i)$ expresses the weight that the decision maker assigns to the probability of losing x_i or more than x_i.

Now, according to CPT, the decision maker prefers the lottery associated with the maximum value of the following functional form:

$$\sum_{i=1}^{k} v(x_i)\left[w^{-}(p_1 + \ldots + p_i) - w^{-}(p_1 + \ldots + p_{i-1})\right] + \sum_{i=k+1}^{N} v(x_i)\left[w^{+}(p_i + \ldots + p_N) - w^{+}(p_{i+1} + \ldots + p_N)\right].$$

Like EU, CPT comes with a preference-based version (Wakker and Tversky 1993). Accordingly, and again just like in the case of EU, two distinct psychological choice-generating mechanisms can be attached to CPT: a multiply-and-add mechanism and a preference-based mechanism.

[8]On the frequent confusion between the two versions of EU in the economic and philosophical literature, see, respectively, Fishburn (1989) and Okasha (2016).

2.4. Priority Heuristic model

The Priority Heuristic model was advanced by Brandstätter *et al.* (2006, 2008) to account for the same type of EU-violating behaviours targeted by CPT, but without bringing into play preference or utility maximization. In the PH model, the decision maker is supposed to face a choice between lottery $A \equiv [x_1, p_1; \ldots; x_N, p_N]$ and lottery $B \equiv [y_1, q_1; \ldots; y_M, q_M]$. In each lottery the outcomes are ordered from the worst (x_1 and y_1) to the best (x_N and y_M). PH posits the following four-step decision mechanism:

(1) The decision maker focuses on the worst outcomes, namely x_1 and y_1. If the difference between them is significant enough, he chooses the lottery with the least-worst outcome; otherwise, he proceeds to step 2. Gigerenzer and co-authors suggest that the difference between worst outcomes is significant if it is 1/10 or more of the overall best outcome.
(2) The decision maker looks at the probabilities of the worst outcomes, namely p_1 and q_1. If the difference between them is significant enough, he chooses the lottery for which the probability of the worst outcome is smaller; otherwise, he proceeds to step 3. For Gigerenzer and co-authors, the difference between worst probabilities is significant if it is at least 10%.
(3) The decision maker considers the best outcomes and chooses the lottery with the higher best outcome. If they are equal, he moves to step 4.
(4) The decision maker considers the probabilities of the best outcomes and chooses the lottery for which this probability is higher.[9]

According to Gigerenzer and co-authors, decision makers do not always use PH. In situations where choice is straightforward, they use other heuristics. In particular, if one lottery stochastically dominates the other lottery, that is, if for every outcome x the probability of getting an outcome at least as good as x is higher in the former lottery than in the latter, decision makers choose the dominant lottery. If the expected value of one lottery is significantly larger than the expected value of the other lottery and, more specifically, at least twice as large, decision makers choose the lottery with the highest expected value.

3. The Multiply-and-add Mechanism of EU and CPT is an As-if Mechanism

In this section, I first follow the line of argument of Friedman and Savage (1948) and argue that the multiply-and-add mechanism featured in Bernoulli's EU is an as-if mechanism and then extend my arguments to the multiply-and-add mechanism featured in CPT.

[9]As an example of how PH works, consider lottery $A \equiv [\$120,\ 0.1; \$0,\ 0.9]$ and lottery $B \equiv [\$50,\ 0.15; \$5,\ 0.85]$. The difference between the worst outcomes (5–0=5) is smaller than 12, which is 1/10 of the overall best outcome \$120, and so the first rule is not conclusive. The difference between the probabilities of the worst outcomes is smaller than 0.1 (0.9–0.85=0.05) and therefore not even the second decision rule is decisive. Since the best outcome of lottery A (\$120) is higher than the best outcome of lottery B (\$50), the third rule selects lottery A.

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3.1. EU

As already discussed, the key building block of the Bernoullian mechanism is the utility function $u(x)$. At first sight, a psychologically realistic interpretation of $u(x)$ appears persuasive: for each possible outcome x_i, the decision maker determines the utility $u(x_i)$ he would experience if he obtains outcome x_i.

A first problem with this interpretation, however, is that it assumes that the decision maker is able to perform the hypothetical reasoning necessary to determine the utility he would obtain in each of the N possible scenarios. From a cognitive viewpoint, this sort of wide-ranging hypothetical reasoning appears highly demanding, especially when the number of possible scenarios is large.

A second problem is that the decision maker is supposed to provide a *numerical* determination of the satisfaction he would obtain from each possible outcome. The decision maker has some degree of freedom in determining the utility numbers, which, however, should be cardinal in nature.[10] Also, the idea that the decision maker is capable of assigning a cardinal number to each possible outcome appears onerous from a cognitive viewpoint.

If we move to the multiplications and additions postulated in steps 2–4 of the Bernoullian process, the problems become even more severe. In fact, it is highly dubious that decision makers actually perform, let alone perform correctly, the N multiplications $u(x_1)p_1, \ldots, u(x_N)p_N$, and that they then sum the multiplied numerical values in order to obtain $\sum_{i=1}^{N} u(x_i)p_i$. This evaluation is based not only on casual introspection (when we choose among risky options, we do not calculate numerical expressions such as $\sum_{i=1}^{N} u(x_i)p_i$), but also on psychological research on numerical skills and cognition (see e.g. Campbell 1997; Zbrodoff and Logan 2005; Nuerk *et al.* 2015). This research shows that normal individuals face significant difficulties dealing with addition and multiplication tasks much simpler than those involved in the calculation of $\sum_{i=1}^{N} u(x_i)p_i$.

3.2. CPT

If we pass to CPT, interpreting its multiply-and-add mechanism as a psychologically realistic process becomes even more awkward than it is for the mechanism featured in Bernoulli's EU.

A psychological interpretation of the value function $v(x)$ in CPT presents exactly the same problems as the psychological interpretation of the utility function $u(x)$ in Bernoulli's EU: $v(x)$ postulates that the decision maker is capable of performing the wide-ranging hypothetical reasoning necessary to determine numerically the value of each of the N possible outcomes, and that the value numbers $v(x_i)$ are cardinal in nature. As already argued, that the decision maker possesses such cognitive abilities appears far-fetched.

[10]Basically, this means that utility numbers should be capable not only of expressing the decision maker's ranking of outcomes, so that, if he prefers x_3 to x_2 and x_2 to x_1, then $u(x_3) > u(x_2) > u(x_1)$. In addition, utility numbers should be also capable of expressing more sophisticated evaluations, such as that the utility increment associated to the transition from x_1 to x_2 is larger than the utility increment associated to the transition from x_2 to x_3, so that $u(x_2) - u(x_1) > u(x_3) - u(x_2)$.

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Even a psychologistic interpretation of the weighting functions $w^{+}(p)$ and $w^{-}(p)$ appears problematic. I shall focus on $w^{+}(p)$, but the same arguments hold for $w^{-}(p)$. In the process interpretation of CPT for risk, the decision maker is supposed to know, or to be able to calculate, the objective cumulative probability $(p_i + \cdots + p_N)$ and then to transform it into the decision weight $w^{+}(p_i + \cdots + p_N)$. But since it is the decision maker himself who is supposed to transform objective cumulative probabilities into decision weights, he cannot ignore that the latter do not coincide with the former, and therefore that decision weights are a biased indicator for decision-making. In other terms, if interpreted as a psychologically realistic function describing an operation that the decision maker performs (rather than an as-if function expressing how the economist models the decision maker's behaviour), the function $w^{+}(p)$ is incongruous because it posits that the decision maker knows the objective cumulative probability $(p_i + \cdots + p_N)$, knows that the decision weight $w^{+}(p_i + \cdots + p_N)$ is a biased transformation of $(p_i + \cdots + p_N)$, and nonetheless uses the decision weight to make his decision.

If we consider the multiplications and additions postulated by the CPT mechanism, the situation is more complex than in the mechanism featured in Bernoulli's EU. The decision maker is supposed to calculate the k differences $[w^{-}(p_1 + \cdots + p_i) - w^{-}(p_1 + \cdots + p_{i-1})]$ and the $N-k$ differences $[w^{+}(p_i + \cdots + p_N) - w^{+}(p_{i+1} + \cdots + p_N)]$ and to multiply each of these N differences by the appropriate $v(x_i)$ to arrive at the value expressed by the CPT formula and choose the lottery associated with the highest CPT value.

These calculations are so complex that even the expert decision theorist finds it difficult to perform them and has a hard time explaining them to graduate students. The idea that normal individuals who are not mathematical prodigies perform these calculations every time they choose between risky options is contradicted by both casual introspection and psychological research on numerical skills and cognition (see the already mentioned studies of Campbell 1997; Zbrodoff and Logan 2005; Nuerk *et al.* 2015).

4. Unconscious Processes?

So far, I have argued that it is preposterous to conceive the multiply-and-add mechanism posited by CPT as a psychologically realistic process. There is, however, a possible defence of the process-interpretation of CPT, and maybe of EU and other decision models, that should be discussed. According to it, CPT describes unconscious processes that do operate in the decision maker's mind, but below the level of awareness.

I think that arguing that the multiply-and-add mechanism posited by CPT is psychologically real but unconscious is only a more convoluted and less transparent manner of saying that it should be conceived as an as-if mechanism.

With unconsciousness, by definition, we do not have direct, introspective evidence about the alleged unconscious processes posited by CPT. In effect, the conscious, introspective evidence speaks against the psychological reality of those

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processes: introspection tells us that we do not calculate mathematical expressions such as $\sum_{i=1}^{k} v(x_i)[w^-(p_1 + \cdots + p_i) - w^-(p_1 + \cdots + p_{i-1})] + \sum_{i=k+1}^{N} v(x_i)[w^+(p_i + \cdots + p_N) - w^+(p_{i+1} + \cdots + p_N)]$.

Because they lack direct, introspective evidence to support them, theories about unconscious processes are only 'stories' about the black box, in the sense that they offer a narrative about how decisions are made, but the narrative does not pretend to be fully true (on the role of stories and narratives in economic modelling, see Morgan 2012). As argued more extensively in section 8.5, insofar as stories allow decision theorists to explain, describe or predict the decision maker's behaviour, they are scientifically useful. This means, however, that the possible support for stories about unconscious processes is indirect and depends on their capacity for accounting for observed choices. But this is exactly how as-if models get their support: just like stories, they are non-committal about the reality of the conscious or unconscious mechanisms they posit and are backed by their ability to describe and explain the decision maker's observable choice behaviour.

Instead of bringing into play the ambiguous concept of unconsciousness, I think it is more straightforward to conceive of the multiply-and-add mechanism posited by CPT as an as-if mechanism. Instead of claiming that calculations such as $\sum_{i=1}^{k} v(x_i)\left[w^-(p_1 + \cdots + p_i) - w^-(p_1 + \cdots + p_{i-1})\right] + \sum_{i=k+1}^{N} v(x_i)\left[w^+(p_i + \cdots + p_N) - w^+(p_{i+1} + \cdots + p_N)\right]$ take place in some unconscious part of the decision maker's mind, I contend that it is more appropriate to acknowledge that they take place in the conscious mind of the decision theorist.

5. The Preference-based Mechanism of EU and CPT is an As-if Mechanism

As already mentioned, like EU, CPT also comes with a preference-based version in terms of a binary relation that is indicated by the symbol $\succcurlyeq$ and is identified with the notion of 'preference'. The expression A $\succcurlyeq$ B indicates that the decision maker prefers lottery A to lottery B. In the preference-based approach it is assumed that the relation $\succcurlyeq$ satisfies certain requirements, defined by a set of axioms. Among them are the axioms of completeness and transitivity, which are also featured in EU and most other behavioural models of decision making. Other axioms change across models and are responsible for their differences.

Completeness requires that the decision maker is aware of all lotteries available to him and that for any two lotteries A and B he faces, he can state whether A $\succcurlyeq$ B or B $\succcurlyeq$ A or both (in which case he is said to be indifferent between A and B). Transitivity states that if for the decision maker A $\succcurlyeq$ B and B $\succcurlyeq$ C, then A $\succcurlyeq$ C.

In the preference-based approach, the decision mechanism is different from the multiply-and-add mechanisms discussed in section 3: it states that the decision maker ranks all lotteries in his choice set from the least preferred to the most preferred and chooses the most preferred one. The axioms of completeness and transitivity play a central role in the preference-based mechanism because they guarantee that the ranking of lotteries does not have any gaps or loops, and thus ensure that the decision maker can in fact identify and choose his most preferred lottery.

My claim that not even the preference-based mechanism featured in CPT can be interpreted as a psychologically realistic process, and that it is best understood as an

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as-if mechanism, is supported by three arguments. Since the preference-based mechanism featured in CPT works like the one featured in the preference-based version of EU, the arguments also apply to EU. For the purposes of the present article, however, I focus on CPT.

5.1. Incomplete and intransitive preferences

First, as signalled by several scholars, the preferences of actual decision makers often fail to be complete and transitive. Completeness can be violated because decision makers often are not aware of all lotteries available to them (see e.g. Gilboa *et al.* 2021). Moreover, even if they are aware of all available options, they may not know what they prefer and be indeed undecided (Aumann 1962; Gilboa *et al.* 2012). Transitivity may be violated when choice options contain multiple dimensions. For instance, when the two basic dimensions of lotteries (monetary payoffs and their probabilities) are inversely correlated (the higher the payoff, the lower the probability of obtaining it), intransitive preference patterns are rather frequent (Tversky 1969).

However, if the decision maker's preferences are incomplete, intransitive or both, he cannot rank all lotteries in his choice set from the least to the most preferred one and choose the latter.

5.2. Unstable preferences

In addition to the explicit requirements stated by the axioms of completeness and transitivity, and again just like EU, CPT also assumes that the decision maker's preferences are relatively stable over time, across choice domains and across elicitation methods. In fact, if the decision maker's preferences are complete and transitive, but they rapidly change from one moment to another, vary when applied to different choice sets, or depend on the method used to elicit them, then they would be of little use in explaining or predicting the decision maker's choice behaviour.

Concerning the issue of temporal stability, a series of studies have shown that preferences between lotteries are, in effect, relatively stable over time (Andersen *et al.* 2008; Zeisberger *et al.* 2012). In contrast, neither stability across domains nor stability across elicitation methods can be taken for granted.

With respect to stability across domains, one form of instability goes under the name of 'menu effects', which occur when adding or subtracting options from the choice set seems to modify the decision maker's preferences (Huber *et al.* 1982; Simonson 1989; Herne 1999; Beauchamp *et al.* 2020). Another form of instability occurs when the decision maker's preferences change when he is faced with lotteries of different types. For instance, decision makers appear to be more risk averse when they choose among insurance policies for their home than when they choose among insurance policies for their car (see e.g. Barseghyan *et al.* 2011; Einav *et al.* 2012).

The third stability issue relates to the circumstance that the decision maker's preferences between lotteries appear to depend on the method used to elicit them. That is, if one method is adopted, he appears to prefer lottery A to lottery B, while if another, theoretically equivalent, method is used, lottery B turns out

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to be preferred to lottery A. The most famous instance of preference instability across elicitation methods is related to the phenomenon of 'preference reversal', first documented by Lichtenstein and Slovic (1971) and confirmed in several subsequent studies.

Summing up the first two arguments, the preferences of actual decision makers appear to be often incomplete, intransitive and unstable. Therefore, the complete, transitive and stable preferences featured in CPT should not be understood as entities actually existing in the decision maker's mind but as theoretical constructs existing in the decision theorist's mind, through which she explains, describes or predicts the decision maker's choice behaviour.

5.3. Not only preferences

The third argument against the interpretation of the preference-based mechanism featured in CPT as a psychologically realistic process is independent of the previous two. Even if we admit, for the sake of the argument, that decision makers harbour in their minds complete, transitive and stable preferences, it is far from obvious that their choices between risky options are determined by a preference-based process.

If we set aside the theoretical practices and habits of thought of neoclassical and behavioural decision theory, we find that in neighbouring fields a variety of preference-free psychological processes have been advanced in order to account for choice behaviour in conditions of risk. If we remain within decision theory, as we saw in section 2.3, Gigerenzer and co-authors conceive of choice behaviour under risk as the result of the application of heuristics on the part of the decision maker. If we move to psychology, choice behaviour is often explained by bringing into play other dimensions of the human mind, such as intelligence and other cognitive abilities; personality traits, such as openness, conscientiousness and extraversion; or transient emotional states (see e.g. Almlund *et al.* 2011; Dohmen *et al.* 2018; Mata *et al.* 2018). Viewed from these neighbouring fields, attempts to account for choice behaviour relying exclusively on a preference-based mechanism appear an idiosyncrasy of neoclassical and behavioural economics.[11]

To be sure, this idiosyncrasy has solid historical and methodological justifications and I am far from claiming that it is scientifically incorrect. What I am claiming is that the preference-based mechanism featured in the axiomatic foundations of CPT cannot be credibly interpreted as a psychologically realistic process. Arguably, the actual psychological processes that account for decision-making under risk are more complicated and involve dimensions of the human mind that are absent from the preference-based mechanism. Therefore, and at least given the current state of scientific knowledge, interpreting CPT and other preference-based models as as-if models, and maintaining a non-committal stance about the psychological reality of the preference-based mechanisms featured in them, seems a reasonable position.

[11]If a reference to popular culture is allowed, in the Oscar-winning animated movie *Inside Out* (2015), the behaviour of the protagonist, a young girl named Riley, is not portrayed as determined by utility, preferences or heuristics, but by five personified emotions that inhabit her mind: Joy, Sadness, Fear, Anger and Disgust. According to psychologists Keltner and Ekman (2015), who served as scientific consultants in the production of the film, the movie successfully dramatizes some 'central insights from the science of emotion'.

6. The Heuristic Mechanism of PH is an As-if Mechanism

Gigerenzer and co-authors (Brandstätter *et al.* 2006, 2008) interpret the Priority Heuristic model as a process model and contrast it with neoclassical and behavioural models such as EU and CPT, which they criticize for being as-if models. In accord with Rieger and Wang (2008), I contend that PH should also be interpreted as an as-if model.

First, as mentioned in section 2.3, when one lottery stochastically dominates the other, or when the expected value of one lottery is at least twice as large as the expected value of the other lottery, decision makers are not supposed to use PH. This means, however, that in order to decide whether to use PH or not, decision makers need to check for stochastic dominance, calculate the expected values of the two lotteries, and assess the ratio of the expected values. Although these tasks appear less challenging than the multiply-and-add tasks required by EU and CPT, they are still cognitively demanding. Moreover, introspective evidence does not support the claim that, before choosing between risky options, we check for stochastic dominance or calculate the ratios of their expected values.

Second, decision makers are supposed to perform tasks that are cognitively demanding and conflicting with introspective evidence, not only in the preliminary step of the PH mechanism but also in the first two steps of the process. In step 1, they should calculate the difference between the worst outcomes and compare it with some fraction (allegedly 1/10) of the overall best outcome. In step 2, they should check whether the difference between the probabilities of the worst outcomes is larger than 10%. Admittedly, these tasks are less demanding than the multiplication and summation tasks posited by EU and CPT. However, they nonetheless require numerical skills that cannot be taken for granted (see the already mentioned studies of Campbell 1997; Zbrodoff and Logan 2005; Nuerk *et al.* 2015). Moreover, introspective evidence does not indicate that, before choosing between lotteries, we calculate some fraction of the overall best outcome, or check whether the difference between the probabilities of the worst outcomes is larger or smaller than 10%.

Finally, the PH mechanism focuses on the worst and best outcomes of the lotteries and completely ignores their intermediate outcomes. The idea that actual decision makers totally ignore the intermediate outcomes of the lotteries contradicts not only introspective evidence but also experimental evidence (see e.g. Glöckner and Betsch 2008; Ayal and Hochman 2009; Fiedler 2010).

In conclusion, it appears that, just like EU and CPT, PH is also best conceived as an as-if rather than a process model.

7. Other Decision Models are As-if Models too

So far I have argued that EU, CPT and PH should be interpreted as as-if models. I also deem that other neoclassical, behavioural and heuristic models in the decision-theoretic literature are best interpreted as as-if models. To fully support this wide-ranging claim would require another paper. However, here I can at least sketch my argumentative strategy.

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7.1. Neoclassical and behavioural models

Besides CPT, other behavioural models for decisions under risk include Prospect Theory, Rank Dependent Utility theory, Regret Theory, various models featuring disappointment and Salience Theory. In the theory of decision in situations of uncertainty, that is, when the decision maker does not know the objective probabilities of the outcomes but might have personal beliefs about their respective likelihood, the neoclassical theory is Subjective Expected Utility theory, while behavioural theories include Choquet Expected Utility, Cumulative Prospect Theory for uncertainty, Maximin Expected Utility and the Smooth Model of Ambiguity. For intertemporal decisions, that is, for situations in which the decision maker chooses between alternative distributions of consumption goods or money over time, the neoclassical model is the Discounted Utility model, while behavioural models include the Quasi-Hyperbolic model, the Discounting-By-Intervals model, various models with temptation and models that emphasize the risky element associated with decisions involving future outcomes.[12]

Their differences notwithstanding, neoclassical and behavioural models all feature multiply-and-add mechanisms or preference-based mechanisms analogous to those featured in EU and CPT. Therefore, it is straightforward to extend to them the arguments used for EU and CPT presented in sections 3–5: (1) neither psychological introspection nor psychological research on numerical skills support the claim that actual decision makers perform the multiplication and summation tasks posited by multiply-and-add mechanisms; (2) just like preferences between risky options, preferences between uncertain and intertemporal options can also easily be incomplete, intransitive and unstable across choice domains and elicitation methods; (3) the actual psychological mechanisms that account for decision-making under uncertainty and over time seem to involve dimensions of the human mind, such as cognitive abilities, personality traits and emotional states, that are not captured by simple preference-based mechanisms.

7.2. Heuristic models

Extending the arguments used to claim that PH is an as-if theory to other heuristic models for decision-making under risk, uncertainty and over time is more difficult because each model posits its own specific heuristic process.[13] However, the following general points can be made.

First, and just as in the case of PH, heuristic models often hypothesize that decision makers perform a series of tasks that, although less laborious than the tasks posited by neoclassical and behavioural models, are nonetheless cognitively demanding and therefore, somehow, implausible. For instance, the Better-than-average heuristic (Thorngate 1980) hypothesizes that the decision

[12]For reviews of neoclassical and behavioural models for decision-making under risk, uncertainty and over time, see Schoemaker (1982), Starmer (2000), Frederick *et al.* (2002), Gilboa (2009), Wakker (2010), Gilboa and Marinacci (2013), Lipman and Pesendorfer (2013), Ericson and Laibson (2019) and Bordalo *et al.* (2022).

[13]For reviews of heuristic models for decision-making under risk, uncertainty and over time, see Thorngate (1980), Payne *et al.* (1993) and Gigerenzer and Gaissmaier (2011).

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maker calculates the overall average of all payoffs of all lotteries, counts the number of payoffs higher than the grand average, and then chooses the lottery with the largest number of such payoffs. Especially the averaging task posited in the first step of the procedure appears quite demanding from a cognitive viewpoint. The Intertemporal Choice Heuristic (Ericson *et al.* 2015) for decisions between an earlier amount of money $\$x_1$ received at time t_1 and a later amount $\$x_2$ received at time t_2 posits, if interpreted psychologically, that the decision maker calculates the following expression: $\alpha + \beta(x_2 - x_1) + \gamma \frac{2(x_2 - x_1)}{x_1 + x_2} + \delta(t_2 - t_1) + \varepsilon \frac{2(t_2 - t_1)}{t_1 + t_2}$, whereby α, β, γ, δ and ε are positive parameters. The cognitive difficulty involved in this calculation appears comparable to the difficulty involved in the multiply-and-add calculation featured in neoclassical and behavioural models.

Second, there is a trade-off between the simplicity of the cognitive tasks posited by a heuristic model and the range of choice behaviours it can account for, so that simple heuristics do not explain much. For instance, heuristics such as Minimax (choose the lottery with the highest minimum payoff), Maximax (choose the lottery with the highest maximum payoff), Least-likely (identify each lottery's worst payoff, then choose the lottery with the lowest probability of the worst payoff) and Most-likely (identify the most likely payoff of each lottery, then choose the lottery with the highest, most likely payoff) involve relatively simple cognitive tasks, but, as discussed by Gigerenzer and co-authors (Brandstätter *et al.* 2006), they do not account well for the choice behaviours recorded in experiments. The Similarity heuristic by Rubinstein (1988), which concerns both decisions under risk and intertemporal decisions, is also relatively simple from a cognitive viewpoint, but applies only to very specific choice situations.[14]

Third, introspective evidence often does not support the claim that we make decisions by completing the series of tasks hypothesized by heuristic models, be they complex tasks such as those postulated by PH, Better-than-average and the Intertemporal Choice Heuristic, or simpler tasks such as those suggested by the Minimax or Maximax models.

Finally, and just as in the case of behavioural models, the actual psychological mechanisms that account for decision-making under risk, uncertainty and over time seem to involve multiple dimensions of the human mind, such as cognitive abilities, personality traits and emotional states, that are not easily captured by heuristic mechanisms.

7.3. Not a sin

As discussed in section 1, behavioural economists who criticize neoclassical decision theories as mere as-if models, as well as advocates of heuristic models who criticize behavioural theories as only a more sophisticated version of as-if models, seem to take for granted that as-if modelling is a sinful scientific practice. If what I have

[14]Rubinstein considers choices between lotteries such as $A \equiv [\$x_1,\ p_1; \$0,\ 1 - p_1]$ and $B \equiv [\$x_2,\ p_2; \$0,\ 1 - p_2]$. The Similarity heuristic applies only when x_1 and x_2, or p_1 and p_2, are sufficiently 'similar' in a specified technical sense. For intertemporal choices between $\$x_1$ at time t_1 and $\$x_2$ at time t_2, the Similarity heuristic applies only when x_1 and x_2, or t_1 and t_2, are sufficiently similar. Often, however, none of these similarity conditions is satisfied, which makes the Similarity heuristic inapplicable.

argued so far is correct, then behavioural economists and advocates of heuristic models are also guilty of this sin. In section 8 I provide an antirealist account of decision theory according to which, in effect, as-if modelling in the analysis of decision-making is not a sinful scientific practice but an epistemologically justified approach.

8. An Antirealist Account of As-if Models

The debate about whether the current economic models of individual decision-making are, or should be, as-if models or process models appears a discipline-specific manifestation of the time-honoured opposition in the philosophy of science between realist and antirealist accounts of scientific theories (for a recent overview, see Chakravartty 2017). Roughly speaking, the view that current decision models are, or should be, process models expresses a realist understanding of scientific theories, while the view that they are best conceived of as as-if models is in accord with scientific antirealism.[15]

However, scientific realism and antirealism are not simple and univocal epistemological positions but each consists of a cluster of related views about the status of theories, and each position has several variants. In this section, I spell out a version of scientific antirealism that offers an epistemological rationalization of as-if modelling practices in decision theory. Following a consolidated approach in the realism-antirealism debate in the philosophy of science (see e.g. Psillos 1999; Chakravartty 2007), I begin by characterizing the version of antirealism on offer along three dimensions, the ontological, the semantic and the epistemic.

8.1. The ontological dimension

Most versions of scientific antirealism maintain that the world investigated by scientists exists independently of the scientific representations of it. That is, from an ontological viewpoint most versions of scientific antirealism are realist. The as-if account of decision models offered in this article is also ontologically realist: decision makers are real, and their minds, bodies and behaviours exist independently of the decision theorists who study and represent them.

8.2. The semantic dimension

At the semantic level, one key element of scientific realism in its various versions is the idea that scientific terms refer to actual entities – objects, properties, relations or mechanisms – that exist in the world. These entities can be observable (by unaided sense or with instruments) or unobservable. According to semantic realism, scientific terms should provide literal representations of the observable and unobservable entities they refer to, although also approximate representations, such as abstractions or idealizations, are admitted.

[15]In other parts of economic theory, such as macroeconomics and econometrics, the opposition between scientific realism and antirealism surfaces through the opposition between, respectively, structural models and reduced-form models of the economy; see e.g. the classic paper by Lucas and Sargent (1981 [1979]).

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In contrast to the semantic tenet of realism, the as-if interpretation of decision theories on offer here is non-committal about whether scientific terms that refer to unobservable entities and mechanisms represent, either literally or approximately, entities and mechanisms actually existing and operating in decision makers' minds. In the as-if interpretation, these entities and mechanisms can be, and often are, purely fictional posits that may lack any factual reference (think multiply-and-add mechanisms) or may have a factual reference but represent it in a false way (think preferences assumed to be complete, transitive and stable binary relations). From an antirealist viewpoint, what is important is not the semantic realism of decision-theoretic constructs referring to unobservable entities and mechanisms, but whether these constructs allow decision theorists to build theories that describe, explain, predict or help control the observable choice behaviour of decision makers.

This semantic agnosticism is supported by the recognition of disciplinary diversity: different scientific disciplines, and often different approaches within the same scientific discipline, represent the human mind and explain human behaviour by using different, and in fact often incompatible, scientific terms and constructs. For instance, as mentioned in section 5.3, psychologists use constructs such as cognitive abilities, personality traits and emotional states that are almost irreconcilable with constructs such as preferences, utility or heuristics. And even within decision theory, while neoclassical and behavioural economists model the human mind and behaviour by preferences and utility, other economists use different constructs such as heuristics.

Since different, but equally respectable, scientific disciplines posit different mental entities and explain human behaviour by hypothesizing different psychological mechanisms, it is difficult to state, at least given the current state of scientific knowledge, which discipline is correct and what entities and mechanisms really exist in the mind of decision makers. An agnostic stance about the semantic realism of decision-theoretic constructs appears therefore justified.[16]

8.3. The epistemic dimension

At the epistemic level, for realists the aim of science is truth and our best scientific theories provide true, or approximately true, descriptions of the world, including its unobservable elements. Instrumentalists, constructive empiricists *à la* van Fraassen (1980) and possibly other groups of antirealists agree that our best scientific theories 'save the phenomena', that is, they provide true, or approximately true, descriptions of the observable aspects of the world. However, these antirealists are agnostic or sceptical about whether scientific theories truthfully represent the unobservable aspects of the world.

[16]A commentator has suggested that the mechanisms featured in decision models could be ranked according to the relation 'psychologically more realistic than', and that this ranking could help us to identify semantically realistic models. I see two major problems in this suggestion. First, since different groups of researchers represent the human mind by using different terms and constructs, they would probably disagree about whether a given mechanism is more realistic than another. Second, even if a consensus is reached about which mechanism is ranked highest, such mechanism can still be cognitively too complex and demanding to be interpreted as providing a literal or even an approximate representation of actual psychological decision processes.

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The scientific practices of decision theory clearly show that describing and predicting correctly the observable choice behaviour of individuals is an important epistemic goal of decision theorists. Irrespective of whether they follow a neoclassical, behavioural or heuristic approach, or whether they interpret their models as as-if models or process models, decision theorists care about ‘saving the phenomena’. As mentioned in the Introduction, behavioural and heuristic decision models were initially advanced precisely to account for behaviours that were recorded in choice experiments and violated neoclassical models. And even today, a significant part of decision analysis consists of experimental tests aimed at assessing whether, or to what extent, EU, CPT, PH and other decision theories fit the available data.[17] Thus, both scientific realism and the previously mentioned versions of antirealism account well for the epistemic attitude of decision theorists toward observable choice behaviour.

As in the case of the semantic dimension, the part of the realistic epistemics that I find hard to reconcile with the scientific practices of decision theory is the one concerning unobservable entities and mechanisms. As I have argued throughout this article, current decision theories do not seem to provide a true, or even approximately true, description of the unobservable entities and mechanisms that produce individual choice behaviour. These entities and mechanism are best seen as fictional and possibly false posits that, however, help decision theorists to ‘save’ choice-behaviour phenomena, that is, to describe observable choice-behaviours in a true, or approximately true, way.

8.4. Beyond instrumentalism

The version of antirealism that I have sketched so far and that appears capable of accounting for the modelling practices of decision theory has the following features:

(1) At the ontological level, it is committed to the existence of a reality independent of its decision-theoretic representations.
(2) At the semantic level, it maintains that decision-theoretic terms provide literal or at least approximate representations of the observable entities they refer to, while decision-theoretic terms referring to unobservable entities and mechanisms can be, and often are, purely fictional posits.
(3) At the epistemic level, it maintains that decision theories aim at providing true descriptions of observable choice behaviour, but is agnostic or even sceptical about whether current decision theories provide true descriptions of the unobservable entities and mechanisms that produce that behaviour.

[17]For some recent experimental tests of decision models, see Hey *et al.* (2010), Kothiyal *et al.* (2014), Bernheim and Sprenger (2020), Cohen *et al.* (2020) and Dertwinkel-Kalt and Köster (2020). An issue that is discussed in this experimental literature is whether behavioural models also account for choice behaviours not accounted for by neoclassical models because they capture some actual psychological mechanism that neoclassical models disregard (as advocates of behavioural models argue), or only because behavioural models have more free parameters than neoclassical models (as critics of behavioural economics claim). Here I do not have room to discuss this issue.

According to Chakravartty's (2007) taxonomy of the different varieties of antirealism, the version on offer here coincides with 'traditional instrumentalism'. And, in effect, the as-if approach to economic modelling has been often interpreted as an instance of instrumentalism (for a discussion, see Mäki 2009a). Basically, according to instrumentalism, scientific theories are useful tools for describing, predicting and possibly controlling certain observable phenomena, but are not aimed at explaining how such phenomena come about.

However, I do not think that instrumentalism provides a satisfactory account of the as-if modelling practices of decision theory. The problem I see with instrumentalism is that it does not account for the important role that the epistemic goal of explanation plays in decision theory. Decision theorists do not want only to save the phenomena, but also to explain them.

There are various theories of scientific explanation (for recent overviews see Woodward 2019 and Verreault-Julien 2022) but I think that the one that best captures the epistemic attitude of decision theorists is the mechanistic account of explanation. According to this account, to explain a phenomenon is to identify the mechanism that, via the activities and interactions of its components, produces the phenomenon. The mechanism and its components can be partially, or even entirely, unobservable.[18]

A satisfactory antirealist account of the modelling practices of decision theory should also be able to account for the important role that mechanistic explanations play in decision analysis. Traditional instrumentalism fails to do that and therefore should be revised.

8.5. An antirealist account of mechanistic explanation

A realist would most likely object that there is a contradiction between the antirealist account of decision theories proposed in this paper and the acknowledgment that mechanistic explanation is an important epistemic goal of decision theorists. However, this objection rests on the realist presupposition that the only good mechanistic explanations are true explanations that capture the actual mechanisms producing the targeted phenomena. In fact, a number of philosophers of science, such as Bechtel and Abrahamsen (2005), Bokulich (2011, 2018), and Colombo *et al.* (2015), have advanced an account of explanation that is either antirealist or at least compatible with scientific antirealism. Thus, for instance, Bokulich (2011: 41) defends the view that 'fictionalized models … can be genuinely explanatory.' Colombo *et al.* (2015: 208) argue that 'good mechanistic explanations do not require a commitment to scientific realism'.

In a nutshell, according to the antirealist account, explanation is itself an epistemic activity of decision theorists and 'what figures in it are not the mechanisms in the world, but representations of them' (Bechtel and Abrahamsen 2005: 425; see also Bokulich 2018: 801–803). Therefore, a mechanistic explanation can carry out its cognitive functions – allowing decision theorists to coherently organize their thinking about choice-behaviour phenomena; allowing them to

[18]For recent applications of the mechanistic account in the philosophy of economics, see Grüne-Yanoff (2016) and Joffe (2019).

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reason counterfactually about how a modification in some unobservable component of the decision mechanism, such as preferences or utility, could modify observable choice behaviour; indicating to decision theorists how to influence the choice behaviour of individuals; and suggesting to decision theorists how to modify models that are unable to save choice-behaviour phenomena – even if the represented mechanisms are not true, that is, even if the represented mechanisms are only 'stories' that decision theorists tell (see section 4 above). Insofar as a decision mechanism produces, i.e. explains, the targeted choice-behaviour phenomena in a simple and parsimonious way, and insofar as the decision theory incorporating the mechanism is successful – possibly for reasons that are different from the ones imagined by decision theorists – in describing, predicting or controlling the targeted choice-behaviour phenomena, the explanation provided by the mechanism is a valid one.

The realist may reply that truth is a necessary condition for proper explanation, so that, in a strict sense, 'false explanations' do not exist. If framed in these terms, however, the issue is converted into an issue about the proper definition of the term 'explanation', and risks becoming merely nominalistic. At any rate, I am even willing to leave the word 'explanation' to the realist, adopt the less charged term 'story', and restate my claim using that term: stories, and more precisely mechanistic stories, carry out important cognitive functions – they allow decision theorists to coherently organize their thinking about choice-behaviour phenomena, etc. – even if the unobservable mechanisms they portray (multiply-and-add mechanisms, preference-based mechanisms, heuristic mechanisms) are not true. And to the extent that the decision theory based on a certain story is successful in saving the phenomena, the story itself is a good one. Following an argument made by Rowbottom (2019), my objection to the realist would be that, by sticking to his strict notion of explanation as true explanation, he can account for little of what goes on in decision theory.

8.6. Local antirealism, in decision theory and quantum physics

In a recent paper, Hoefer (2020) has argued that scientific realism provides a plausible account for several areas of current science, such as microbiology, chemistry and astrophysics. However, for other scientific fields, and notably for quantum physics, scientific antirealism offers the most plausible account. For Hoefer, the difference between the two groups of disciplines is that for the former we cannot conceive that our current theories are mistaken in certain fundamental ways, nor imagine that future theories will be radically different from the present ones. For the latter group, in contrast, 'we can all too easily imagine sweeping changes occurring in the future' (2020: 31). According to Hoefer, quantum physics belongs to the second group because it has postulated 'ever-more-severely-unobservable entities and properties' and has offered multiple 'possible stories about the unobservable substructures of the world that give rise to the behaviours of the material stuff that we can observe' (2020: 21). Moreover, quantum physicists themselves openly conceive of the possibility of coming up with an entirely different fundamental physical theory.

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The situation of quantum physics as described by Hoefer is strikingly similar to the situation of decision theory as described in this paper. In both disciplines there exist diverse but equally respectable theories which posit diverse unobservable entities through which they describe and explain phenomena. For both disciplines, it is possible to imagine future scenarios in which the behaviour of physical particles or individual decisions will be described and explained within a radically different conceptual framework. For instance, in decision theory some scholars have argued that neuroeconomics will finally provide decision theory with a sound and unified theoretical foundation (see e.g. Glimcher 2011).[19]

The present paper therefore can be seen as providing a case for a local antirealist account of decision theory analogous to Hoefer's local antirealist account of quantum physics. Here 'local' has both a disciplinary and a temporal meaning. At the disciplinary level, it is not the case that the arguments I made in favour of an antirealist account of decision theory apply straightforwardly to other areas of economics or other scientific disciplines. I do not hide my antirealist sympathies, but I readily acknowledge that attempting to extend the antirealist case beyond decision theory would require significant work.

At the temporal level, I do not deny that decision theory may evolve in a way that a realistic account of its models and mechanisms will become the most plausible one. At the moment, however, this is not the case, and philosophers of economics should acknowledge what the current epistemological situation of decision theory is, and attempt to account for the actual scientific practices of current decision theorists.

9. Relationship with Behaviourism, Mentalism and Realistic Accounts

This has been a long paper, but it would be incomplete without relating, at least cursorily, the antirealist account of decision models on offer to the recent debate about the mentalist versus the behaviourist interpretation of preferences and other decision-theoretic constructs, and to two notable realist accounts of decision models, namely those advanced by Dietrich and List (2016) and Mäki (2009b, 2012).

9.1. Neither behaviourist nor mentalist

Some economists and philosophers of science have recently defended a behaviourist, i.e. anti-psychologistic, account of economic theory in general and decision theory in particular (see e.g. Gul and Pesendorfer 2008; Binmore 2009; Ross 2014; Clarke 2016). According to more radical versions of behaviourism, decision models should be freed from unobservable psychological concepts and expressed only in terms of observable variables, such as choice data or market

[19]Although I do not have room to discuss neuroeconomics here, I will note that I do not share this reductionist view. Basically, explaining the behaviour of decision makers as generated by their neural processes appears to me too indirect and complicated to be explanatorily useful. On this point, I subscribe to the arguments against the reduction of economics to neuroscience made by Fumagalli (2013) and Dietrich and List (2016).

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prices. According to milder versions, psychological concepts are admitted in economic theorizing, but merely as redescriptions of, and therefore ultimately identical to, choice behaviours.[20] Other economists and philosophers of economics, including myself, have criticized the behaviourist account of decision theory as invalid not only at the descriptive level (among other things, because behaviourism cannot make sense of the counterfactual type of reasoning that plays a key role in decision and game theory), but also at the normative level (for behaviourism relies on outdated epistemological presuppositions; see e.g. Caplin 2008; Hausman 2008; Moscati 2010; Dietrich and List 2016; Guala 2019; Moscati 2021).

The antirealist account of decision models advanced in this article also opposes behaviourism, as it recognizes, and epistemologically justifies, the role that preferences, utility, heuristics, beliefs and possibly other unobservable psychological concepts, such as intelligence, personality traits and emotions, play or could play in the description and explanation of observable choice behaviour. However, as argued in section 8, the rejection of behaviourism does not imply a commitment to a realist, or mentalist, interpretation of the psychological concepts featured in decision models.

Therefore, and to echo the title of Guala's (2019) article, the antirealist account of decision models I have advanced here is neither behaviourist nor mentalist. A possible label for it could be 'as-if mentalism'. This expression may appear to be a curious oxymoron, but this appearance vanishes if the term 'mentalism' is not intended as indicating the realist view that decision-theoretic constructs refer to entities and mechanisms actually existing and operating in the decision maker's mind, but as indicating the anti-behaviourist view that the use of psychological constructs in decision theory is fully legitimate.

9.2. Dietrich and List's naturalistic ontological attitude

Dietrich and List (2016) articulate a criticism of behaviouristic accounts of decision theory, to which I largely subscribe. In opposition to behaviourism, in the second part of their article they advance a mentalist interpretation of decision models that is based on a 'naturalistic attitude' towards ontological questions. According to this attitude, 'once something – say, an entity or property – is among the ontological commitments of a well-established scientific theory, ... our acceptance of the theory... commits us to accepting the existence of that entity or property' (2016: 268). For Dietrich and List, insofar as preferences, beliefs and other mental-state constructs are among 'the ontological commitments of our best theories of economic decision making', these constructs 'should be treated, at least provisionally, as corresponding to real phenomena' (2016: 270).

[20]The terminology of decision theory is unfortunate because two almost identical words – *behavioural* and *behaviourist* – have almost opposite meanings. It might be therefore useful to reiterate that, roughly speaking, behavioural economists want to provide decision theory with more psychological underpinnings, while behaviourist economists argue that decision models should be freed from psychological concepts.

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My objection to this argument is that one of its premises, namely that there exists a well-established scientific theory, does not hold for current decision analysis (and, as argued in section 8.6, not even for current quantum physics). In fact, there exist diverse but equally respectable theories of decision-making, within and outside economics, that are committed to different mental states (utility, preferences, beliefs, disappointment, decision weights, heuristics personality traits, cognitive abilities, emotions) and different decision mechanisms (utility maximization, preference maximization, heuristic mechanisms). In this situation, a naturalistic ontological attitude generates contradictory commitments. For instance, the preference-based version of EU indicates that preferences between lotteries are real while heuristics are not; according to the PH approach, instead, in the mind of decision makers only heuristics exist.

The antirealist account of decision models advanced in this article avoids such contradictory commitments, while steering clear of behaviourism. It avoids contradictory ontological commitments by acknowledging that current decision-theoretic constructs can be, and often are, purely fictional posits that may lack any mental reference, or have a mental reference but represent it in a false way.

9.3. Mäki's minimal realism

Over the years Mäki has advanced a sophisticated version of scientific realism that he has labelled 'minimal realism' and that, unlike conventional realism, should be able to accommodate the scientific practices of economics. At the semantic level, minimal realism does not require that 'an item examined or postulated by science exists, it is enough to suppose that there is a chance that the item exists' (Mäki 2012: 6). At the epistemic level, minimal realism admits that scientists can 'suspend judgement as to whether a theory is true and remain agnostic, for however long' (6). Mäki also acknowledges that the assumptions of scientific models are often idealizations that can be just false: 'In describing imaginary model worlds, scientists employ idealizing assumptions that are false' (Mäki 2009b: 78). I largely agree with these statements which, however, appear to me more in line with scientific antirealism than scientific realism.

The point where the realist component of Mäki's epistemology comes forth, and our paths diverge, is in the interpretation of how models based on false assumptions can account for real phenomena. For Mäki, imaginary models based on false assumptions allow the scientist to isolate some important causal mechanism from the influence of other confounding factors, and models can account for real phenomena because the imaginary mechanism operating in them corresponds to some actual mechanism operating in the real world: 'Economists can be philosophical realists about their models even though these describe imaginary situations … This is because it is possible that the mechanisms in operation in those imaginary situations are the same as or similar to those in operation in real situations. A model captures significant truth if it contains a mechanism that is also operative in real systems' (Mäki 2009b: 79).

My objection to this view is that it presupposes that the scientist already knows, at least approximately, what the actual mechanisms operating in the world are, so that she can tailor the imaginary mechanisms featured in the model to the actual ones. But such a presupposition is far-fetched: often, scientists do not know, not even approximately, what the actual mechanisms operating in the world are, and their main job, in effect, is to figure out what these mechanisms could be. In decision theory, for example, decision theorists do not agree on whether the actual mechanisms determining choice behaviour are based on utility or preference maximization, heuristics or some other mechanism involving, say, cognitive abilities or emotional states.

As argued in section 8, decision theorists have crafted different models, possibly containing purely fictional variables and mechanisms, that tell different stories about what the actual decision mechanisms are. And these models do not receive their support because decision theorists already know that the mechanisms in their models mirror, at least approximately, the mechanisms in the world. Rather, models receive support in an indirect way, according to their ability to account for, and make sense of, observed choice-behaviours, possibly more accurately or more simply than other available models.

10. Conclusion

In this article I have argued that the models that are currently used in decision theory, not only neoclassical models, but also behavioural and heuristic models, are best understood as as-if models. I have also sketched a local version of scientific antirealism that attempts to account for the as-if, and nonetheless explanatory, modelling practices of decision theory and thus goes beyond traditional instrumentalism. Finally, I have rejected both the mentalist and the behaviourist interpretations of the psychological constructs used in decision theory and offered an alternative, 'as-if mentalist', interpretation of these constructs.

The views presented in this article, if correct, have various implications. Here, given space constraints, I mention only two of them. First, the difference between the modelling approach *à la* Bernoulli, in which utilities, probabilistic beliefs, decision weights or discount and impulsivity factors are posited as primitive concepts of the analysis, and the modelling approach *à la* von Neumann–Morgenstern, where the primitive concepts are the preferences between alternative choice options, is less significant than what is often deemed in decision theory. According to a tradition that goes back to Pareto (2014 [1906/1909]), many decision theorists in fact consider the preference-based approach superior to the utility-based approach because, to simplify, they judge preferences to be psychologically more realistic and more directly connected to observable choice behaviour than utilities and other decision-theoretic constructs. In contrast with this opinion, the account of decision models advanced in this article suggests that preferences are in the same category as utilities and other decision-theoretic concepts, for all of them are best understood as as-if constructs.

Admittedly, positing preferences as the primitive element of the analysis has a series of advantages (see Spiegler 2008; Cozic and Hill 2015; Gilboa *et al.* 2019). However, in this modelling strategy preferences remain unexplained: the decision maker prefers option A to option B just because he prefers A to B.

When the choice options are simple, such as between dishes at a restaurant, this approach may be satisfactory. But when the choice options are more complex, such as between lotteries with many possible payoffs, courses of action involving multiple uncertain scenarios, or streams of payments over long intervals of time, the modelling approach *à la* Bernoulli may offer richer explanations, that is, if you accept the account of explanation advanced in section 8.5, richer explanatory stories.

Second, since all models currently used in decision theory are as-if models, the comparison between them in order to select the 'best' model of decision-making cannot rely on the criterion of being a process model rather than an as-if model. To be sure, not all as-if models are equally valuable and different decision models perform differently not only with respect to their ability to account for observed choice behaviours but also with respect to other, less empirically oriented desiderata, such as simplicity, tractability, parsimony and possibly other 'morphological' virtues of scientific theories.

In effect, in the theoretical and experimental literature in decision theory the comparison between rival models already bears upon their empirical and morphological desiderata, rather than upon the alleged process-model status of some of them (see the references in footnote 17). If this is the case, however, the widespread habit of promoting the favoured decision model as a model that captures the actual psychological mechanism generating choice behaviour should be seen as belonging more to the rhetoric of decision theory than to its actual scientific practices. Accordingly, abandoning this habit and, correspondingly, acknowledging the as-if character of the models currently used in decision theory would free the field from a significant amount of methodological noise.

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