

Computer Simulation: The Third Symbol System

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The role of computer simulation for theory construction in social psychology needs to be better understood. It should be viewed as a medium through which theoretical propositions can be articulated and predictions can be generated. It is one of several symbol systems available to theorists for expressing theoretical ideas. The first symbol system acquired by students in social psychology is natural language and the second is mathematics. Computer simulation offers a third symbol system. Theorists express their ideas in a program, and a computer is used to facilitate the generation of predictions from the theory-as-program. Five complexities inherent in social behavior have resisted theoretical understanding using the first two symbol systems. They are multiple manifestations of a single latent variable, qualitative cognitive and social structures, models of the linkage between latent variables and their overt expression, the interface between multiple latent variables, and time. The third symbol system, computer simulation, offers a substantial advantage to social psychologists attempting to develop formal theories of complex and interdependent social phenomena. © 1988 Academic Press, Inc.

Computer simulation is finally coming of age in social psychology. The other papers in this issue of the *Journal of Experimental Social Psychology* illustrate the breadth of phenomena for which simulations have been developed. The papers use simulations to theoretically probe social memory, impression judgments, and group discussion and decision making.

Simulation approaches have been advocated by social psychologists for more than 25 years. In 1960, Carl Hovland strongly encouraged their use in theorizing about complex human processes. His paper nicely summarized the value of simulations for theory development, and went on to discuss the empirical obligations of researchers who use simulations.

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Unfortunately, the illustrations offered by Hovland only pertained to subjects like problem solving, learning, concept formation, and neural networks, and not to topic areas of more direct interest to social psychologists.

Eight years later, Robert Abelson (1968) published a chapter in the *Handbook of Social Psychology* on the "Simulation of Social Behavior." It presented a thorough analysis of the virtues of simulations, and even today provides the best starting point for social psychologists interested in learning about simulation approaches.

Abelson reviewed some of the same simulations of cognitive processes that Hovland had covered. But more usefully, he also provided a review of complete simulations that dealt with fundamental social processes. These models pertained to issues at the heart of social psychology, including social exchange, coalition formation, emotional responses to other people, attitude change, and social influence.

Despite the clear relevance of these models to social psychology, the simulation approach had not caught the imagination of main stream social psychologists. Very few simulations had appeared in the core journals of the field prior to the publication of Abelson's chapter. In fact, only 5 of the 206 references in his chapter were to papers in the *Journal of Abnormal and Social Psychology*, *Journal of Personality and Social Psychology*, and *Journal of Experimental Social Psychology*. At the time of Abelson's writing, simulation models had not made much contact with the dominant empirical pursuits of the field.

The present issue of this journal demonstrates that computer simulations can play an integral role in advancing understanding of important social psychological phenomena. The papers share a similar structure. They all begin with a well-established empirical phenomenon that had been the target of inquiry in main stream journals. The papers offer fairly intricate models, verbally conveyed to the reader, that provide a possible account for the empirical findings. In each case, the complexity of the model is so great that it is impossible to tell from the verbal presentation whether the model does, indeed, account for the data. Therefore the authors chose to represent the model as a computer program and run it on a computer to generate the models' predictions. Predictions are then presented and comparisons with the data are made. Finally, the model's viability is assessed.

COMPUTER SIMULATIONS AS THEORY

This paper offers a view of simulations that may be at odds with the views held by some readers, especially those whose primary acquaintance with simulations is from Abelson's (1968) chapter in the *Handbook*. Many in the field appear to regard computer simulation as merely a method. This erroneous view of simulations was encouraged in part by the placement

of Abelson's chapter into Volume 2 of the *Handbook*. This volume was devoted exclusively to research methods in social psychology. Other chapters in that volume covered topics like data analysis, attitude measurement, observational methods, and interviewing techniques.

A second reason workers may regard simulations as a method is that the longest section in Abelson's chapter is titled "The methodology of computer simulation." It covers issues like problem selection, preparation of flow charts, computer capacity, selection of programming languages, and debugging of programs. All of this could lead the casual reader to assume that computer simulation is merely a technology, like content analysis and attitude measurement, that is only used for special purposes.

The view offered in this paper is that computer simulation is a *symbol system*; it is a medium through which theoretical concepts can be represented and communicated. Rather than being a special-purpose technology, it is regarded as offering theorists in all areas of social psychology an alternative way of expressing their ideas.

I refer to computer simulation in this paper as the third symbol system. By symbol system, I refer to the symbols through which we express our theoretical (as well as all other) ideas and communicate them to others in the field. We use a symbol system to represent concepts and to express propositions that causally relate concepts to one another. Symbol systems have an associated syntax that provide rules for manipulating the symbols, and so allow predictions to be generated from primitives and propositions.

The first symbol system that is universally used by social psychologists is natural language, such as English in the case of this paper. Natural language is rich in concepts and provides an enormous flexibility to the theorist in representing conceptual nuances. It has the additional advantage that social psychologists (like all other scientists) are fluent in this symbol system prior to receiving their formal training in the field. For most of the problems addressed by theorists in social psychology, the natural language symbol system has been adequate to yield substantial advances in understanding.

Social psychology has also recognized the theoretical utility of a second symbol system, mathematics. This symbol system offers quantitative precision and unequivocal specificity in articulating variables and relationships. The field's acceptance of mathematics as a symbol system can be seen in Volume 1 of the 1968 *Handbook of Social Psychology* (Lindzey & Aronson, 1968). This volume was devoted to systematic positions (i.e., theories) in social psychology. It contained chapters covering stimulus-response, psychodynamic, cognitive, and role theories. It also contained a chapter titled "Mathematical models of social behavior." The editors recognized that mathematics, as a symbol system, provided unique assets to the theorist and accorded it the stature of inclusion in the theories volume. The same recognition was not extended to computer simulations.

Any theory that can be expressed in either of the first two symbol

systems can also be expressed in the third symbol system. Computer simulations can be used for representing both qualitative, natural language constructs and quantitative, mathematical constructs. The basic idea is simple. The theoretical constructs are expressed through a higher level language like BASIC, FORTRAN, or LISP in the form of a detailed computer program. The symbol system is defined in terms of the properties of that programming language.

The program becomes the theory. Programs also contain some book-keeping information that is irrelevant to the processes being modeled, but these can easily be separated from the key theoretical propositions.

The predictions of the theory can efficiently be obtained by running the program on a computer. The computer itself, then, plays no role other than providing a speedy way of discovering the implications of one's theoretical ideas. It is like using a pocket calculator for obtaining the product of two five-digit numbers rather than doing it with paper and pencil.

VERBAL THEORIES AS COMPUTER SIMULATIONS

Social psychology is replete with verbal theories. Sometimes people have contrasted verbal theories against computer simulations, implying that a theory can be one or the other, but not both. This is a misconception. In fact, any verbal theory can be expressed in the form of a computer simulation. All existing theories of attraction, competition, aggression, attitudes, attribution, and leadership, along with theories regarding every other facet of social psychology, can be stated as a simulation.

For most theories in social psychology, there is not a great deal to be gained from translating it into a simulation. The major benefit would be an increase in the precision of the formulation. The theorist would be made more aware of unstated assumptions and of the need to unambiguously delineate all relevant contingencies and ramifications. But for most verbal theories in social psychology, the theorist provides sufficient specificity to allow empirical evaluation of the model's basic tenets. Also, the theorist is as able to generate predictions from the theory in its verbal form as would be the case if a simulation had been prepared.

Over the last 40 years or more (since the work on "grand theories" such as Lewin's field theory), social psychology had become preoccupied with the development of mini theories. Typically, these are theories that focus on a single latent variable such as attitude, leadership, or judgment. Verbal theories have been productive in uncovering the processes operative within such focused, yet limited, modules of understanding. But the field is now ready to move beyond these mini theories and to theoretically address more complex social behavior.

FIVE UNSOLVED COMPLEXITIES OF SOCIAL BEHAVIOR

Verbal theories in the field have not come to grips with many of the fundamental complexities of social behavior. In this section I outline five complexities that have proven elusive to social psychological theorists. The first symbol system allows us to acknowledge and discuss these complexities, but it has not led to any substantial advancement in our conceptual understanding of them. On the other hand, the third symbol system, computer simulation, holds great promise in illuminating the dynamics underlying these complexities. Herein lies the enormous potential of computer simulation for social psychology.

The First Complexity: Multiple Manifestations

Almost all of our theories are univariate in nature. In reading through introductory textbooks, we see a portrait of the field as dependent variable oriented. Theories of attitude, aggression, attraction, and attribution are all theories that aim to explain the determinants of single dependent variables.

Every construct (or latent variable) in social psychology has multiple manifestations. Attitudes, as one example, is most often measured on a self-rating scale. The field has recognized for a long time that there is more to attitudes than a simple self rating (e.g., Breckler, 1984; Ostrom, 1969). People engage in a variety of approach or avoidance behaviors, they carry a variety of beliefs about the attitude object, and they experience a variety of emotional responses when encountering or thinking about the object. These implicit responses may or may not be communicated to others verbally and nonverbally. They may be brief or extended in time.

Verbal theories of attitude view these multiple manifestations as outcroppings or multiple indicators of the construct (Webb, Campbell, Schwartz, Secrest, & Grove, 1981). By doing so, theorists implicitly dismiss the importance of understanding the underlying dynamics of these multifaceted phenomena. Researchers make no attempt to provide a theory of when one vs another manifestation will emerge. The third symbol system holds out hope for providing systematic theory that addresses this complexity. The paper by Stasser in this issue provides one illustration of how this can be accomplished in the area of group decision making.

The Second Complexity: Qualitative Structures

Not only have theories in social psychology been dependent variable oriented, but they have further restricted the constructs by representing the latent variable as a continuum. Attitudes fall on a pro-to-con continuum, aggression varies from low to high, and attributions go from situational

to dispositional. The objective of these theories is to discover the forces that move a person from one point to another on the dimension.

There is more to social behavior than just locating it as a point on a continuum. As I have argued elsewhere (Devine & Ostrom, in press; Ostrom, 1981a; 1981b; 1987; in press), the dimensional approach overlooks many important qualitative phenomena. Only recently have qualitative cognitive structures become a focus of research in social psychology. Researchers in the area of person perception are moving away from their previous preoccupation with impression ratings (on a scale of favorable to unfavorable) and trait ratings. They have now begun to look at the determinants and consequences of such qualitative structures as scripts, linear orders, hierarchies, images, and story representations. Smith's paper in this issue of the journal illustrates how simulations can provide a powerful symbol system for representing the processes of information storage and access in terms of qualitative feature arrays.

Qualitative structures are also important in the study of group processes. The emergence of roles and dominance structures, the patterning of formal and informal communication actions and the sequencing of communication content (as with the Bales categories) are all central to the understanding of social aggregates. In both the group and cognitive realms, verbal theories descriptively acknowledge the importance of these phenomena, but they have proven inadequate to illuminate the dynamics through which these qualitative structures come into existence and are subsequently modified. Artificial intelligence programming languages, such as LISP, provide an excellent symbol system for the theoretical representation of such structures.

The Third Complexity: Modeling of Response Systems

A latent variable is a construct that cannot be observed directly, but rather must be inferred on the basis of its observable manifestations. This is a basic tenet of the multiple indicator approach (Cook & Campbell, 1984). The third complexity pertains to the manner in which a latent variable is related to its observable variables.

Most theorists in social psychology link the construct to its observables by assuming a simple monotonic relation between the two. As aggressive tendencies, incentives, or motivations increase (in the form of a latent variable), the likelihood of engaging in an aggressive behavior will increase. These theories are generally silent on the processes that mediate the actual behavioral enactments. Asserting a monotonic relationship may describe the form of the function, but does nothing to explain the underlying processes.

This theoretical arena may best be addressed through modeling of qualitative structures. For understanding the initiation of deliberate aggressive acts, for example, it is necessary to know (1) what leads people

to generate particular action alternatives and (2) how people select among them. These in turn require an understanding of how people sample their situated repertoire of actions, how they assess the meaning and implications of each alternative, and how they match the features of each alternative against their current interaction goals.

Social psychological theory has also been weak in the area of linguistic communication. This is a crucial response system to understand; social behavior is dominated by people talking to one another. Yet we know very little about how thoughts, feelings, and plans get conveyed to other people. A related concern is nonverbal behavior. What leads people to smile and scowl, wink and touch, and gaze longingly and embrace?

Computer simulation provides a symbol system adept at formally representing these kinds of processes. A great deal of work in artificial intelligence has already been devoted to understanding natural language processing and pragmatics in linguistics. In terms of better understanding nonverbal behavior, theorists could benefit from drawing upon current work in robotics. This is a field where workers are trying to model the relation between motor systems (which in nonverbal behavior would include facial expressions, eye contact, and posture) and control systems.

Many overt displays reflect affective processes. Aggressive action, for example, may be produced by feelings of anger or fear. Some workers in social psychology appear to think that just because a computer is made up of cold steel and plastic, of impersonal chips and wires, that computer simulations are unable to model affective and motivational processes. But this is completely untrue. Any theory of emotional dynamics that can be articulated in a verbal form, can also be expressed through the third symbol system. In fact, issues surrounding the simulation of motivation and affect have long been addressed by artificial intelligence researchers (e.g., Loehlin, 1963; Simon, 1967).

The Fourth Complexity: Interfacing of Multiple Systems

As mentioned previously, verbal theories in social psychology focus on single dependent variables. Introductory textbooks decompose the person into multiple independent compartments, each containing its own latent variable. We have, for example, theories of attitude, theories of self, theories of altruism, theories of coalition formation, theories of attribution, theories of mood, and theories of aggression. Rarely are attempts made to examine the interdependencies among two or more of the latent variables.

Nowhere in this picture do we see the whole person. Yet in almost any social encounter the person collectively activates many of these systems. They are not isolated from one another as the person interacts with other people. These latent variables act in unison to characterize the whole person. An insult may lead to attitude change, to altruistic or

aggressive actions, to inferences and attributions, to a change in mood, to a revision of self perception, and to the dissolution of coalitions.

There is no question that social psychology has advanced understanding of social behavior through this strategy of balkanizing the whole person and applying theories of the first symbol system to understand each latent variable in isolation. But verbal theories have provided very little leverage in understanding how each construct interfaces with other latent variables.

Verbal theories, for example, have been used in research on how attitude affects behavior (e.g., Fazio & Zanna, 1981) and how behavior (via cognitive dissonance) affects attitudes (e.g., Aronson, 1969). Yet little is known about the mutual interdependence between attitudes and behavior (or between attitudes and cognitive dissonance). Given that an attitude has led to a behavior, under what conditions will that behavior alter the initiating attitude?

The best answer that current theories offer to this kind of question is a concatenation of independent processes. That is, one set of principles apply going from attitude to behavior and another set apply when going from behavior to attitude. Each set of principles is regarded as being independent of the other set.

There indeed may be some pairs of latent variables where simple concatenation occurs. But this answer requires that the processes operate in sequence rather than in parallel, a requirement that cannot be met for all pairs of latent variables studied in social psychology. For example, variables like mood and attributional inference appear to coexist as parallel, yet interdependent, processes during social encounters. This would seem to necessitate the development of nonconcatenated theories of on-line interdependence.

The "concatenation of processes" answer is also inadequate when we consider the case of three or more latent variables. If the variables are sequentially activated, the order of activation will necessarily be important in knowing how each is affected by the preceding ones. The theorist is also required to establish priorities as to which contingencies take precedence when any two or more come into conflict. These types of issues are at the heart of understanding the whole person as an integrated system. This means that it is necessary to supplement existing theories (which deal with how one variable affects a second) with theory regarding the determinants of order of activation.

Computer simulations are well suited for specifying multiple interdependencies. These if-then contingencies could easily number into the hundreds when combining three or more latent variables, a number far too great for the theorist to keep track of when asked to generate predictions. But with theory-as-program, predictions can be easily and accurately obtained by running the program on a computer. As example

of interfacing systems, the paper by Hastie in this issue of the journal offers a model of the interdependence between judgment and recall.

The Fifth Complexity: Time

Social behavior is extensive over time. The course of all social interaction involves continuous action (at both the psychological and overt levels) on the part of all participants. That is, latent variables are continuously operating for each person and observable manifestations of one or more of these psychological systems are always present. Psychological systems cannot be turned off.

People closely monitor how others react to them. The behavior of the other interaction participants offers a guide to how one's own behavior is being interpreted. These feedback cues are also extensive over time and can be continuously observed for purposes of adjusting and fine tuning our on-line actions.

Research practices in social psychology lead us to develop theories that need only to explain the determinants of one step stimulus-response sequences. That is, experiments commonly manipulate an independent variable and assess its consequences on a single dependent variable. Resulting theories need not have anything to say about the interaction history that preceded the manipulation nor anything to say about responses subsequent to the dependent variable.

Ultimately, theory in social psychology will need to deal effectively with how people make use of this continuous social feedback in guiding their own actions. More formal and elaborated treatment is needed to fully understand the kinds of feedback and control processes described, for example, by Carver and Scheier (1982). This requires a theory of attentional shifts from one part of the stimulus field to another. It requires theory of the effects of such feedback on each separate latent variable. It requires theory regarding how each of the manifestations of a particular variable are affected. And it requires theory of how the principles of interfacing between the several systems may be affected by feedback. Time is the carrier of the other four complexities.

As we combine all five complexities, it can be seen that the ultimate task of the theorist in social psychology is overwhelming. Verbal theories can observe and categorize these complexities, but they are at a loss in providing a workable model of how they may operate in detail. Verbal theories can (and should) be used to articulate small conceptual modules. These modules will encompass manageable sets of theoretical propositions reflecting one or more of the five complexities. The modules are manageable in the sense that the theorist can hold all the variables and relationships in mind, and be able to accurately generate predictions.

Computer simulations come into play when the theorist wants to combine these manageable modules into a larger scale model of social behavior.

When several modules are combined, and the relations among them are conceptually specified, the theorist encounters two serious problems. One is to know whether all necessary theoretical decisions have been addressed. If some intermodule relationships have been inadvertently omitted, the theorists of the first symbol system may never discover it. Second, as more modules are combined into a more comprehensive model, the verbal theorist finds it increasingly impossible to know what the theory predicts.

These problems with verbal theories are solvable by using the third symbol system. By stating the modules and their interconnections in the form of a program, key theoretical omissions will lead the program to crash. The theorist knows then that more conceptual work is needed. Once the model is complete, a computer can be used to quickly and reliably derive the model's predictions, regardless of its level of complexity.

THE FADING SOURCES OF PREJUDICE AGAINST SIMULATION

For many in social psychology, computer simulations represent an alien and perhaps even aberrant approach to theory construction. It is an approach that has been avoided, and sometimes even castigated, by established theorists in the field. But there are several reasons to believe this prejudice is changing.

Part of the negative feelings derive from the fact that specialized knowledge is required to implement a simulation. The theorist must be facile with computer programming. Since most of the senior people currently in the field did not receive training in programming simulations during their formal education, they naturally find these skills to be somewhat arcane. This should be much less of an impediment for young scholars currently entering the field.

A second source of resistance has been the absence of recognized examples of theory advancement through the use of simulation. Even though Abelson (1968) reviewed simulations that dealt with several fundamental topics in social psychology, these models were almost completely neglected by mainstream theorists. They were seen more as a curiosity than as a substantial contribution to understanding. The papers in this issue of the journal show that computer simulation is finally coming out of the social psychological closet. Scattered papers have also appeared in recent years in such key journals as the *Journal of Personality and Social Psychology* and *Social Cognition*.

A related source of resistance is the lack of role models. Theory is done by theorists, and new people entering the field look to the careers and intellectual styles of established theorists for guidance. The strongest influence of senior scholars is on the graduate students who work with them and take courses from them. From the time of Hovland's and Abelson's papers to the present, there has been less than a handful of

such role models active in the field. That number has more than doubled in the last 5 years and should continue to increase rapidly in the future.

There is a particularly pernicious stereotype among social psychologists that is sometimes offered as a justification for rejecting simulations as a valid avenue for theory construction. This stereotype is all the more deadly because it is often advanced by persons who appear to hold a positive attitude toward the use of simulations. These persons correctly note that simulations have proven most successful in cognitive psychology, and have helped to illuminate our understanding of processes underlying such topics as recall, attention, and visual perception.

The critics conclude from these successes that computer simulation is most appropriate for problems of cognitive psychology. They note that these successful problem areas all deal with "cold cognition" and that most of these simulations attempt to account for findings obtained in controlled laboratory tasks. In contrast, the problems of social psychology are not so neat. Our theories must ultimately include an understanding of affective and motivational processes, and they must deal with the complexities inherent in interactions over time between two or more persons. The stereotype argues, then, that the problems of social psychology are just too complex to yield to antiseptic and sterile simulations.

This stereotype could not be more wrong. In fact, just the opposite is true. Simulations are not needed when theorizing about simple and uncomplicated processes. Verbally expressed theories and mathematically expressed formulations are fully adequate to this task. In fact, in the early stages of developing a theoretical module, verbal theories may prove superior to simulations. The inherent ambiguity of natural language provides a richness and flexibility that allows the theorist to mentally explore a vast array of possibilities. For example, premature simulation of dissonance theory could well have interfered with discovering the "nonobvious" implications of the model.

Simulations should only be undertaken when the complexity of the theoretical processes exceed the ability of the theorist to hold all relevant postulates in mind and to accurately generate predictions. The computer program becomes the mode through which the theoretical ideas are expressed and the computer is the device that enables the theorist to generate the model's predictions. As this view of computer simulation becomes more widely accepted, its use in theory construction should increase and the field's ability to address truly complex phenomena will advance dramatically.

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