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Simulation and a Theory of Organizational Behavior*

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SIMULATION AND A THEORY OF ORGANIZATIONAL BEHAVIOR

The history of the behavioral sciences is a history of a large number of attempts to construct theories to explain and predict a wide variety of individual and group behavior. In fact, diversity is one of its chief characteristics, where the variety is reflected both in the languages and the techniques with which its theories are formulated and discussed. In keeping with this pronounced tendency toward heterogeneity, the advent of computer simulation has stimulated the development of a further set of behavioral theories. Formerly theories of human behavior were stated either in prose or in mathematical notation. More recently the ability to simulate the behavior of divers systems on a computer has led to the inclusion of computer programs as a method of expressing theories of individual and group behavior. Indeed, simulation has been proposed as a new and powerful technique for assisting in the development and testing of theories in the behavioral sciences.

Initial applications of this technique to the construction and testing of such theories have raised a number of important methodological issues. Since the practical problem of creating simulation models has been solved in a variety of cases, the major questions that have yet to be answered center around the testing and "justification" of the theories once they have been built. For example, if we are asked to consider a theory which purports to simulate some aspect of observed human behavior what criteria are we to use to measure the "goodness-of-fit" of the theory to the observed data? If the computer program chooses a response that differs from the observed, is this difference to be recorded as an "error" or do

we search back in the computer program to identify what we might call the "errors" in the decision-process? Or, consider the case where we are presented with a computer program that reproduces with a high degree of accuracy some observed set of human behavior. Given that such a successful program exists can we identify that set of its components which are "necessary" and/or "sufficient" for the explanation of this decision-making behavior? Finally, what if this successful program pertains only to individual decision-making behavior--namely, it is accepted as being sufficient to explain and predict some aspects of an individual's decision processes? In this case the question then arises of how to "aggregate" the theory of an individual into a theory of group or organizational behavior. That is to say, the issue is raised of whether it is possible to identify a part of the theory of the individual that can then be used as the basis of an "aggregate" theory of this type of behavior? While these examples by no means cover the range of methodological issues raised by simulation, they are indicative of the variety of problems that are being posed by the application of this technique.

Since both the genera and number of computer simulations of human behavior are rapidly increasing, the methodological problems raised by this technique can perhaps best be solved if we approach their solution through a central or underlying structure that applies to the appropriate cases within each class of simulation. If we do not tackle the problem in this fashion, then we will have to seek a separate solution for each of the major questions every time the technique of simulation is employed

to construct or test a new type or class of theory. As a result, our chief concern must be to delineate that structure which is common to simulations within a particular genus, and if possible that structure which is common to simulations among genera such that the structure itself provides the basic principles to be followed in arriving at solutions to the multiplicity of methodological issues.

In order to be able to delimit and describe such a structure we need to know the material assumptions about the behavior of individuals and organizations within which the technique of simulation is to be applied. Without such a set of assumptions or appropriate theory it is not even possible to begin our search for problem solutions. That this is in fact the case is clear from a brief examination of what is meant by simulation.

Simulation is not a type of theory. It is at best a precept, a method, a technique for orienting inquiry in the study of the conditions and behavior of human organizations. In practice, simulation is a technique for building theories that reproduce part or all of the output of a behaving system. However, unless this precept is supplemented by a set of assumptions or postulates about individual and organizational behavior its theoretical and empirical import is meagre to the vanishing point.

Clearly, the theoretical and empirical import of simulation would be quite significant if it were employed, for example, as a method of testing

various parts of an existing theory of human or organizational behavior. That is to say, if a theory of human behavior existed such that it was possible to employ the technique of simulation as the method of constructing and testing empirical models of the theory, then and only then would it be pertinent to develop solutions for the methodological problems created by this approach to model construction and testing. Consequently, the basic problem posed by the consideration of these methodological issues concerns the theoretical framework within which they are to be explored. If an appropriate theory of organizational behavior exists we can employ the structure of this theory as the basis from which to consider these issues. If such a theory does not exist we must first decide upon its content, or at least the outlines from which the theory can be developed, before we can proceed to discuss in any significant sense the problems arising from simulations conducted under this theory.

While we have no wish to disparage or belittle the research that has been conducted to date on the behavior of human organizations, the position taken in this paper is that a requiste theory of organizational behavior does not yet exist. This is not to say that the foundations for or some components of such a theory have not yet been deveoped. Rather, it is a statement that a theory of organizational behavior does not yet exist which can serve as the theoretical basis for a series of empirical tests conducted by employing the technique of simulation. Consequently, if we are to be able to come to grips with the problems associated with the testing technique we must first construct an outline of the theory which is to be subjected to these tests.

Because theories that are not empirically testable cannot be employed to generate empirically significant explanations and predictions, our first major task is to construct a theory of organizational behavior from which empirically significant predictions and explanations can be made. If we accept the role of simulation as a technique for testing the empirical significance of a theory, then we can restate our first objective. In brief, it is the task of developing an empirically testable theory of organizational behavior where the technique of simulation is to be used as the method for testing the empirical significance of the theory.

Imagine, for the moment, that a testable theory of organizational behavior exists. Given such a theory we can construct simulation models, based upon the theory, and perform some empirical tests. Within this context it is now meaningful to discuss such methodological issues as are raised by this testing procedure. Since a testable theory of organizational behavior would belong to the corpus of empirical science, it follows that if we are to find solutions to the methodological problems posed by simulation then we must view these problems in terms of their counterparts in other branches of empirical science. In other words, if we are to develop empirical theories of organizational behavior, then the methodological issues raised by this endeavor must be of the same class of problems as are posed by the construction and testing of theories in all branches of empirical science. This is not to say that answers can immediately be found in empirical science for all the problems presented by simulation. Rather, we are suggesting that the approach to the solutions must be that of the approach employed for similar problems in empirical science.

The object of this paper, then, is to propose and discuss some of the methodological issues raised by a particular use of the technique of simulation. In particular we shall consider simulation as a method for testing the empirical significance of a theory of organizational behavior. Since a theory of organizational behavior does not yet exist to which we can directly apply the testing technique of simulation, this paper has two principal goals. The first is to develop the outlines of an empirical theory of organizational behavior. The second is to evaluate within the context of this theory some of the issues posed by employing simulation as the method of testing its empirical validity.

I. Toward a Testable Theory of Organizational Behavior[1]

If we are to construct the outline of an empirical theory of organizational behavior our problem can be expressed in terms of the problem of constructing a theory in empirical science. Under this formulation, we will have solved the problem when we have developed a theory that meets the criteria accepted by empirical science. That is to say, by expressing our task in this fashion we have already provided ourselves with the criteria with which we can adjudge the success or failure of our efforts. Consequently, if we can develop a theory that

1/For a more detailed analysis of the problems involved in developing a body of theory that can be considered to be a part of empirical science, upon which this section is largely based, See: G.P.E. Clarkson, *The Theory of Consumer Demand: A Critical Appraisal*, Prentice-Hall, 1963, and the references cited therein.

meets these criteria we will have achieved our first objective and we can then turn our attention to the problems involved in testing by simulation the behavior described by the theory.

In order to develop an empirically testable theory of organizational behavior we must first be aware of the criteria that our theory must meet. Accordingly we shall devote the next section to a brief examination of some of the basic requirements a theory must conform to if it is to be classified as belonging to the body of empirical science.

A. Criteria of Empirical Science

"Empirical science, in all its major branches, seeks not only to describe the phenomena in the world of our experience, but also to explain or understand their occurrence: it is concerned not just with the 'what?', 'when?', and 'where?', but definitely and predominantly with the 'why?' of the phenomena it investigates."[2/]

From this statement it appears that not every theory we might see fit to develop to "explain" a particular set of observations would be classified as belonging to the body of empirical science. Some of our theories, e.g., theories about the behavior of small groups under certain conditions, might only contain a description of the events and behavior patterns under consideration. In this case there would be an implicit understanding that we would be able to "explain" the behavior of another small group if the

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2/ Carl G. Hempel, "The Logic of Functional Analysis," in L. Gross (ed.), Symposium on Sociological Theory, Row, Peterson and Company, 1959, p. 271.

description of their behavior coincided with the description in our theory. Alternatively, we might have constructed a more general theory that appeared to "fit" or "explain" a number of individual cases, e.g., a "mathematical model" with which the data of a particular set of observations can be generated, but from which we could not predict with any assurance of success the "what?', "when?", or "where?" of the next relevant case. In some fashion the theories of empirical science are supposed to combine all of these elements; and it is evident that to be able to answer the 'why?' of an event is not perhaps as easy as it may appear.

In order to provide a "scientific explanation"[3/] for the occurrence of an event three conditions must be met. The first is that the phenomena to be explained must be inferable from the theoretical structure. That is to say, the occurrence of the event to be explained must be deducible as a direct consequence from the conjunction of the theory and the appropriate initial conditions. For this condition to be satisfied the theoretical system must conform to the general rules of logic that govern the formation and manipulation of deductive systems. Theories which are stated in verbal or mathematical form are able to meet this condition as well as theories stated in terms of a computer program. In all cases the theory can be constructed so that the process of deducing the occurrence of an event will conform to the general rules governing deductive systems.

[3/] The term "scientific explanation" has no honorific connotations. It is employed to distinguish the type of explanation described above from teleological, and other types of explanations found in scientific literature. In the remainder of this paper terms "scientific explanation" and "explanation" will be used interchangeably.

The second condition is that the theory itself must contain at least one general law that has been subjected to a process of refutation by empirical test. In the literature of the physical sciences the term "general law" is usually taken to mean a universal statement of conditional form, stated in such a manner that it can be corroborated or confuted by empirical test. Hence, this requirement will be satisfied if the theory contains at least one hypothesis or law that asserts as a matter of empirical fact that every occurrence of a specific kind of event is always related in a particular manner to the occurrence of another specified kind of event.[4/]

The third condition requires that the statements delineating the initial conditions be empirically true.

Since an explanation of the occurrence of an event is achieved by deducing its occurrence from the conjunction of some initial conditions and the theoretical system the second and third criteria must be met if the explanation is to have empirical content. If either condition were ignored then either the theory would not contain any empirical laws,[5/] or

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[4/] It should be noted that these hypotheses or laws can have either a universal or probabilistic character, and that both fulfill the requirement mentioned above. Explanations involving probabilistic laws, however, present some special and interesting problems which are discussed in illuminating detail in: Carl G. Hempel, "Deductive-Nomological vs Statistical Explanation," in H. Feigl, et al, (eds) Minnesota Studies in the Philosophy of Science, University of Minnesota Press, Vol. III, 1962, pp. 98-169.

[5/] The term "empirical law" is used to identify general laws that are considered to be satisfactorily confirmed by empirical evidence.

the initial conditions would not be stated in observational terms. If the former were true the theory would lack empirical content and could not be considered a part of empirical science. If the latter were true the explanation would lack empirical content and could not be classified as a scientific explanation.

From this brief discussion it is apparent that it is possible to determine whether any given explanation is a scientific explanation or not. It is also evident from this discussion that a theory cannot be considered a part of empirical science unless it is possible to subject it to a process of confirmation or disconfirmation by empirical test. This is not to say that each hypothesis in the theoretical structure must be directly and independently refutable by empirical test. To insist on this criterion would imply that all hypotheses or general laws containing terms called "theoretical concepts"[6/] would have to be rejected. Such a position would seriously undermine a number of theoretical structures, since under this rule we would have to reject such concepts as Schroedinger's ψ function in wave mechanics, and demand and supply schedules in economics. Clearly this is not an acceptable procedure. The problem is resolved by allowing the testability of the hypothesis containing theoretical concepts

[6/] The term "theoretical concept" is taken from R. B. Braithwaite, Scientific Explanation, Cambridge University Press, 1953, p. 51, and is used to identify terms like "electron", "utility", "level-of-aspiration", etc. that are employed in general laws but cannot themselves be directly observed.

to be determined by the testability of the empirical hypotheses that are deducible from them. Consequently, if these procedures are followed the testability of such hypotheses are ensured, and they may be employed in the establishment of scientific explanations.

B. Some Theories of Organizations

In the literature on organizations the dominant tendency has been to strive for a theory of behavior that encompasses the major characteristics of human organizational behavior. As a result these theories have largely ignored descriptive detail in the attempt to develop hypotheses of a general and universal character.[7/] If this approach is to prove successful it must produce a theory that can be subjected to the process of confirmation and disconfirmation by empirical test. Before a theory can be subjected to such a series of empirical tests it must be possible, as we have seen, either to test some of the hypotheses directly or to be able to deduce from the theory some hypotheses that are in turn capable of being submitted to empirical test. That neither of these two conditions have been met by current theories of organizational behavior is readily apparent once we stop and examine some representative examples.

For example, consider the theory proposed by H. Guetzkow[8/] to account for the tendencies toward isolation and collaboration on the part

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[7/] For an excellent survey and analysis of organizational theory see: J. G. March and H. A. Simon, with H. Guetzkow, Organizations, Wiley and Sons, 1958.

[8/] H. Guetzkow, "Isolation and Collaboration: A Partial Theory of Inter-Nation Relations," Journal of Conflict Resolution, Vol. I, 1957, pp. 48-68.

of various nations. While this proposal is noted as representing only a first step on the road toward a more general and complete theory, it is nevertheless an excellent example of the current state of theoretical development. The object of the theory is to explain inter-group relations. The theory focuses upon the factors governing the behavior of individuals and groups within the nation which in turn, it is hypothesized, strengthen or weaken the tendency toward isolation or collaboration in its external relations. Consequently, the principal hypotheses are concerned with identifying at a general level the most important factors affecting these tendencies. Such factors as past experience with collaboration or isolation, the nations ideological attitude toward self-reliance, and the issues posed by short-run, inter-nation problems are considered and included in the set of general hypotheses.

The hypotheses themselves, however, are all stated in a manner that precludes the possibility of submitting them to empirical test. For example, consider the following two hypotheses dealing with the effects of past experience on a nation's present tendency toward isolation or collaboration:

(i) "Other things being equal, <u>the more consistently and the more fully members' needs have been satisfied through internal or self-reliant measures, the greater the tendency for members to seek solutions to their new needs in isolation</u>".

(ii) "Other things being equal, <u>the more satisfactorily group members have been able to solve past problems through inter-group relations, the more likely they are to collaborate with other groups when new needs arise</u>."[9]

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[9] H. Guetzkow, <u>op. cit.</u> p. 51.

While both of these hypotheses assert the existence of particular relations between specific sets of variables, they both fail to meet the criteria of empirical testability. In the first place the hypotheses are stated in terms of ill-defined, qualitative concepts which, as yet, do not appear to be subject to empirical investigations. For example, how are we to empirically interpret the concepts "consistent", "satisfaction", and "self-reliant" that appear in the first hypothesis; and in the second hypothesis is the "satisfaction" derived from group problem solving the same concept of "satisfaction" as appears in the first hypothesis? Consequently, unless some interpretive rules are provided which permit us to specify and investigate the empirical content of these concepts, these relations can only be regarded as uninterpreted theoretical statements incapable of being confuted by empirical test.

Suppose for the moment, however, that further research provided us with the necessary interpretive rules such that these concepts could now be subjected to extensive empirical investigation. Under this condition it might now be supposed that these hypotheses would meet the requirement of empirical testability. Indeed, it might well be argued that we could now directly observe whether for particular sets of data the hypotheses were in fact supported by the empirical evidence. Even though it might be the case that data could now be found to support these hypotheses, it would not be the case that the hypotheses had met the criterion of empirical testability. To satisfy this criterion it must be possible to specify a set of data such that, if these data should be observed then the

hypothesis would be disconfirmed. Since the hypotheses are all qualified with an uninterpreted ceteris paribus (other things being equal) clause, any unfavorable data can always be excused on the grounds that some of the "other things" did not remain the same.[10] In other words, unless the components of the ceteris paribus clause can be specified and empirically interpreted, it is clearly not possible, even in principle, to confute these hypotheses by empirical test.

Lest the reader feel that undue emphasis is being placed on the analysis of one particular theory, consider as well the excellent examples of organizational theory to be found in the study on organizations by March and Simon.[11] In this work we again find the hypotheses stated in a form which precludes the possibility of being able to submit them directly to a series of empirical test. For example, consider the following hypotheses that are included in their theory of organizational conflict: (1) "The greater the amount of past experience with a decision situation, the less probable that intra-individual organizational conflict will arise."; (2) "The less the complexity of the decision situation the less probable that intra-individual organizational conflict will arise.";[12] (3) "The existence of a positive felt need for joint decision-making and of either

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10/ For a discussion of the role of the ceteris paribus clause in the testability of economic hypotheses see: G.P.E. Clarkson, "Verification and the Function of Laws in Micro-Economics," Industrial Management Review, Vol. 4., Fall, 1962. For a detailed examination of the problems raised by the use of the qualifying ceteris paribus clause see also: G.P.E. Clarkson, Theory of Consumer Demand, op. cit., ch. 6.

11/ J. G. March and H. A. Simon, with H. Guetzkow, op. cit. especially Chs. 5,6,7.

12/ Ibid. p. 119.

a difference in goals or a difference in perceptions of reality or both among the participants in the organization are necessary conditions for intergroup conflict."[13/] While these are only three examples the remaining hypotheses are stated in a similar form. Further, it should be clear to the reader that without the addition of a set of interpretive rules these hypotheses must also be placed in the class of non-testable, theoretical statements.

This is not to say that these theoretical structures cannot be turned into scientific theories of organizations. Nor is it being suggested that these theories do not provide a useful framework within which to pursue the task of developing testable theories of organizations. On the contrary, all that is being asserted is that these theories cannot as yet be considered a part of empirical science. Consequently, the question still remains of how to construct an empirical theory of organizational behavior.

C. Two Approaches to an Empirical Theory

In the preceeding examples the most obvious deficiency is the absence of a set of empirical relations that have in fact been well confirmed by empirical test. By this statement I do not mean to suggest that no evidence can be found to support these hypotheses. Such an assertion would be manifestly false. But, as noted above, there is an important and significant difference between submitting a hypothesis or theory to a process of refutation by empirical test and employing the results of a collection of varied experiments as supporting evidence for a theory

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[13/] Ibid. p. 121.

which cannot itself be directly submitted to test. As a result, it is clear that if we are to develop a testable theory of organizational behavior our first concern must be to isolate and identify a set of empirical relations which can serve as the empirical basis for our theoretical structure.

One method of approach would be to start with a set of postualtes or hypotheses about organizational decision-making behavior. Assuming for the moment that these postualtes could not be submitted to empirical test we would then want to deduce from them hypotheses about behavior which could be corroborated by empirical test. If these deduced hypotheses are in fact confirmed then we would have the beginnings of a scientific theory of organizational decision-making behavior. Clearly, this is the general procedure that guided the development of the theories of organizational behavior noted above. It is also apparent that despite the efforts of these distinguished researchers this approach has not yet produced the desired results. Consequently, it is pertinent to enquire into the possible existence of a second or alternative approach which may have a greater chance of success. And it is toward this objective that the remainder of this section is devoted.

If we are to construct a new set of hypotheses that can be corroborated by empirical test, and if these hypotheses are to be confirmed independently of a particular organizational context, then it would appear that they must be tested by direct reference to a fairly wide range of

observable behavior. Further, if we put to one side for the moment the thought of trying to directly construct a theory of organizational behavior, this train of reasoning suggests that the construction of these testable hypotheses would require a fairly close inspection of individual decision-making behavior. It would also appear to suggest that such hypotheses could then be employed to form the basis for a theory of individual decision-making behavior, which in turn would be required to act as the empirical basis for a theory of organizational behavior.

We are suggesting, therefore, that a possible solution to our problem can perhaps be found by first constructing a theory of individual decision-making behavior. This theory must be a testable theory of behavior, and hence must be based and tested upon a wide variety of decision-making behavior. The second step is to employ the theory of individual behavior as the empirical basis for a theory of organizational behavior. If this procedure is to succeed the current theories of organizations may have to be revised to accommodate such new concepts and relations as are introduced by the underlying theory of individual decision-making behavior. But, if the price of revision is the development of a testable theory of organizational behavior, the cost of the change will have been well worth the effort. In affect, we are suggesting that a solution can be found by "reducing"[14/] existing theories of organizational behavior to a testable theory of individual decision-making behavior.

[14/] For an excellent discussion of the process of reduction in empirical science see: E. Nagel, The Structure of Science, Harcourt, Brace and World, 1961, Ch. 11; and P. Oppenheim and H. Putnam, "Unity of Science as a Working Hypothesis," in H. Feigl, et al (eds)., Minnesota Studies in the Philosophy of Science, University of Minnesota Press, Vol. II, 1958, pp. 3-36.

If this reduction process is to succeed it implies that the theory of individual decision-making behavior must be constructed in such a fashion that it is sufficient to explain individual as well as group behavior. For this to occur two conditions must be satisfied. The first requires that the laws or hypotheses of organizational theories must be deducible or inferable from the laws and postulates of the theory of individual behavior. If the hypotheses of the organizational theories contain terms and expressions that do not appear in the theory of individual decision-making behavior, then it is not possible to meet the first criterion. In this case various assumptions or further hypotheses must be introduced to link the terms in the laws of the individual theory to the terms and expressions contained in the organizational theories. For example, if we are to be able to infer hypotheses about organizational conflict or the tendencies toward isolation and collaboration between large groups from a theory of individual behavior, the individual theory must either already contain the terms and expressions appearing in those hypotheses or further assumptions or postulates must be introduced to allow the derivation to take place.

The second main condition is that the basic postulates or principal hypotheses of the individual theory must be empirically testable as well as being reasonably well confirmed by the available evidence. The purpose of this criterion is to ensure that we do not construct essentially trivial reduction theories. It would not be an important scientific accomplishment merely to construct a set of hypotheses about individual behavior from which theories of organizational behavior could be deduced if we were then unable

to test or empirically confirm them. Therefore, before we can accept a theory of individual decision-making behavior as a possible basis for the reduction of organizational theories we must be sure that the postulates or principal hypotheses of the individual theory are both capable of empirical test and reasonably well confirmed by the available evidence.

II Toward a Testable Theory of Individual Decision-Making

Having outlined in brief the conditions under which the reduction of one theory to another is said to have taken place, we can now return to the task of determining whether we can construct a theory of individual behavior that will serve as the basis for the micro-reduction of organizational theories. Because we are interested in individual behavior it is apparent that we should begin our search for the postulates of our reduction theory among the recent researches in the simulation of individual decision-making behavior.[15/] But before inspecting these theories to see if they can serve as the basis for our reduction theory we need to examine the theory of human problem solving from which they have evolved.

The theory of human problem solving that we shall briefly consider was developed by Newell, Shaw, and Simon[16/] to explain and predict the performance of a human problem solver handling various specified tasks.

[15/] For a survey of recent research in the simulation of decision-making behavior, wee the papers presented by G. H. Orcutt, M. Shubik, and G.P.E. Clarkson and H. A. Simon in; "Simulation: A Symposium," American Economic Review, Vol. 50, December, 1960, pp. 894-932. For a more extensive analysis of the task of simulating individual decision-making behavior see; A. Newell and H. A. Simon, "The Simulation of Human Thought," Current Trends in Psychological Theory, University of Pittsburgh Press, 1961, pp. 152-179.

[16/] A. Newell, J. C. Shaw, and H. A. Simon, "Elements of a Theory of Human Problem Solving," Psychological Review, Vol. 65, 1958, pp. 151-166.

The object of the theory is to explain the process of human problem solving by identifying the types of decision processes that humans employ while solving a variety of problems. While questions about problem solving behavior could be answered at several levels and in varying amounts of detail, this theory seeks to explain such behavior in terms of a set of basic information processes. The processes are partially defined by the theory's three principal postulates which state that for each problem solver there exists:

> "(1) A control system consisting of a number of memories which contain symbolized information and are interconnected by various ordering relations...
>
> (2) A number of primitive information processes which operate on the information in the memories...
>
> (3) A perfectly definite set of rules for combining these processes into whole programs of processing..."[17]

It is apparent from these postulates that it is a basic assumption of this theory that decision processes can be isolated as well as identified. Indeed, it is also assumed that they can be represented by a series of straight forward mechanical processes. This does not imply that decision processea are either simple or easy to represent. What is being asserted is that they can be broken down into their elemental parts, e.g. the memory, the rules for processing information, and the rules for combining these processes into whole programs, which in turn consist of collections of simple mechanisms.

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[17] Ibid. p. 151.

For example, consider the more general theory of human problem solving which has been proposed under the name of General Problem Solver.[18] This theory was developed to explain the problem solving behavior of individuals involved in the solution of tasks for which means-ends analysis is an appropriate method of solution. Consequently, although it is not possible to say that GPS can solve all problems stated in this form, it is possible to delimit the class of problems to which this theory of human problem solving applies.

In order to operate within the context of a specific problem the basic postualtes of GPS require that the following information be provided:

> "(1) A vocabulary, for talking about the task environment, containing terms like: object, operator, difference, feature...
>
> (2) A vocabulary, dealing with the organization of the problem solving processes, containing terms like: goal type, method, evaluation...
>
> (3) A set of programs defining the terms of the problem solving vocabulary by terms in the vocabulary for describing the task environment.
>
> (4) A set of programs (correlative definitions) applying the terms of the task-environment vocabulary to a particular environment..." [19]

Accordingly within the context of a particular problem GPS is a theory of human problem solving which essentially consists of a collection

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[18] A. Newell, J. C. Shaw, and H. A. Simon, "Report on a General Problem Solving Program for a Computer," <u>Proceedings of the International Conference on Information Processing</u>, UNESC, Paris, 1959. (Reprinted in <u>Computers and Automation</u>, Vol. 8, 1959.)

[19] A. Newell, J. C. Shaw, and H. A. Simon, <u>Ibid</u> (<u>Computers and Automation</u>) pp. 11-12.

of general but fairly powerful rules for generating problem solutions. Because these processing rules are largely independent of the subject matter of the problem, GPS is more than a theory of one individual's decision-making processes. It is in fact the beginnings of a general theory which when suitably interpreted can be used to reproduce the decision-making processes of a variety of individuals.[20]

That such a set of rules can be considered to be a theory is evinced by the requirement that it must be possible to deduce unequivocally the externally observable behavior that will be generated from it. In order to ensure that this condition is satisfied, the set of postualtes and statements are translated into a formal language (in this case a computer language) and the logical consequences are derived by performing the particular operations according to the specified rules.

That such a set of rules can be considered to be an empirically testable theory can be determined by subjecting the theory to a series of empirical tests. While the specific problems connected with such testing procedures will be discussed in the following sections, we have yet to establish the basis from which a theory of individual decision-making behavior could be employed to micro-reduce theories of organizational behavior. Consequently, before we proceed to discuss the testing proceudres we must first delimit the basis from which the reduction can take place.

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[20] The discussion of how such a theory can be submitted to empirical test and an examination of some of the evidence currently available is left until later in this essay.

A. The Basis for a Micro-Reduction

If a theory of individual decision-making behavior is to be employed as the basis for a micro-reduction of organizational theories then the theory of individual behavior must be supported by a wide variety of empirical evidence. Since theories of individual behavior are concerned with explaining a number of aspects of human problem solving there does not appear to be any inherent impediment precluding the possibility of studying human decision-making behavior in a divers number of empirical contexts. For example, the decision-making behavior of individuals engaged in the solutions of problems in geometry, logic, or chess,[21/] to mention but a few examples, could be used as the basis from which to test the empirical validity of many of the hypothesized decision processes. This is not to say that all the hypotheses of a particular theory, say the General Problem Solver, could be tested in this fashion. Clearly, some of them will be peculiar to particular problem contexts. What we are suggesting is that a certain number of these hypotheses can be tested in a variety of empirical contexts and that this number is sufficient to guarantee the empirical testability of the resulting theory.

[21/] See for example: A. Newell, J. C. Shaw, and H. A. Simon, "Empirical Explanations of the Logic Theory Machine," Proceedings of the Western Joint Computer Conference, Feb., 1957, pp. 218-230, and "Chess-Playing Programs and the Problem of Complexity," IBM Journal of Research and Development, Oct., 1958, pp. 320-335; and H. L. Geternter, J. R. Hansen, and D. W. Loveland, "Empirical Explorations of the Geometry Theorem Machine," Proceedings of the Western Joint Computer Conference, 1960, pp. 143-159.

Implicit in this last assertion is the assumption that invariances exist in the decision processes of different problem solvers. Indeed, it is being assumed that these invariances not only exist but that they can also be isolated, identified, and empirically confirmed. For example, the theory of human problem solving contains three main postulates which assert the existence in a human decision-maker of a memory, some primitive information processes, and a hierarchy of decision rules. The General Problem Solver turns these postulates into testable hypotheses by specifying in detail the contents of the memory and the information processes as well as the content and order of the decision rules required for the solution of a particular problem. If it were not possible to specify the character of these processes, then it would not be possible to directly transform the postulates of the theory of human problem solving into the hypotheses of a theory such as GPS. In effect, it has been assumed that unless invariances, like the structure of the contents in memory, exist among problem solvers, then it is not possible to construct an empirical theory of individual decision-making in this fashion.

If we assume for the moment that such invariances exist and that their specific structure can be isolated and identified by the appropriate empirical tests,[22/] then it follows that if the evidence corroborates

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[22/] Note that we are not asserting that these assumptions have been submitted to a series of empirical tests. Rather we are asserting that it is in principle possible to do so and our references to the literature on the simulation of individual decision-making behavior contain examples where such a program is already being carried out.

these assumptions the theory of problem solving will rest on a sound empirical foundation. However, to be able to transform an empirical theory of individual behavior into a theory of organizational decision-making behavior requires a further, important assumption.

If we are to reduce a theory of organizations to a theory of individual behavior we clearly need to have some hypothesis or assumption that permits us to take a theory of individual decision-making behavior and infer from it the outlines of a theory of organizational behavior. To construct an empirical theory of individual behavior _a postulate of the invariance of decision processes among problem solvers_ has been employed. Since groups of all sizes are composed of individuals, and since it is posited that these individuals have certain invariances in their decision processes, the ability to infer from individual to organizatioral theory would be provided by _a postualte that asserts the existence of invariances between the structure of individual and organizational decision processes_. The basis of this postulate lies in inductive and empirical grounds and hence it cannot be proved as a theorem. Indeed, the only grounds upon which it can be supported, other than by empirical test, is its consistency with the theory of individual decision-making behavior. Essentially, this is nothing more than an appeal to parsimony as a rule of procedure and a suggestion that this is the appropriate way in which Occam's razor should be applied. The empirical value of the postulate resides in our ability to interpret organizational theories on the basis of the empirical theories of individual behavior. Accordingly, its value to research can only be

determined by empirical test. But it should not be forgotten that the empirical basis for such a postulate is in part already emerging.

Consider, for example, a selection of hypotheses that are taken from a general theory of planning and innovation in organizations.[23/]

> (1) "Those variables that are largely within the control of the problem-solving individual or organizational unit will be considered first."
>
> (2) "If a satisfactory program is not discovered by these means, attention will be directed to changing other variables that are not under the direct control of the problem solvers."
>
> (3) "If a satisfactory program is still not evolved, attention will be turned to the criteria that the program must satisfy, and an effort will be made to relax these criteria so that a satisfactory program can be found."
>
> (4) "In the search for possible courses of action, alternatives will be tested sequentially."[24/]

Clearly, without further elaboration and specification of the meaning of these variables and the conditions under which the hypotheses apply, such hypotheses must be classified, for the same reasons as were given before, as uninterpreted theoretical statements. However, if we accept, temporarily, the postualte of the invariance of structure between individual and organizational decision processes (a postulate that is manifestly implicit in the hypotheses quoted above), these hypotheses need no longer remain in their uninterpreted state. If the postulate of invariance is employed the variables can be specified and interpretive rules can be proved by an empirical investigation of these hypotheses among individual decision-makers.

[23/] March and Simon with Guetzkow, _op_. _cit_.

[24/] Ibid, pp. 170-180.

For example, if a theory of individual behavior is to be able to establish scientific explanations of individual decision-making, then it must be possible to determine the empirical validity of the following hypotheses concerning individual behavior:

(1) Within a given problem context individuals will select those parts of the problem to be worked on first that are within his ability to control.

(2) If a solution cannot be reached in this manner, the individual will then direct his attention to the remaining parts of the problem that are not under his direct control.

(3) If a solution is still not attained, attention will be directed to the criteria that the solution must satisfy, and an attempt will be made to relax these criteria so that a satisfactory solution can be found.

(4) In the search for a solution, alternatives will be examined sequentially.

That these hypotheses can be subjected to empirical test is clear. That they will in fact turn out to be general empirical laws of decision-making behavior can only be determined by empirical test. What is more important, however, is that whether they turn out to be empirically true or false, a method has been provided for determining their empirical validity. Without the postulate of invariance (or some similar postulate) this advance could not have been achieved. Consequently, to the extent

that empirical laws of individual decision-making behavior can be established, and to the extent that the postulate of invariance between decision structures is supported by the available evidence, a method had been developed for transforming theoretical structures about organizational behavior into testable theories of organizational decision-making behavior.

III Simulation and its Methodological Problems

Having developed at least in outline form one approach to the development of a testable theory of organizational behavior, we can now return to the task of examining the problems[1] generated by employing the technique of simulation as the vehicle for conducting the empirical tests. As noted earlier in this essay, this is by no means the only possible way in which the technique of simulation can be employed. But in order to be able to find solutions for the issues raised by simulation it is necessary to provide a theoretical and empirical framework within which these questions can be considered. Accordingly, by confining the technique to the task of generating and testing empirical hypotheses of organizational behavior we can now proceed to consider the problems raised by this application of the technique.

A. Some Applications

If we assume for the moment that we have at hand either a theory of individual or organizational behavior, then we would proceed to test it

by simulation in the following way: First, a particular "model"[25/] of the theory would be constructed by specifying, where necessary, the particular parameter values and decision rules that pertain to the specified context in which the theory is to be tested. Second, the model, i.e. the statements and decision rules that describe the behavior under investigation, and the statements containing the appropriate initial conditions would be translated into a suitable computer language. Third, the computer is activated and, as in the more familiar case of scientific theories, the logical consequences are derived by performing the particular operations according to the specified rules. Finally, in an actual test the behavior generated by the model is then compared to the observed decision behavior of the individual or organization under consideration.

Consider, for example, a model of the theory of human problem solving that was developed to explain and predict the portfolio selection process of a particular trust investor.[26/] In keeping with the general theory, the postualtes of the model state that for the trust investor there exist:

[25/] Since one theory is a "model" of another theory only if their laws are structurally similar, the term "model" will be used in this essay to designate the particular instance of the more general theory that is being submitted to empirical test. For a most illuminating discussion of the uses and meaning of the term "model" in the social sciences see: M. Brodbeck, "Models, Meanings, and Theories," in L. Gross (ed), Symposium on Sociological Theory, op. cit., pp. 373-403.

[26/] G.P.E. Clarkson, Portfolio Selection: A Simulation of Trust Investment, Prentice-Hall, 1962.

"(1) A memory which contains lists of industries each of which has a list of companies associated to it. The memory also contains information associated with the general economy, industries and individual companies. [Investors categorize companies by industry. Not all investors may associate identical companies with a given industry, but the process of classification by industry remains invariant as the primary basis for listing companies in the memory. The information associated with each company also varies among investors, but each may be represented as having a list of attributes with their values stored in memory, e.g. growth rate, divident rate, price earnings ratio, expected earnings, expected yield, etc.]

(2) Search and Selection procedures which perform the task of searching the lists of information stored in memory, selecting those items that have the required attributes, regrouping the selected pieces of information into new lists, and performing algebraic operations when necessary. These procedures function in a manner similar to that of the traditional clerk who prepares lists of stocks suitable for current investment by scanning a master list.

(3) A set of rules or criteria which guide the decision-making process by stipulating when and how each process is to be used. The set of rules constitutes the structure of the decision process for an individual investor. It might be compared to the heuristics of the traditional "expert," but as previously noted, there is an important difference--namely, the set of rules must be defined unambiguously."[27]

The model was prepared for empirical test by translating it and the requisite initial conditions into a particular computer language.[28] The tests were conducted by comparing the behavior generated by the model against the observed behavior of the trust investor at four different periods of time. That is to say, in order to test the model's ability to reproduce the observed behavior of the trust

[27] Ibid. p. 27.

[28] The program was written in Information Processing Language V. For a detailed description of the language see: A. Newell (ed) Information Processing Language V Manual, Prentice-Hall, 1961.

investor--i.e. to simulate the trust investment process--the model was required to select a series of portfolios for a specific set of trust accounts. In particular the model was tested by requiring it during the first and third quarters of 1960 to generate portfolios for four accounts that the trust investor had dealt with during the same period.

Given this specific model (and others that will be noted as we proceed) we can now begin to pose the questions that are raised by this application of simulation. For example, what criteria are we to use to discriminate between models that successfully reproduce the observed behavior and those that do not? One answer would be to accept the model as having been corroborated by empirical test when the results generated by it are consistent with those obtained from the human subject--namely, accept the model, and hence the theory, when it is sufficient to account for the observed behavior. Such an answer, however, does not provide us with operational criteria for distinguishing when the results are to be considered "consistent". Therefore, we still have not provided an answer for the question: under what conditions can the model be said to be sufficient to account for observed behavior?

Unfortunately, there is no one criterion that can perform this service for us directly. As in any branch of empirical science it is not possible to "prove" that a theory or model is "true" by empirical test. The best that can ever be said for a theory is that is has not

yet been disconfirmed by empirical test. Accordingly, we cannot "prove" that a simulation model is "empirically true". The best we can do is submit these models to more and more stringent tests in the hope that we shall gradually be able to eliminate those hypotheses and theories that are demonstrably false.

One testing procedure that meets this more general requirement is the adaptation of Turing's Test[29/] suggested by Newell and Simon.[30/] Turing was interested in creating a test that would determine whether a machine could "think". To answer this question he devised a test called the "imitation game".[31/]

The game is played by three players--a machine, a human and an interrogator--and there are two channels of communication (say teletypes) which link the interrogator, separately, to the human and the machine. The object of the game for the interrogator is to identify which of the two players is the machine. Active questioning is allowed, and the machine's task is to fool the interrogator while the human is assumed to want to do his best to reveal his "true" identity. The interrogator

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29/ A. M. Turing, "Can a Machine Think?" in J. R. Newman (ed), The World of Mathematics, Simon and Schuster, 1956, Vol. IV, pp. 2099-2123.

30/ A. Newell and H. A. Simon, "The Simulation of Human Thought," op. cit. p. 160.

31/ For a more detailed discussion of the game see: A. M. Turing, op. cit. p. 2099-2102.

succeeds and the machine is declared unable to "think", if on a given number of trials he is able to identify which player is which on a better than chance basis.

The adaptation of Turing's Test to the problem of discriminating between the output of a particular model of human behavior and the decision behavior of the human proceeds as follows: Data are gathered on the human's decision processes by collecting "protocols"[32/] or other records of his decision-making processes. The output generated by the model is also collected and can now be directly compared with the recorded decision behavior of the human. This comparison process can be carried out at many levels. The only restriction is the level of detail of the data that can be gathered on the human's decision processes. When the model generates decision behavior that meets the criterion of Turing's Test, the model is said to be sufficient to account for the human's decision-making behavior.

[32/] A "protocol" is a transcript of the verbalized thought and decisions of a subject when he has been asked to problem solve aloud. Consequently, it is a record of a subject's thought process while engaged in making a decision. For further discussion of this data collection technique see: Newell, Shaw, Simon, "Elements of a Theory of Human Problem Solving," op. cit. p. 15§ and for examples of the decision processes recorded in protocols see: G.P.E. Clarkson, Portfolio Selection, op. cit. ch. 6.

Clearly, such a test can be applied to the output of the model as a whole as well as to the behavior of the individual decision processes. In the former case the test might be considered to be quite weak, since there presumably are a variety of computer programs that will yield a specified output. But, by carrying the matching process down to the level of the individual decision processes the tests become more and more discriminating. Consequently, the strength of the test can be determined by the experimenter; and our confidence in the empirical validity of a model is manifestly a function of the level of detail at which the matching processes are carried out.

For example, in order to determine the trust investment model's ability to reproduce the portfolio selection process of trust investor, the first test consisted of comparing against each other the two sets of portfolios for the four different accounts. To achieve a perfect score in this test, the model not only had to select the correct number of securities for each portfolio, but it also had to select the same securities and the same number of shares of each security as was purchased by the trust investor. Even though the model did not pass the test with a perfect score, the similarity between the two sets of four protfolios, all of which were chosen at different periods of time, is quite striking.[33/]

[33/] For a detailed presentation and analysis of these portfolios see: ibid, ch. 6.

Since there are a variety of models that could generate the same portfolios, the next test was concerned with determining whether the investment model's decision processes were consistent with the trust officer's recorded decision behavior. To conduct this test a record was made of the problem solving behavior of the model which was then compared to the statements contained in the trust investor's protocols. To succeed in this test the model's decision behavior had to be sufficiently similar to the trust investor's so that a direct examination of the two streams of behavior would not provide a basis for deciding which was produced by the human and which by the model. As a further check on the model, outputs of some individual decision processes were also compared in a similar manner to the appropriate portions of the trust investor's protocols. While it is certainly not possible to state that this testing procedure unequivocally confirmed both the model and its individual processes, the evidence was such that it strongly supported the hypothesis that the model's decision process were sufficient to reproduce a considerable portion of the trust investment process.[34/]

From this discussion it is apparent that simulation models of this sort can be subjected to a series of empirical tests, and that these tests can be applied to the model as a whole as well as to the individual decision processes of which the model is composed. Consequently, Turing's

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[34/] The evidence and the tests are presented in detail in ibid, ch. 7.

Test is a powerful method for determining the empirical validity of models whose object is to reproduce human decision-making behavior.

B. Errors and the Identification Problem

Unfortunately, the discriminatory power of these tests is somewhat impaired by the absence of suitable measures for determining the "type" and "degree" of failure of such tests. That is to say, although some models may reproduce the observed human behavior with great accuracy, other models will not be so successful. Hence the question immediately arises of how to classify, identify and measure the types of "errors" that such models must contain. One answer might be to postulate that all errors are due to an incorrect specification of the decision process within the model. If this rule were accepted as the principal criterion then whenever "errors" occurred this would be a signal to go back and retest the appropriate parts of the decision process until such time as the model's output was similar to that of the human's.

Such a rule, however, despite its apparent simplicity does not provide us with a complete answer to the problem. If all "errors" are errors in the processes then this rule will motivate theorists to include as many parameters in the model as are necessary to produce the desired stream of behavior. Consequently, models will tend to contain an abundance of free parameters, and general rules about parsimony will tend to be ignored. This is not to say that as these models are subjected to an increasing number of empirical tests, excess parameters will not be

deleted where possible. Rather we are suggesting that unless some measures are developed which permit us to determine the degree to which a model fails a particular test, the tendency will be to produce models which have a large number of free parameters and hence are capable of being "fitted" to a wide range of observed behavior.

The problem is clearly one of how to distinguish between models that are in some reasonable sense empirically "true" from those that are corroborated by the available evidence because they contain so many free parameters that they can almost invariably be fitted to the test observations. Turing's Test provides us with a method for distinguishing between those models that can and those models that cannot produce behavior that is indistinguishable from its human counterpart. But of the set of models which more or less pass this test, how are we to avoid accepting as empirically "true" models which have passed the test for essentially trivial reasons. In effect, the answer to this question is no different for these models than it is for other models in empirical science. In science it is never possible to tell whether a particular theory or model is empirically "true." The best that can ever be said is that so far it has passed all the tests to which it has been submitted. Consequently, until such time as it is disconfirmed or replaced by a more comprehensive or detailed theory it must be accepted as it stands--an empirically testable theory of a particular set of behavior.

To illustrate these remarks consider for a moment the task of deciding whether a particular model of the theory of problem solving

contained in GPS should be considered to be corroborated or confuted by a specific empirical test. The model in question was designed to reproduce the behavior of particular human subjects when engaged in the solution of a specific set of problems in symbolic logic. After providing the model with a vocabulary, a set of definitions sufficient to allow it to consider problems in symbolic logic, (see page 21) and the initial conditions i.e. the theorems to be proved, the model was set to work to develop the required proofs. At the same time protocols were made of the decision processes of a number of students who were asked to construct proofs for the same theorems. To test whether this model can be considered to be sufficient to generate the students' behavior we compare the output of the model's decision processes against the observed behavior of the students. Such a comparison is given by the following excerpts from the decision behavior generated by a student and the model when they were considering the problem of transforming the statement $R \cdot (\sim P \supset Q)$ into the statement $(Q \vee P) \cdot R$.[35]

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[35] For a detailed discussion of the model and this test see: Newell and Simon; op. cit., pp. 155-176.

	Simulation	Student's Protocol
1.	$\underline{L}_0$: $(Q \vee P) \cdot R$	(Expression to be obtained[36/])
2.	$\underline{L}_1$: $R \cdot (\sim P \supset Q)$	(Expression given at start)
3.	Goal 0: <u>Transforms</u> $\underline{L}_1$ and $\underline{L}_0$	(Goal set by experimenter)
4.	Match gives position difference ($\underline{\Delta}$p)	I'm looking at the idea of reversing these two things now.
5.	Goal 1: <u>Reduce</u> $\underline{\Delta}$p between $\underline{L}_1$ and $\underline{L}_0$	(Thinking about reversing what?)
6.	Search list of rules	The R's...
7.	Goal 2: <u>Apply</u> $\underline{R}_1$ to $\underline{L}_1$	
8.	Match: $\underline{R}_1$ applicable	
9.	Test rule functions: reduces $\underline{\Delta}$p	Then I'd have a similar group at the beginning but that seems to be...
10.	no others	
11.	<u>Set to execute</u> $\underline{R}_1$ when analysis complete	I could easily leave something like that to the end, except then I'll...
	. . .	. . .
23.	Goal 7: <u>Apply</u> $\underline{R}_3$ to right $\underline{L}_1$	Well...then I look down at rule 3
24.	Match: $\underline{R}_3$ not applicable	and that doesn't look any too practical
25.	Goal 8: <u>Apply</u> $\underline{R}_4$ to $\underline{L}_1$	Now 4 looks interesting.
26.	Match: $\underline{R}_4$ not applicable[37/]	Its got three parts similar to that ...and...there are dots so the connective...seems to work easily enough,

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[36/] Statements in parentheses are experimenter's statements and explanatory statements. All other statements are the subject's.

[37/] But the subject mistakenly thinks R_4 is applicable; therefore, tests its function.

28.	Test rule functions: doesn't reduce Δp	but there's no switching of order.
	. . .	. . .
33. 34.	Search rules again, but don't reject without attacking subproblem	I need that P and a Q changed so...
35.	Goal 14: Apply R_1 to right L_1	
36.	Match: R_1 fails, right L_1 has $\supset$ (Δc)	I've got a horsehoe there.
37.	Test rule functions: reduces Δp, [illegible] others.	That doesn't seem practical any place through here.
38.	Set to execute R_1, if applicable	
39.	Goal 15: Reduce Δc between right L_1 and R_1	I'm looking for a way now, to get rid of that horseshoe.
40.	Search list of rules; for rule	
41.	with $\supset$ that reduces Δc	
42.	Goal 16: Apply R_6 to right L_1	Ah...here it is, Rule 6.
43.	Match: R_6 applicable	
	. . .	. . .
67.	Match: L_4 identical with L_0	And...that's it.[38/]

38/ For a complete history of these statements see: ibid pp. 171-173.

Given this evidence can we now state that the model has been confirmed or disconfirmed by such a test? Manifestly this is a difficult question to answer directly. In a number of ways the model closely parallels the student's problem solving, and yet there are cases, notably line 26, where the student makes an error and unnecessarily proceeds to test the function. Also it is evident that the model examines the applicability of all rules, while the student gives evidence of only examining the first few. This is not to say that the behavior generated by the model does not come very close to matching that of the student, especially if we imagine the model generating gramatical sentences instead of chopped up statements. But since no method has yet been devised for measuring the difference, if any, between these two streams of verbal behavior it is not possible in this case to answer directly the question: how close is close enough?

If we had a method for measuring the difference between two sets of verbal behavior, then we could begin to explore the answer to the question: how many excess parameters are there in our model? Given that we can measure the "goodness" of performance, empirical exploration of the model will allow us to identify those parameters and processes that can be deleted without lowering the level of performance below some acceptable standard. Clearly, such is the case, if our model produces an output that is amenable to numerical analysis.

For example, if the model is concerned with reproducing the pricing process within a particular firm then part of the output will be a collection

of items each of which is labelled with a particular price. The actual prices set for these items can be readily observed and the differences between these two sets of prices noted. For a given level of predictive success, say 90%, the model can now be tested to see which set of parameters and processes can be deleted so that its ability to predict the actual prices never falls below 90%.[39]

Further, by repeatedly testing the model against a set of observed data the decision processes can also be explored to determine the effect that alterations in these processes have on the predictive success of the model as a whole. That is to say, once the model has been built and has passed an initial set of empirical tests, the decision processes as well as the individual parameters can be subjected to what might be called sensitivity analysis. Therefore, as long as we can measure a model's predictive success, and as long as we can agree on the significance of specific levels of success, say 95%, then empirical explanations can be conducted so that excess parameters and processes are deleted and parsimony is preserved.

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[39] It should be noted that a model has already been constructed to simulate the pricing decisions in a department store. Further, in the tests that have been conducted the model predicts correct prices, including special sale prices and mark-downs, approximately 95% of the time. While tests have not been conducted to determine the number, if any, of excess parameters and decision processes, the model clearly meets the conditions required for such explorations. The model is described and the data are presented in: R.M. Cyert and J.G. March, The Behavioral Theory of the Firm, Prentice-Hall, 1963, ch. 7.

C. Heuristics, Algorithms and Statistical Tests

So far we have discussed the problems raised by the testing of simulation models in terms of Turing's test. While it has been noted that this test can be applied in stronger and stronger forms it has also been pointed out that when comparing two sets of verbal behavior it is not yet possible to measure the degree of difference or error between them. Despite the absence of such a measure it is still possible to distinguish between models whose generated behavior come close to reproducing observed decision behavior and those that do not. Consequently, even though this difference is not expressible as a numerical function of specific variables, the model can be subjected to a series of empirical tests.

It is important to remember that the testing procedure can also be applied to the model's decision mechanisms and that the limit of detail at which this testing can take place is defined by the level of detail recorded in the protocols. Accordingly, if a model is not to be rejected by empirical test then both the model as a whole and its decision processes must generate behavior that is consistent with observed behavior. By emphasizing the fact that the decision processes themselves must also be submitted to empirical test we have provided ourselves with a criterion for identifying the types of decision mechanisms that are most appropriate for each type of model. Since we are only concerned with discussing models of testable theories of organizational behavior, this criterion enables us to specify directly the cases where heuristic or algorithmic decision rules should be employed.

To illustrate this point consider for a moment, the decision processes that are employed to select portfolios in the model of trust investment behavior. These processes are all stated in the form of heuristics--that is, they describe the search and selection procedures which delimit the available alternatives which in turn provide the basis for the final selection. In particular the final selection of securities for a specific account is made by choosing the first security that passes the relevant criteria from each of a number of industry lists. As a result, selections are made sequentially and many securities, although quite suited for the particular portfolio, may never even be "brought up" for consideration. If, on the other hand, a set of algorithmic decision rules were employed, e.g. choose only those securities which maximize expected returns, where these algorithms were specified in complete detail, the behavior generated by the processes would be strikingly different from that generated by the model. Clearly, before one can maximize expected returns one must be able to measure it. Hence, the decision behavior generated by this decision rule can be compared to the behavior recorded in the protocols. If the algorithmic rules produce behavior that is inconsistent with the observed, then these processes must be rejected in favor of decision mechanisms which are consistent with observed behavior.

For example, assume for the moment that we wish to test the hypothesis that the trust investor employs algorithmic decision rules. Further, assume that these rules take the form of some optimizing routine, e.g. choose those securities which subject to certain constraints maximize expected returns. With such a decision rule we can predict that the model will examine

all available alternatives before selecting its portfolio--i.e. an optimizing decision rule implies that all alternatives are to be examined before a choice is made. As a result, this pattern of search and selection behavior can be contrasted with the observed and consistencies and inconsistencies noted. Also, if an algorithm of this sort is employed, processing time should be roughly equivalent for each security that is examined. That is to say, given the decision rules and the appropriate data, there is no reason to suppose that it will take longer to evaluate the expected returns of one security rather than another. But human processing time can also be observed, and if, as indeed happens to be the case, some securities are accepted or rejected quite rapidly while others take much longer to decide upon, then this evidence would also tend to confute what we might call the algorithmic hypothesis. Therefore, when the decision processes themselves are subjected to a process of refutation by empirical test, the debate over heuristic vs algorithmic decision rules rapidly disappears. Because it is highly unlikely that two such different types of processes could generate identical streams of decision behavior the problem of choice is simply resolved by selecting the one that most closely reproduces the test data.[40/]

When carrying out such a series of tests it might be supposed that we are able not only to identify that set of decision mechanisms which are

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[40/] For a most stimulating discussion and examination of the power of a specific set of heuristic decision rules to reproduce the search and selection procedures of grandmaster and expert chess players see: H.A. Simon and P.A. Simon, "Trial and Error Search in Solving Difficult Problems: Evidence from the Game of Chess," Behavioral Science, Vol. 7, Oct., 1962, pp. 425-429.

sufficient to reproduce the human decision behavior but also, at the same time, identify and delete from the model what we have called excess free parameters. Earlier we saw that if the model's predictive success can be adequately measured then excess free parameters can be isolated by repeated empirical explorations. Consequently, once a criterion of predictive accuracy has been accepted or established for a particular class of models, then there is no reason to suppose that sensitivity analysis will not allow us to construct more parsimonious models which will still be confirmed by the empirical tests.

The point that should be noted in this respect is that statistical tests are unfortunately of little use in helping to isolate the surplus or excess free parameters. If these models were stated in terms of standard difference or differential equations with a limited number of independent variables, then the problem of excess parameters can be answered within the confines of, "the identification problem."[41] But as previously noted, both the theories of individual and organizational problem solving are stated in terms of programs of processing rules which are not amenable to a similar mathematical analysis. As a result, despite the fact that we are faced with the same "identification problem" the standard mathematical methods of solution are no longer directly applicable.

[41] For an extensive discussion and analysis of the "identification problem" see: H. A. Simon, "Causal Ordering and Identifiability," in Models of Man, John Wiley and Sons, N. Y., 1957; and T. C. Koopmans (ed), Statistical Inference in Dynamic Economic Models, Cowles Commission Monograph, 10, John Wiley and Sons, N. Y., 1950, Chs. I, II, and VI.

For example, consider the problem of estimating the statistical significance of each parameter in a small set of decision processes. Assume for the moment that these processes describe a sequential selection process that contains fifteen different tests. Also assume that we wish to set up some kind of statistical test, say an analysis of variance test, that will allow us to identify which of the fifteen parameters play a statistically significant rôle in accounting for the actual set of observed data. Ideally, if we could estimate the sample of observations that are required so that statistical tests can be made on the significance of each parameter, then all we would need to do is conduct the required number of experiments. For instance, if samples of twenty were sufficient to generate statistically significant results, and if each of the fifteen parameters were employed each time the decision process was used, then twenty experiments employing this selection process would provide us with the requisite data. But if, as is most likely to be the case, each time the selection process is employed not all the decision points are evoked and used, and if it takes on the average twenty-five applications of the selection process to ensure that each parameter has been evoked at least once, then it will take approximately five hundred experiments to generate samples of at least twenty observations for each parameter. Further, if the selection process itself is not employed each time this part of the model is subjected to empirical test(e.g. if the selection process is employed as a sub-routine that is only used from time to time), the number of experiments required has now increased to a very large and

impractical number.[42/]

From this brief example it should be clear that it is simply not feasible to employ the standard techniques to examine the sample distribution and to evaluate the statistical significance of each parameter in a simulation model of any reasonable size. This is not to say that the task of eliminating excess parameters is, for all practical purposes, hopeless. Rather this problem must be approached in the same spirit as we approach the development and testing of theories in any branch of empirical science where theoretical speculations are always controlled and refined by direct confrontation with empirical observation. Therefore, even though we are always anxious to simplify and increase the power of our theories, progress can only be achieved by the diligent application of empirical tests.

IV <u>Concluding Remarks</u>

At the beginning of this essay we noted that the principal methodological issues posed by the use of simulation as the method by which theories of organizational behavior are to be subjected to empirical test center around the determination of the empirical significance of these theories. We also pointed out that before the problems could be properly phrased and solutions derived we first had to delineate the theoretical

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[42/] For an illuminating analysis of the problems posed by the measurement of the statistical significance of specific parameters in a simulation of a behaving system see: C. P. Bonini, <u>Simulation of Information and Decision Systems in the Firm</u>, Prentice-Hall, 1963, Chs. 7 and 8.

structure within which these issues could be raised and examined. Without such a theoretical context the technique of simulation is nothing more than a method or precept for orienting inquiry into organizational behavior. Under such conditions the methodological issues raised by this precept are devoid of empirical significance. Consequently, our first task was to specify the theoretical context within which this technique was to be employed.

Because we are primarily interested in developing theories which can explain and predict organizational behavior the required theoretical context is clearly that which is provided by empirical science. Hence, before we can begin to frame the questions posed by simulation we must first have an empirical theory of organizational behavior which is to serve as the basis for the empirical tests. Since a theory does not yet exist which can be directly submitted to a series of empirical tests the object of this paper has been two-fold: The first has been to develop the outlines of an empirical theory of organizational behavior; and the second has been to evaluate within the context of this theory some of the issues posed by employing simulation as the vehicle for testing its empirical significance.

The first two main sections, then, have been devoted to a discussion of some possible approaches to the problem of developing a testable theory of organizational behavior. After presenting the criteria by which a theory can be adjudged to belong to the body of empirical science we examined two leading examples of the class of organizational theories currently available. While both of these theories were proposed by their

authors as tentative statements to guide future research, it was pointed out that neither of them could be subjected to a process of refutation by empirical test. This is not to say that the approach taken in the development of these theories is such as to preclude the possibility of ever being able to submit them to empirical test. All that we have asserted is that in their current state of development neither of these theories possess sufficient empirical interpretation to permit them to be confronted by a series of empirical tests.

Since our objective is to develop a theory that contains a set of empirically tested relations, and since the general theories developed so far have not yet isolated or produced such a set of hypotheses, the alternative proposed in this essay is to develop a testable theory of individual decision-making behavior which in turn can be employed as the empirical basis for a theory of organizational behavior. If this approach is to succeed two conditions must be met. The first is that a theory of individual decision-making behavior must not only exist but it also must be shown to be subjectable to and confirmable by empirical tests. We suggested that this condition has, at least in part, already been met and briefly discussed the theory and the conditions under which it is currently being submitted to empirical tests.

The second condition requires that a theoretical and empirical link be constructed between individual and organizational theories so that a

testable theory of the former type of behavior can serve as the empirical basis for the latter type of theory. For this condition to be met the laws or hypotheses of the organizational theories must be inferable or deducible from the laws and postulates of the individual theory. Moreover, the theory of individual decision-making behavior must be empirically testable as well as reasonably well confirmed by the available evidence. Since we have argued that a testable and partially tested theory of individual behavior already exists, this second requirement will be satisfied if we can provide the necessary theoretical link.

To effect this reduction process we have proposed a postulate that asserts the existence of structural invariances between the decision processes of individuals and organizations. Although no formal proof for this postulate can be given its empirical value can be established by testing its ability to interpret theories of organizational behavior on the basis of the empirical theory of individual decision-making behavior. Accordingly, if empirical laws can be established for individual decision-making behavior, and if the postulate of structural invariance is supported by the available evidence, then a theoretical and empirical link has been provided for transforming theoretical structures about organizational behavior into empirically testable theories.

Having developed a theoretical framework within which to conduct empirical tests, we then discussed the manner in which the technique of

simulation can be employed to serve as the vehicle for carrying out the empirical tests. Since the theories of decision-making behavior discussed in this essay contain a detailed description of the decision processes employed, the determination of the empirical significance of these theories presents several difficulties. The principal obstacle concerns the criteria that are to be used for evaluating when a particular theory can be said to have been corroborated by an empirical test. Turing's Test has been proposed as a powerful and practical solution to this problem. But as there is yet no good measure for determining the "degree of difference" between two sequences of verbal behavior, the application of this test alone does not surmount all of the problems.

The mischievous effects of these difficulties can be reduced, however, by insisting that the output of the decision mechanisms themselves as well as the output of the model as a whole be subjected to the process of comparison with the recorded human behavior. Under this condition differences or "errors" in the output can be identified as "errors" in the relevant decision processes. Moreover, even if these "errors" cannot be isolated and removed, at least their source can frequently be determined.

The complexity of the decision models and the absence of adequate measures for the "degree of difference" between two sets of verbal behavior also makes it difficult to determine the number of excess free

parameters in any specific model. If the model's output is amenable to numerical analysis the task is made some what easier, since empirical explorations can now be conducted by a form of sensitivity analysis to determine the empirical significance of some parts of the decision process. The complexity of the models, however, precludes the use of statistical techniques to identify and isolate all the excess parameters. Consequently, the search for parsimony has to be conducted through empirical explorations in conjunction with the theorist's estimates of the processes that are in the greatest need of revision.

Despite the fact that we do not have a set of criteria which allow us to identify errors and free parameters by numerical analysis, it would seem to be mistaken to argue that their absence substantially reduces the discriminatory power of these tests. For to assert that the absence of numerical measures reduces the power of, say Turing's Test, is essentially to argue that its power would be increased if we only had a set of numbers to judge instead of a set of words. This is not to say that numerical measures would not be a useful and important addition to the testing process. Rather we are suggesting that the acceptance or rejection of theories in science is always based upon a "process of judgement"; and further, that this process consists of the application of a set of criteria which scientists have agreed to consider as adequate for the purpose at hand. Hence, while the "process of judging" the difference

between two sets of verbal behavior may not be considered to be very precise the process differs in no important respects from the commonly accepted statistical criterion of accepting or rejecting a hypothesis at the 5 per cent level.

Therefore, even though a number of problems remain to be solved, it appears that a testable theory of organizational behavior can be constructed, and that within the context of a theory the technique of simulation provedes us with a powerful vehicle for developing and testing the theory's empirical significance.