2 Modeling Cognitive Processes

Mildred L. G. Shaw and
James C. Mancuso

CONSTRUCTIVIST PARADIGM AND COGNITIVE SCIENCE

The constructivist paradigm that underlies personal construct psychology is an alternative to the positivistic, behavioristic approaches that have rested on mechanistic paradigms. Although mechanistic paradigms have been difficult to dislodge from the favored position they have held in the behavioral sciences, scholars have steadily moved toward constructivist approaches. It is not a surprise that a new metaphor, the computational model, has carried forward the constructivist metaphors. The development of computer-based modeling systems has allowed the operationalization of constructivist formulations. Work in artificial intelligence, the emulation of high-level human capabilities on the computer, has led to representations of systems that model human performance. Parallel to this, the acceleration of the development of cognitive science follows from the use of such computer-based emulations of human performance to provide a model of human functioning.

Whereas strict behaviorism legitimated only models of human functioning that could be inferred from human behavior, cognitive science legitimates mental models whose functioning parallels that of

people, but whose processing structures cannot necessarily be inferred from observable output (Gentner and Stevens 1983). Such models are possible inferences from human behavior in that they are consistent with it, rather than necessary inferences in that they are strictly derivable from it. The influences of positivism and early computer technology are evident in the information-processing models of the first accounts of cognitive science (Lindsay and Norman 1977). However, in recent years the role of a wider variety of mental processes has been realized, and the models are being extended to account for such phenomena as emotions and consciousness (Norman 1980).

Parallel to this legitimation of mentalistic concepts through developments in artificial intelligence and computer modeling, one observes an increased acceptance of such concepts as those expressed in studies of the social construction of self and others (Gergen and Davis 1985) and in personal construct psychology. In particular, Kelly's (1955) construct of anticipatory construction (p. 46), which stands in his theory as the fundamental dynamic of human functioning, resonates with the cognitive science emphasis on the key role of planning and of hierarchical goal structures (Anderson 1983: 33). In effect then, personal construct theory and cognitive science share a heavy reliance on the concept of anticipation as a constructive process that underlies all human activity. With this reliance comes an ancillary dependence on the concept of a schema, which designates an inner representation of events that is constructed through the use of organized cognitive systems. This concept was first put forward by Head in 1920, and has had a long history in psychological science (Bartlett 1932; Kant 1934; Vernon 1955; Bruner, Goodnow, and Austin 1956; Neisser 1967), but it assumes new significance with the legitimation of mental models.

Bartlett (1932: 201) developed the idea of a schema in his widely cited work on remembering. He defined schema as follows:

> "Schema" refers to an active organization of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response. That is, whenever there is any order or regularity of behavior, a particular response is possible only because it is related to other similar responses which have been serially organized, yet which operate, not simply as individual members coming after one another, but as a unitary mass.

Bartlett further suggested that there is a gradual buildup of such cognitive structures which are nonspecific, but organized, classifications

of many events. These events are linked by a classification schema that he described as "effort after meaning," that is, the perception or construction of similarity in the events themselves. It seems that it is anticipation that determines the meaning of an event, and that one construes an event as being the same or different from the anticipated schema.

Piaget emphasizes the dynamic nature of schemata by stating that a person constructs events in his or her world by assimilating schemata, while accommodating these schemata to input-associated constraints (Flavell 1963). Neisser (1967, 1976) similarly suggests that a person forms cognitive structures that are the result of the constructive processes involved, and emphasizes their anticipatory role: "At each moment the perceiver is constructing anticipations of certain kinds of information, that enable him to accept it as it becomes available" (1976: 20).

Osgood, Suci, and Tannenbaum (1957) introduce the social aspect of schemata by noting that while each person has a unique system of dimensions that are used to perceive and judge the environment, some of these are common to large segments of people who share a common culture.

The underlying theme of all these approaches is that an individual uses a system of organization together with interrelationships between components in the system, which, by interacting with the structure, produce interdependencies. Kelly's (1955) personal construct psychology provides a systematic, comprehensive framework for this kind of cognitive psychology. In particular, Kelly suggests that if the person becomes aware of the structure and of the organization within the structure, he or she becomes more able to make adequate predictions and to act according to those anticipations. Kelly (1955) explains construing as a process of abstraction: "We look at the undifferentiated stream of circumstance flowing past us, and we try to find something about it that repeats itself. Once we have abstracted that property, we have a basis for slicing off chunks of time and reality and holding them up for inspection one at a time . . . this is done by construing" (p. 120).

He also describes the relation between construing and anticipation of events: "When one abstracts replicated properties in the events he has already experienced, it becomes possible for him to chart events to come in terms of these same properties. . . . What one predicts is not a fully fleshed-out event, but simply the common intersect of a set of properties. If an event comes along in which all the properties intersect in the prescribed way, one identifies it as the event he expected" (p. 121).

Kelly proposes that each person constructs his own version of reality using a hierarchical system of personal constructs. These processes, to him, constitute a personality — the ways in which each person constructs his or her view of reality and lives within it. In the context of a person learning from experience, the theory describes the ways in which one can negotiate a viable position in his or her own reality, review it, revise it, and refine it within his or her own world.

PERSONAL CONSTRUCT PSYCHOLOGY AS A THEORY OF THE PERSON

Kelly expresses personal construct psychology as a postulate and eleven corollaries. The Fundamental Postulate states that "a person's processes are psychologically channelized by the ways in which he anticipates events" (p. 46). It has been noted:

> Kelly was careful in wording the central statement of this theory to surmount or avoid three of the most persistently knotty problems in psychology — namely, why people do anything at all; why over a period of time, or at any choice point, they do certain things rather than others; and how people who are so obviously different in so many ways can yet be compared within some consistent conceptual framework. (Bannister and Mair 1968: 10)

The anticipatory emphasis of personal construct psychology is inherent in Kelly's approach:

> According to his Fundamental Postulate, all of our representation, including the represented action elements, are anticipatory. Human action, from the standpoint of Kelly's theory, flows from an intention to bring about a correspondence between a person's constructions of the future and his mental representations (personal constructions) of information-producing events. (Mancuso and Adams-Webber 1982b: 8)

ORGANIZATION AND DYNAMICS OF CONSTRUCTS

Kelly (1955) states the corollaries as necessary extensions of the foregoing proposition. They are attempts to expand the theory in a strict formulation, and hence they may appear to be of different types and levels. The Construction Corollary states that "a person anticipates events by construing their replications" (p. 46). In construing or placing an interpretation on events, the individual places into categories those which he/she determines to be similar to and different from others, building up a

set of constructs which enable him/her to pick out recurring patterns that he/she can then use to anticipate and predict. It is this tendency which makes an adequate model an essential part of success in any field. One does not always build a new model when faced with new events, but anticipates on the basis of the models which he or she has already developed.

Kelly states his Individuality Corollary as follows: "Persons differ from each other in their constructions of events" (p. 55). This corollary expresses Kelly's stress on the personal nature of construing, but he emphasizes also that "persons can find common ground through construing the experiences of their neighbors along with their own" (p. 56), although "individuals can be found living out their existence next door to each other but in altogether different subjective worlds" (p. 56). He suggests that to obtain the best explanation of a person's organization of experience or behavior, one should find ways to inquire of the person who does the organizing.

The Organization Corollary states that "each person characteristically evolves, for his convenience of anticipating events, a construction system embracing ordinal relationships between constructs" (p. 56). Kelly recognized that "different constructs sometimes lead to incompatible predictions" (p. 56), and he saw a hierarchical relationship that ordered constructs relative to one another as a basis for explaining such contradictions. He conceptualized hierarchic functioning as a process in which the stability of the upper levels allowed for change in the lower ones, so that the arrangement of constructs in a particular hierarchy would be more a determinant of personality than are the constructs themselves.

On stating the Dichotomy Corollary, Kelly proposed that "a person's construction system is composed of a finite number of dichotomous constructs" (p. 59). Kelly saw concepts of similarity and contrast between elements forming the two "poles" of a construct. This does not necessarily involve a binary evaluation of elements; a person can locate an element somewhere between the poles of a construct.

On what basis would a human psychological system process an event in terms of one construction rather than another? To answer this quasi-motivational question, Kelly included a Choice Corollary in his theory: "A person chooses for himself that alternative in a dichotomized construct through which he anticipates the greater possibility for extension and definition of his system" (p. 64). To explicate the system's functions one must keep in mind that constructs are dichotomous, and that they are

hierarchically organized. A person locates an event at one or another end of a hierarchically interconnected construct in ways that will maintain the greatest anticipatory power of which the system is capable. To contrast his contextualist motivational position with that of the mechanists Kelly explained that "there is a continuing movement toward the anticipation of events, rather than a series of barters for temporal satisfactions" (p. 68).

Correlatively, not every construct can allow convenient anticipation of every event. Convenience in psychological processes refers to the extent of revision and alteration of the hierarchical structure that would be occasioned by fitting one or another event into one or another pole of a particular construct. The necessary constraints on haphazard, immediate construing is expressed in the theory's Range Corollary: "A construct is convenient for the anticipation of a finite range of events only" (p. 68). This may be thought of as introducing a concept of relevance into the definition of construct systems.

Each of a person's attempted anticipatory constructions represents a hypothesis to be tested not only for its convenience in anticipation, but also for its extending and defining capabilities. Such continual experience leaves a residue of change in the person's system; to formalize his view that the resulting accommodations of the system constitute learning, Kelly stated an Experience Corollary: "A person's construction system varies as he successively construes the replications of events" (p. 77). In a way, the Modulation Corollary takes into account the metaphorizing character of a person's constructs. Novel inputs to the system will be anticipated and will change the system if the system can access permeable constructs, that is, constructs that are "so constituted that new experience and new events can be discriminatively added to those which it already embraces" (p. 81).

The theory's Fragmentation Corollary states that "a person may successively employ a variety of construction subsystems which are inferentially incompatible with each other" (p. 83). Through this corollary Kelly allows for the operations of different psychological systems and hence different methods of inference and forms of rationality within a single individual.

Kelly completed his system of formal propositions by giving two corollaries that relate construing processes to social interaction events. Another person's constructions of events, as well as the events themselves, provide input relative to those events, and, thereby, become a part of the experience of those events. A personal construct theorist must consider that "to the extent that one person embraces a construction

of experience which is similar to that employed by another, his psychological processes are similar to those of the other person" (the Commonality Corollary, p. 90). This corollary complements the Individuality Corollary and allows for the "fact that certain groups of people behave in certain respects" (p. 93).

The Sociality Corollary states that "to the extent that one person construes the construction processes of another, he may play a role in a social process involving the other person" (p. 95). Kelly here acknowledges that the construal processes of one person can become elements for construal by another and hence can model the process by which we anticipate the actions of others.

CONSTRUCTIVISM AND CONSTRUCTIVE ALTERNATIVISM

In light of the difficulties in which personality theorists still become ensnared when they take up issues related to reality, or subjectivity, or objectivism, one could easily agree that Kelly's most radical departure from standard theorizing is reflected in his stance on the issue of constructive alternativism. Maddi (1984) very cogently disassembles Fiske's (1977) suggestion that small concrete data units are more real, and that objectivity is to be found in avoiding interpretation or abstraction. He neatly counters Fiske's effort to promote objectivity with the observation, "While there may be an immutable thingness out there, we have only our perceptual systems with which to apprehend it" (p. 18). But nowhere in his prescription for a personology for the 1980s does Maddi advocate, as did Kelly, that the behavioral scientist approach his target of study from that same ontological position. Maddi, as a representative mid-twentieth century scientist, seems unable to acknowledge that individual persons, like individual scientists, cannot render "objective" statements about the universe of events, and he seems unable to grasp the radical significance of Kelly's emphatic assumption that "all of our present interpretations of the universe are subject to revision or replacement" (p. 15).

Although Kelly specified his conclusion that "the universe is really existing and that man is gradually coming to understand it" (p. 6), he also was astute enough to avoid equating reality with "immutable thingness." He notes specifically that "within our universe something is always going on. In fact, that is the way the universe exists; it exists by happening" (p. 7). To come gradually to understand the universe, for both the scientist

and the target of the scientist's work, is to come gradually to construct a system of understanding the processes of a "happening world." As personologists who adopt constructivism, and as construing persons (Mancuso and Adams-Webber 1982a), we take it as a given that we create the shared and the private meanings of events. A personal construct theorist cannot have the construct objectivity–subjectivity as a core construct because "it is fundamental to the constructivist's view that the environment can never be directly known but that conception determines perception. We know reality only by acting upon it. . . . The active interaction between the individual and the environment is mediated by the cognitive structures of the individual" (Nystedt and Magnusson 1982: 34). Or as Kelly (1955) said, "No one needs to paint himself into a corner; no one needs to be completely hemmed in by circumstances; no one needs to be a victim of his biography" (p. 15).

PROBING THE CONSTRUCT SYSTEM — REPERTORY GRIDS

Each person may be seen as a personal scientist (Shaw 1980), classifying, categorizing and theorizing about his/her world, anticipating on the basis of his/her theories, and acting on the basis of his/her anticipation. The personal scientist models his/her world, using his/her theory or model to make predictions or to act in the world, and experiencing events that may or may not be influenced by his/her actions. This experience of events is then fitted to the model, which may be reviewed or revised in light of experience to make more "successful" predictions.

> A theory is a device to enable man to deal comprehensively with what might otherwise be an overwhelming variety of events. . . . Strictly speaking, man invents his theory; he never discovers it. . . . The process by which a theory is derived is known as abstraction, and the complementary process by which it is extended to events is known as generalization. Both may properly be regarded as psychological processes, or even as aspects of the same psychological process. . . . Thus meaning is not extracted from nature, but projected by man upon it. (Kelly 1965: 289, 290)

THE REPERTORY GRID AS A REPRESENTATION OF PERSONAL MODELS

Kelly suggested the technique of the repertory grid to represent the repertoire of constructions that the individual has acquired from his or her

personal observations of the world. A repertory grid or "construction matrix" is essentially a two-way classification of data in which events and abstractions, or constructs, are interlaced. In his own terms, "it expresses one's own finite system of cross-references between the personal observations he has made and the personal constructs he has erected" (Kelly 1965: 291).

The personal observations are known as elements. Elements were originally constituted from the role titles of significant people in the life of the particular individual. The personal constructs are bipolar dimensions that group the elements into varying clusters according to their similarities and differences within the individual's frames of reference. Kelly used the repertory grid as a tool to assist with psychotherapy, using significant others as elements. Since its introduction, it has been used in many settings to probe the construct systems of psychiatric patients, student teachers, effective managers, knitwear inspectors, and rivet selectors in the aircraft industry. The elements may be people, things, events, or experiences, which are related to the particular problem or purpose for using the grid.

PRECOMPUTER ELICITATION TECHNIQUES

Constructs may be elicited by many means, the most common being the minimal context form or triadic method (i.e., "Can you say in what way two of these elements are alike, and in the same way different from the third?"), and the full context form ("Considering the whole set of elements, think of an important way they divide into two [or more] groups"). Other methods derived from these are splitting the two most similar elements to put one on each pole of a new construct, and naming of a construct to describe the difference between the two most dissimilar elements.

Another useful form of construct elicitation is a technique developed by Hinkle (1965) called *laddering*. Initially, constructs are elicited by a standard method, then one construct is selected and the question asked, "Which pole is the one you would prefer to be rated on?" then "Why would you prefer that pole?" and "What is the opposite of that?" This then provides a new construct that is more superordinate or generalized than the original one. As this process is repeated, a hierarchy or heterarchy of superordinate constructs is elicited.

THE ROLE AND SIGNIFICANCE OF COMPUTERS

During the past 20 years, the digital computer has come to assume a role of increasing importance in psychology and in the application of psychological techniques. During this period also, the nature of available computer resources has itself changed dramatically. In the early 1960s we submitted massive computations of variance and factor analyses to some remote computing center that punched our data onto cards and sent back the results, often days later. By the early 1970s we had our own minicomputers in our laboratories giving a hands-on system for direct experimental control, but they were so expensive that they were available only as a shared resource to a group of researchers on a booking basis. The central computers also changed during that period, to allow some form of interactive time-sharing whereby we could enter our own data on a local terminal and receive the analysis back reasonably rapidly on the same terminal. In the last few years, a further development has taken place in that so-called personal computers have become available, offering us great power and a wide range of facilities at such a low cost that an individual can have one or more such machines dedicated to his or her work.

These advances in computer technology have offered opportunities for the automation of psychological testing, which have been widely taken advantage of (Elithorn and Telford 1969; Gedye and Miller 1969; Elwood 1972a, 1972b, 1972c; Klinge and Rodziewicz 1976; Thompson and Wilson 1982; Volans and Levy 1982). Direct interaction between patients and computers has now been shown to be successful and acceptable in an experimental environment (Card et al. 1974; Lucas 1977), and it has even proved possible for the computer to act as an effective therapist (Stodolsky 1970). Automated psychological testing has also been widely validated against experts administering the same test (Ridgway, MacCulloch, and Mills 1982; Calvert and Waterfall 1982; Watts, Baddeley, and Williams 1982; Acker 1982). These advances in technology have also offered the opportunity for new approaches to the testing process that are dependent on having powerful computational facilities in operation during the test. In particular, it has become possible to obtain test results speedily and in a manner that aids both expert interpretation and self-interpretation.

Many researchers have developed computer techniques for the elicitation and analysis of personal construct psychological data, some of which are reported in the following chapters. Many of these are

interactive programs that allow a greater degree of autonomy and more control to be given to the user. It would be easy to assume that such interactive programs are merely more convenient ways of eliciting construct systems through extensions of Kelly's repertory grid and do not themselves add anything qualitatively new to the process. However, such an assumption would be missing certain crucial psychological factors in the person–computer situation and its differences from the person–person situation. For example, we have observed informally, in making the grid elicitation program PEGASUS (see Chapter 3) available to a wide range of people in a variety of situations, that those coming to it for the first time often seem to find it a very dramatic experience. They react to it intensely and become gripped by the interactive process of construct elicitation. They also feel that they are learning something new from the process and are prepared to use this in determining their behavior.

Probably such involvement is also significant in the elicitation of construct systems by a person rather than by computer interaction. However, we believe there are certain quite fundamental differences when the elicitation is done in such a way that interpersonal interaction is clearly absent. In particular, when a person is feeding back comments and guidance, it is a natural and ready assumption that the constructs are being injected rather than elicited. It is easy for the subject to believe that the elicited constructs do not come from him/herself, but that a tutorial or debating situation with another person is taking place. It is necessary to persuade him/her that this is not so, and the persuasion has to be stronger the more striking and significant the constructs elicited. However, when a computer is the tool by which his/her construct structure is being reflected or laid bare, then such an assumption of outside injection and interference is far less tenable.

When constructs are being elicited by a computer program, then it is more likely to be accepted that it is precisely and only oneself that is being portrayed. We trust a computer program to be doing just what it appears to be doing without deeper motivations and without attempting to persuade us to its point of view. No one is telling the user anything. One is seeing, in interacting with PEGASUS, possibly for the first time, the basis for one's own thought processes. Very often extreme surprise is the first reaction. If another person were eliciting the construct structure, then the surprise would be taken as an indication that he or she was incorrect, and one would ignore or argue with him/her. With computer elicitation, it is more likely that one will accept the reflected

structures as self-generated, and the surprise will act as a motivation to know more.

That this knowledge can be totally private is another important feature of interaction with the computer. We do not like to be caught, as Kelly put it, with our constructs down. When another person is involved, we are more reluctant to expose and explore our constructs the more surprising they are, perhaps because the surprise is often the result of a conflict between our ostensive value judgments and the basis of our behavior. Or it may just be sloppy verbal behavior that we are naming two distinct constructs with the same label. For example, in using PEGASUS, a scientist found that he was using the word *time* to label several different elements and was generating confusion in his arguments because of this.

Another reason that we are reluctant to explore construct structures freely in interacting with another person, particularly a professional, is that we are acutely aware of the possible waste of their time. This phenomenon has been noted (Card et al. 1974) as a major reason for the preference expressed by patients to be interviewed through an interactive computer program rather than by their doctors. There are many pressures and artifacts of interpersonal relationships that can totally obscure and undermine such reflective processes that we require in the elicitation of personal constructs.

It is interesting to note that this argument has been put in reverse. Adams (1979) notes that children learn quickly to play games on a personal computer and conjectures that this is because of the lack of interpersonal complications. She suggests, however, that "one of the benefits of game-playing is that a child learns how to behave with and towards others, how to cope with success and failure, and what effect it has on others. In the human–computer relationship the child does not learn these valuable social skills" (p. 29). We are arguing conversely that the need to deploy such "social skills" is a burden that can seriously detract from the exploration of the self.

SIGNIFICANT APPLICATION AREAS

These cognitive modeling techniques have been used widely in many areas of work. The ones covered in this book are clinical psychology, education, management, and computer science. Commenting on clinical psychology, Shepherd and Watson (1982) state, "Personal meanings arise from events and relationships which a person interprets within his

most basic frame of reference — his awareness of being an individual, conscious of personal agency and personal biography" (p. 1). Fransella (1982) explains, "To construe is to impose meaning or interpretations upon something or some things" (p. 47). Many clinical psychologists have used personal construct psychology to explore a patient's personal meaning system, and to make explicit the implicitly held models of the world that lead to behavior, that is, prediction or action.

In education and learning, many groups are using personal construct psychology techniques. Phillips (1981) has studied the development of research skills and the styles of supervision of doctoral students. She elicited information from the viewpoint of the students at stages during the progress of their research over three or four years, and from the viewpoint of their supervisors. Valuable insights were acquired by both parties about this process, and some interesting results were obtained. Pope and Shaw (1981) and Pope and Keen (1981) have related personal construct psychology to various philosophies or ideologies of education mainly as they applied to school learning, and they extended this to areas of educational research and to some of the current issues in education.

Personal construct psychology has been found to apply equally well in helping an expert articulate her skill, as it has been in more traditional uses, such as in helping a person referred for psychotherapy to articulate her problems, or a student her needs for learning. The initial success of expert system developments (Michie 1979; Gevarter 1983; Reitman 1984) and the development of a number of reasonably domain-independent software support systems for the encoding and application of knowledge (Hayes-Roth, Waterman, and Lenat 1983) has opened up the possibility of widespread usage of expert systems. In particular, the Japanese Fifth Generation Computing System development program (Moto-oka 1982; Gaines 1984) assumes this will happen and is concerned with knowledge processing rather than information processing. However, what Feigenbaum (1980) terms *knowledge engineering* (the reduction of a large body of knowledge to a precise set of facts and rules) has already become a major bottleneck impeding the application of expert systems in new domains. We need to understand more about the nature of expertise in itself (Hawkins 1983) and to be able to apply this knowledge to the elicitation of expertise in specific domains.

Shaw (1983) and Boose (1984) have used personal construct psychology techniques to elicit and structure expert knowledge, and to analyze and refine this knowledge into production rules. (An example of a production rule so obtained is: If a database is inverted, then it will not

run on a Vax computer.) These rules can then be assembled into an expert system building tool or shell for immediate refinement and debugging. Boose (1985a) has developed over 200 expert systems, using personal construct psychology as a base.

PERSONAL CONSTRUCT PSYCHOLOGY IN THE ERA OF MENTAL MODELS AND THE PERSONAL COMPUTER

These are exciting times for psychologists. The constructivist paradigm, the development of cognitive science, the legitimation of mental models, and the availability of the personal computer together offer the vehicles to explore new territories. The remaining chapters in this book are by those who have constructed those vehicles and have begun to use them. All those who have participated in generating this book hope that the wider dissemination of these tools, techniques, and experience will encourage others to join in the exploration. Many different disciplines of psychology have much to gain from the constructivist paradigm and its operationalization through the personal computer. The following chapters should promote this symbiotic relationship.