Decision Theory

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but also of the philosophical views that correspond to them and (4) the philosopher's primary duty is to follow the lead of the Central Committee. Deborin never disputed the third and fourth points, but he was reluctant in his acquiescence to them, and the bulk of his writings antedated the announcement of them, when the tone of Soviet philosophy was much freer than it has been since. Although some Soviet intellectuals in the post-Stalin era have indicated repeated dissatisfaction with the third and fourth points, they show no signs of Deborinite inspiration. Deborin's Hegelian studies seem turgid and derivative to many, and they have had little influence on the Hegelian revival in the post-Stalin Soviet Union, much less, certainly, than the works of Georg Lukács, which Deborin and all subsequent officials of Soviet philosophy have condemned.

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Deborin's chief works are *Vvedenie v Filosofiiu Dialekticheskogo Materializma* ("Introduction to the Philosophy of Dialectical Materialism," Petrograd, 1916) and several collections of his articles: *Lenin kak Myslitel'* ("Lenin as a Thinker," Moscow, 1924), *Filosofiia i Marksizm* ("Philosophy and Marxism," Moscow, 1926), *Dialektika i Estestvoznanie* ("Dialectics and Natural Science," Moscow and Leningrad, 1928), and *Filosofiia i Politika* ("Philosophy and Politics," Moscow, 1961). See also his *Sotsial'no-politicheskie Ucheniia Novogo Vremeni* ("Sociopolitical Doctrines of Modern Times"), Vol. I (Moscow, 1958); a posthumous edition of the second volume was promised at the time of his death.

For studies of Deborin see René Ahlberg, *"Dialektische Philosophie" und Gesellschaft in der Sowjetunion* (Berlin, 1960), and David Joravsky, *Soviet Marxism and Natural Science, 1917–1932* (New York, 1961).

D. JORAVSKY

DECISION. *See* CHOOSING, DECIDING, AND DOING.

DECISION THEORY. The fundamental problem of decision theory may be characterized in the following way: A person, or group of persons, is faced with several alternative courses of action but has only incomplete information about the true state of affairs and the consequences of each possible action. The problem is to choose an action that is optimal or rational relative to the information available and in accord with some definite criteria of optimality or rationality. The main branches of decision theory may be characterized by the accompanying table of examples.

	INDIVIDUAL DECISIONS	GROUP DECISIONS
NORMATIVE THEORY	Classical economics Statistical decision theory Moral philosophy	Game theory Welfare economics Political theory
DESCRIPTIVE THEORY	Experimental decision studies Learning theory Surveys of voting behavior	Social psychology Political science

The discussion of the philosophical significance of decision theory will be broken down here according to the four entries in the table. The emphasis will be on normative rather than on descriptive theory.

INDIVIDUAL NORMATIVE THEORY

Criteria of rationality. A common problem confronting the theory of induction and moral philosophy is that of giving an adequate account of the concept of rationality. The normative theory of individual decision making has been concerned with explicating the notion of rationality in what is in some respects a very thorough fashion. However, an essential difficulty has arisen that is of considerable philosophical importance. Recent work in decision theory has shown that there is no simple coherent set of principles capable of precise statement which correspond to naive ideas of rationality. Just as research in this century in the foundations of mathematics has shown that we do not yet know exactly what mathematics is, so the work in decision theory shows that we do not yet understand what we mean by rationality. Even in highly restricted circumstances it turns out to be extremely difficult to characterize in a nonparadoxical fashion a rational choice among alternative courses of action.

Principle of utility. In setting forth the difficulties of individual normative theory it will perhaps be clearest to approach the subject historically. A good place to begin is the definition of utility given in the first chapter of Jeremy Bentham's *The Principles of Morals and Legislation:*

> By utility is meant that property in any object, whereby it tends to produce benefit, advantage, pleasure, good or happiness (all this in the present case comes to the same thing), or (what comes again to the same thing) to prevent the happening of mischief, pain, evil, or unhappiness to the party whose interest is considered: if that party be the community in general, then the happiness of the community; if a particular individual, then the happiness of that individual.

Bentham interpreted his maxim of "the greatest good for the greatest number" as meaning that utility is maximized, and he spent considerable effort in formulating a program for measuring utility. From the standpoint of decision theory the rationale proposed by Bentham is clear enough: always choose that action which maximizes utility. Unfortunately, Bentham's ideas on how to measure utility were vaguely formulated, to say the least.

In the tradition of Bentham and within the framework of classical economics, one of the biggest steps forward was taken by Vilfredo Pareto (1906), who showed that only a very weak theory of measurement was needed for the classical theory, namely, that the individual or group be able to say which of any two actions or decisions had the greater utility (in terms of its consequences). This ordinal theory of Pareto, which dominated the economic theory of utility from the beginning of the twentieth century to the publication of John von Neumann and Oskar Morgenstern's treatise on the theory of games in 1944, rested squarely on the assumption that the individual who is choosing among alternatives has no uncertainty about the consequences of these alternatives. Once uncertainty in the consequences is admitted, no ordinal theory of decision can be satisfactory. A simple example will suffice to make this fact clear: A typical middle-class member of our society now has insurance coverage for a wide variety of contingencies. In each case the taking out of this insurance

depends on a theory of decision that goes beyond ordinal considerations.

Theory of expected utility. The expected utility hypothesis, which apparently was first clearly formulated by Daniel Bernoulli in 1738, is the most important approach that has yet been suggested for making decisions in the context of uncertain outcomes. The central idea is extremely simple: The individual must choose between several possible decisions. The possible decisions may have a variety of consequences, and ordinarily the consequences are not simply determined by the decision taken but are also affected by the present state of affairs, or, as it is often termed, the present state of nature. It is supposed that the individual has a utility function on the possible consequences and that he has a probability function on the possible states of nature which expresses his beliefs about the true state of nature. According to the expected utility hypothesis a decision maker should then select a decision or course of action that maximizes his expected utility. It will perhaps be useful to consider a simple example that illustrates these ideas. Suppose that an individual must decide whether to go in uncertain weather to a special lecture on phenomenology. Let the set S of states of nature have as members the two possible states of raining, s_1, and of not raining, s_2. Let the set C of possible consequences be those of going to the lecture and not being rained on, c_1, of staying home, c_2, and of going to the lecture and being rained on, c_3. The two decisions are going to the lecture, d_1, and not going to the lecture, d_2. Formally, d_1 and d_2 are functions from S to C such that

$$d_1(s_1)=c_3, \qquad d_1(s_2)=c_1, \qquad d_2(s_1)=d_2(s_2)=c_2.$$

Suppose now that the individual assigns a subjective probability of .4 to s_1 and .6 to s_2 and that he prefers consequence c_1 to c_2 to c_3. It should be evident, as was already remarked, that the merely ordinal preference for c_1 over c_2 over c_3 is insufficient to lead to a rational decision between d_1 and d_2. We must suppose also that the individual assigns numerical values to the consequences; in particular, let his utility function u be such that

$$u(c_1)=10, \qquad u(c_2)=5, \qquad u(c_3)=-10$$

(and we suppose u is unique up to a choice of unit and zero). Then the expected utility hypothesis leads him to compute the expectation (in the ordinary sense of random variables) for both d_1 and d_2, using the numerical utility function to define the values of the random variables, and then to choose the decision that has the greater expected utility. Let $E(d_1)$ be the expected utility of decision d_1, and similarly for $E(d_2)$. In our particular example the individual finds that

$$E(d_1)=(.4)(-10)+(.6)(10)=2,$$
$$E(d_2)=(.4)(5)+(.6)(5)=5,$$

so he should elect not to go to the lecture; that is, he should take decision d_2.

Utility and probability. A central problem for both normative and descriptive decision theory is to state axioms of behavior that lead to a numerical representation of utility and probability so that decisions are based on maximization of expected utility. A little reflection on this problem suggests two different ways to proceed. One is to attempt to state axioms in such a way that we first obtain a measure of utility, which is then used to obtain a measure of subjective probability. The other approach proceeds in the reverse order: we state axioms that permit us first to obtain a measure of subjective probability, which is then used to measure utility. The earliest approach, that of F. P. Ramsey (1931), follows the first course—that is, utility is measured first. Ramsey's essential idea was to find a random event of subjective probability 1/2, to use this event to determine the utilities of outcomes or consequences, and finally to apply the constructed utility function to measure the subjective probabilities of the states of nature. This approach has been used extensively in descriptive studies of decision theory since 1957.

The approach that begins with a consideration of probability rather than of utility was originated by Bruno de Finetti, although its historical antecedents go back to the famous work of Thomas Bayes (1763, 1764). The most important recent work on these matters is L. J. Savage, *The Foundations of Statistics*. Savage extends de Finetti's ideas by paying greater attention to the behavioral aspects of decisions. He postulates a single primitive relation of weak preference on the set of decisions; it is called a relation of weak preference because the individual may be indifferent about two distinct decisions and not strictly prefer one to the other. Even a rough gloss of Savage's axioms is too technical for the present context. As might be expected, he does require that the relation of preference among decisions be transitive and that it be connected—that is, given any two decisions, one must be weakly preferred to the other.

Criticisms of expected utility theory. From the viewpoint of the general theory of rational decisions, there are two points to be emphasized about the rule enjoining the decision maker to maximize his expected utility. The first is that the adoption of this rule of behavior as an important part of one's concept of rationality does not in any sense commit one to a hedonistic calculus of pleasure, as might be thought if Bentham's definition of utility were too systematically associated with the application of the rule. No material doctrine of pleasure enters in formulating the expected utility theory, and the theory could in principle be adapted without change to a calculus of obligation and a theory of expected obligation. This material indifference means that the theory of expected utility offers a rather incomplete theory of rationality from the standpoint of moral philosophy.

The second point to be made about adopting the rule of maximizing expected utility concerns a charge that the theory is too complete. It is too much, it is said, to demand the existence of a subjective probability distribution representing beliefs about the true state of nature and a utility function on consequences. Decisions, even rational decisions, are taken on the basis of a much less complete analysis of the alternative courses of action. Evaluation of the general merits of this criticism is difficult and will not be gone into thoroughly, but it is important to recognize that a good deal of the modern theoretical literature about decisions made in uncertain situations concentrates on principles

other than the Bayesian one of maximizing expected utility. The basic motivation for this work is the recognition that often a decision maker does not have adequate information to assign probabilities to the possible states of nature. This is especially a problem when the uncertainty arises not only from random factors in the environment but also from the more or less rational decisions taken by other people.

Weaker principles. If the decision maker is unable, or unwilling, to act as though he knows the probability of occurrence of each event, then he must invoke some weaker decision principle than the maximization of expected utility. The formulation and mathematical development of such principles is the focus of the theory of games and of much of statistical decision theory, which is a well-developed branch of mathematical statistics.

The simplest and least controversial of these principles is the sure-thing principle. This principle asserts that if two decisions are such that for each possible state of nature the consequences of choosing the first decision are at least as desirable as those of choosing the second, then the first one should be weakly preferred to the second. The obvious central weakness of the sure-thing principle is that it can rarely be applied. In general, neither of two given decisions is better than the other in the sense of the sure-thing principle.

Another thoroughly explored principle is the maximin or minimax principle of von Neumann. Suppose that for each of his possible decisions an individual determines what is the worst (minimum) consequence that can occur. He then selects the decision for which the worst consequence is as good as possible; that is, he selects the decision which has the largest value for its worst consequence. For obvious reasons such a decision is called a maximin decision. (The minimax terminology of von Neumann originates from a slightly different way of formulating the problem—in terms of minimizing the maximum loss instead of, as we have put it here, maximizing the minimum gain.) The famous result of von Neumann is that for a very wide class of two-person, zero-sum games each player has a minimax strategy; moreover, if both players are rational, neither can do better than to adopt his minimax strategy. In this context a two-person, zero-sum game is defined by a set of strategies for each of the two players and a payoff function for any pair of strategies used such that the numerical payoff to one player is the negative of that to the other. On the other hand, for situations that are not gamelike in character the principle underlying maximin decisions is conservative in the extreme. Concern is focused exclusively on the worst possible consequence of any course of action, no matter how improbable that consequence may be. For many practical decisions the maximin principle does not lead to intuitively acceptable results.

A third example of a principle of decision is Savage's principle (1951) of minimizing the maximum regret that can arise from making one decision rather than another. Still another is the concept of equilibrium, particularly as applied to nonzero-sum games. In this case the basic idea is that if a single player changes his strategy and all other players hold to theirs, then any change will make the first player worse off.

Axiomatic decision theory. In view of the difficulty of fixing upon any one principle as clearly satisfactory in all situations, several authors, most notably John Milnor, have attempted an axiomatic approach to a better understanding of what is involved in the concept of a rational decision. The basic idea of this line of attack is to list intuitively appealing criteria that a decision principle should satisfy and then to ask what principles do indeed jointly satisfy the criteria proposed. The results of Milnor's investigation have particular bearing on the remarks made earlier about the indefiniteness at present of the concept of rationality. Milnor proposes nine criteria that any acceptable principle of decision should satisfy. He goes on to show that none of the standard decision principles proposed satisfy all nine. More generally, his results, like those of Russell's paradox for the foundations of set theory, yield an impossibility theorem and show that the naive theory of rationality, like the naive theory of sets, cannot easily be systematically reconstructed.

Randomization. An important concept for the theory of rational decisions appeared with the work of von Neumann and others on optimal strategies in gamelike situations. This was the idea that the most rational decision may be one that has a random component. In general, the minimax strategies for players in a game are probabilistic rather than deterministic in character. Without doubt this is a genuinely new and surprising idea in the theory of rational or prudent behavior. Again, it is a result at variance with naive intuition, which urges us to deliberate and to use all possible information available in making a decision. Unfortunately, the reconciliation of this approach with the Bayesian rule of maximizing expected utility is still far from being reached.

GROUP NORMATIVE THEORY

The table shown earlier lists three disciplines in the quadrant for group normative theory: game theory, welfare economics, and political theory. The relations of game theory to the concept of a rational decision have already been discussed. From the standpoint of decision theory perhaps the most important element is the widening of the concepts of welfare economics to include the more general concepts of social decision appropriate to political theory. The classical central problem of welfare economics has been the Benthamite one of devising and analyzing schemes for the distribution of economic goods. It is now increasingly recognized that the restriction to economic goods can be dropped and that the problem may be regarded as the more general one of deciding social and political policy. The over-all aim of this work is to analyze and propose schemes for making social and political decisions in what seems to be a just and equitable manner.

Arrow's results. As in the case of the normative theory of individual decisions, the results of perhaps the greatest philosophical significance are negative results that call into question the naive concept of rationality as applied to the decision-making procedures of a group. The best-known impossibility theorem in this connection is that of Kenneth J. Arrow, which is concerned with the existence of a just or equitable method of social decision. Arrow presupposes a number of possible social states, with each member of the society having a preference ordering for these states. The problem is to construct an intuitively reasona-

ble social preference ordering from the given individual orderings.

One simple proposal is the method of majority decision. Social state A is preferred to social state B by the group as a whole if a majority of the members of the group prefer A to B; otherwise it is not preferred. Unfortunately, there are intuitively desirable axioms that are violated by the method of majority decision. Perhaps the easiest way to illustrate the difficulties is to describe the so-called paradox of voting, which apparently was first noted by E. J. Nanson in 1882. Suppose there are three issues A, B, and C and three people voting on these issues. Let us assume that the first person prefers A to B to C, the second person prefers B to C to A, and the third person prefers C to A to B. The issues are voted on in pairs. It is easily checked that if the first choice is between A and B, the selected issue will be C; if between A and C, the outcome will be B; and if between B and C, the outcome will be A. In other words, the outcome chosen is completely dependent, in this symmetrical situation, on the arbitrary choice of which issues are to be voted on first. That the order of voting on bills and their amendments can seriously affect the outcome is part of the folklore of practical politics and indicates that the paradox of voting reflects a relatively deep problem for any defense of the rationality of simple majority voting.

What Arrow has done is to present four reasonable axioms that any social decision method should satisfy and then to ask if there exist any methods satisfying the axioms. The first axiom postulates a positive association of social and individual values. In particular, if one among alternative social states rises in the ordering of every individual without there being any other change in the orderings, it is natural to postulate that it rises, or at least does not fall, in the social ordering.

The second axiom states the independence of irrelevant alternatives. If, for instance, a set of candidates is being considered for an office and the voters' preferences for these candidates are known, then the removal of one candidate from the list will not affect the relative preferences for the other candidates. It should be emphasized that this postulate takes no account of strategic considerations. Its concern is with the actual preferences of the group members, not with their behavioral use of a strategy in situations where they feel their first choice could not possibly be elected.

The third axiom asserts that the social decision method is not to be imposed. A decision method is said to be imposed when there is some pair of alternative social states X and Y such that the community can never express its preference for Y over X, no matter what may be the preferences of all the individuals concerned. Outmoded cultural and religious taboos furnish examples violating this condition.

The fourth axiom asserts that the social decision method shall not be dictatorial; that is, the preferences shall not simply correspond to those of one individual in the social group. Arrow proved that if there is any degree of variety in the individual preference orderings, then there exists no social decision method satisfying the axioms.

Positive group decision principles. Duncan Black's work on the theory of committees and elections shows that simple positive results very close to the framework developed for Arrow's negative results can be established when some fairly sharp restrictions are imposed on the variety of individual preferences. Necessary and sufficient conditions on the group decision function in order that individual preferences may be satisfied by the simple majority decision functions were given by Kenneth O. May in 1952. In general, the negative and positive results on group decision principles would seem to hold promise for the renascence of systematic political theory.

DESCRIPTIVE THEORY

The descriptive theory of decision has less direct philosophical relevance than the normative theory, but a few points may be mentioned. Among descriptive theories the main division is between algebraic and probabilistic theories. The algebraic theories are the natural extensions of the theories discussed earlier to empirical studies of actual behavior. Perhaps the most intensive study has been of the algebraic theory of maximizing expected utility. The postulate involved here is that when one decision has a greater expected utility than another, it is certain which decision the individual will choose.

Probabilistic theories, on the other hand, make this choice a matter of probability rather than a certainty. The probabilistic theories have arisen in a natural way from the familiar psychological observation that in highly similar situations individuals will on one occasion make one choice and on another occasion another choice. Empirical observation of such "inconsistencies" has been the main impetus to the study of probabilistic theories. These theories all assume that when a set X of alternatives is presented, there exists a probability $p(x)$ that any particular member x of X will be chosen. Each of these probabilities is, of course, nonnegative, and the sum of the probabilities over the set X is equal to 1. The theoretical problem is to investigate what mathematical constraints individuals impose on the probabilities beyond those automatically implied by probability theory. It is to be emphasized that the probabilities in question here have a different significance from those involved in the deliberate use of a randomizing device to select a minimax strategy. The probabilities of choice studied in descriptive theories do not arise from deliberate computations on the part of the individual but are characteristic above all of his nonverbalized actual choices.

Although connections between decision theory and learning theory are being explored in the current literature, it is impossible to consider them here. (A probabilistic utility theory, for example, is derived from learning theory in Patrick Suppes, "Behavioristic Foundations of Utility.") Their promise for the future is a stronger psychological foundation for decision theory.

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DEDUCTION. *See* FORMAL SYSTEMS AND THEIR MODELS; LOGIC, MODERN.

DEFINITION. The problems of definition are constantly recurring in philosophical discussion, although there is a widespread tendency to assume that they have been solved. Practically every book on logic has a section on definition in which rules are set down and exercises prescribed for applying the rules, as if the problems were all settled. And yet, paradoxically, no problems of knowledge are less settled than those of definition, and no subject is more in need of a fresh approach. Definition plays a crucial role in every field of inquiry, yet there are few if any philosophical questions about definition (what sort of thing it is, what standards it should satisfy, what kind of knowledge, if any, it conveys) on which logicians and philosophers agree. In view of the importance of the topic and the scope of the disagreement concerning it, an extensive re-examination is justified. In carrying out this conceptual re-examination, this article will summarize the main views of definition that have been advanced, indicate why none of these views does full justice to its subject, and then attempt to show how the partial insights of each might be combined in a new approach.

All the views of definition that have been proposed can be subsumed under three general types of positions, with, needless to say, many different varieties within each type. These three general positions will be called "essentialist," "prescriptive," and "linguistic" types, abbreviated as "E-type," "P-type," and "L-type," respectively. This classification is not intended as a precise historical summary, but merely as a useful schema for stating some of the problems and disputes. Thus, some outstanding philosophers may very clearly belong to one of these types. Others who, for the purposes of this article, are placed in a certain class hold positions varying considerably from the presentation to be given. It must therefore be borne in mind that not all the criticisms that will be made apply to all philosophers included in the class being criticized. Writers whose accounts of definition fall largely under the E-type include Plato, Aristotle, Kant, and Husserl. Those who support P-type views include Pascal, Hobbes, Russell, W. V. Quine, Nelson Goodman, Rudolf Carnap, C. G. Hempel, and most contemporary logicians. Supporters of L-type views include John Stuart Mill (in part), G. E. Moore (in part), Richard Robinson, and most members of the school of linguistic analysis.

According to essentialist views, definitions convey more exact and certain information than is conveyed by descriptive statements. Such information is acquired by an infallible mode of cognition variously called "intellectual vision," "intuition," "reflection," or "conceptual analysis." Prescriptive views agree with essentialism that definitions are incorrigible, but account for their infallibility by denying that they communicate information and by explaining them as symbolic conventions. Although linguistic views agree with essentialism that definitions communicate information, they also agree with prescriptivism in that they reject claims that definitions communicate information that is indubitable. The linguistic position is that definitions are empirical (and therefore corrigible) reports of linguistic behavior.

ESSENTIALISM

An essentialist account was first proposed by Socrates and Plato. Socrates is renowned for having brought attention to the importance of definitions. His favorite type of question, "What does (virtue, justice, etc.) mean?," became the characteristic starting point of philosophical inquiry. But Socrates did not make clear what kind of answer he was looking for. In Plato's *Euthyphro* Socrates is reported to have said that the kind of answer he expected to his question "What is piety?" was one giving an explanation of "the general idea which makes all pious things to be pious" and "a standard to which I may look and by which I may measure actions." He did not explain, however, what he meant by "idea" and "standard" nor