Structural Approach to Empirical Testing: A Contrast with Normative Methods in Cognitive Psychology†

JOSEPH M. SCANDURA
University of Pennsylvania, U.S.A.

One of the fundamental assumptions underlying cognitive psychology is the belief that complex human behavior can only be understood in a normative—or average sense. Structural learning theories adopt a different view. Among other things, they ask what human behavior would be like under idealized conditions—such questions as how a person would behave: (a) if he really understood and wanted to solve a given problem, (b) if he knew and had available certain relevant items of knowledge (e.g. rules) and only that knowledge, and (c) if he had an unlimited processing capacity. Specifically, theory construction and empirical testing in structural learning is a generalization of the classical approach (e.g. in physics). In the former case, idealized theories are complemented with observation theories that take into account deviations from idealized conditions. Idealized theories, complemented with observation theories, may be tested against real data as in the standard psychological approach. The major difference is that a sharp conceptual distinction is maintained between structural factors, associated with the idealized theory, and incidental factors, associated with deviations from idealized conditions. Making such a distinction between structural and incidental factors in behavioral theorizing/testing is shown to have several major advantages.

In spite of the paradigm shift toward cognition, theories of complex human behavior still tend to be highly restrictive. The scientific literature is replete with theories of reading comprehension, theories of memory (of both the permanent and working varieties), and specialized problem solving and other performance theories. The vast bulk of research and theory construction in behavioral science today is still very much a matter of building from the ground up—of “bricklaying.”

In contrast, my collaborators and I have worked under the assumption that content, cognition, and individual differences all play a crucial role in understanding complex human behavior—and that any complete understanding of such phenomena will require a synthesis of all three aspects.

The purpose of this short commentary is neither to summarize relevant basic theory nor to report new research data. (For these purposes, e.g., see Scandura, 1971, 1973, 1977a, 1977b†.) Rather, I shall comment on a basic

†Problem Solving: A Structural/Process Approach with Instructional Implications (Scandura, 1977b) will be subjected to open-peer commentary in Volume 6, Number 4.
issue that seems to have caused some confusion in cognitive psychology. This issue concerns the goals of the Structural Learning Theory and some of the implications of these goals for empirical testing. (For further discussion and elaboration on the views expressed below, see Scandura, 1971, 1977b, 1977c; Hilke, Kempf, and Scandura, 1977.)

One of the fundamental (yet typically implicit) assumptions underlying the practice of cognitive psychology is the belief that we can only understand complex human behavior in a normative—or average sense. No one expects our theories to explain predict the behavior of each and every subject in given situations. We are quite happy to have theories that do a good job of predicting group means and other sample statistics.

The Structural Learning Theory adopts a different view. Among other things, it asks what human behavior would be like under idealized conditions—such questions as how a person would behave: (a) if he really understood and wanted to solve a given problem, (b) if he knew and had available certain relevant items of knowledge (e.g., rules) and only that knowledge, and (c) if he had an unlimited processing capacity. Under these circumstances, the basic questions concern how subjects make use of their available knowledge. Perhaps surprisingly, there seems to be a simple and general answer in the form of a universally available goal switching control mechanism, but I will not try to convince you of this here and must refer to relevant theory and data in the literature (see Scandura, 1971, 1973, 1974, 1977b).

My experience suggests that if one identifies suitable idealized conditions, then it is often feasible to devise relatively simple yet general, precise, and operational explanations of the remaining phenomena—explanations upon which one can build with far greater confidence than is the case with the explanatory mechanisms in most cognitive theories. In any case, each such explanation (e.g., universal characteristic of the human information processor) says something about behavior but not all. Accordingly, one can conceive of a succession of partial theories, each of which says progressively more about human behavior. Each partial theory deals with the behavior of given subjects in particular situations (see Scandura, 1977b, Chapter 1).

Specific predictions of this sort may be expected to hold, however, only in situations that satisfy appropriate boundary conditions. For example, the "memory-free" (partial) theory of structural learning fully accounts for behavior only in situations where all relevant knowledge may be assumed to be readily available (cf. Scandura, 1974; 1977b, Chapter 5). This partial theory involves only the control mechanism and does not, for example, take processing capacity into account. To the extent that processing capacity is involved, theoretical predictions can be expected to deviate from obtained results. The idea is directly analogous to the situation with the inclined plane law of elementary classical physics. This law allows one, for example, to calculate the exact force needed to move a given cart up an inclined plane, but only where the inclined plane is perfectly smooth and the wheels on the cart are frictionless. Deviations from prediction may be expected just to the extent that the inclined plane is bumpy and/or that friction otherwise plays a role.

In effect, the structural theory of cognition is a "top-down" theory. Progressively more structure may be added to the theory by adding more and more (possibly universal) constraints. Thus, adding processing capacity to the "memory-free" theory, which involves only the control mechanism, makes it possible to account for behavior under a wider variety of conditions.

The possibility of adding increasingly more structure implies a particular (structural) approach to theory construction that is an essential aspect of the structural learning theory. In turn, this aspect of the theory has important implications for empirical testing.

Suppose, for example, that we have an answer to the question of how people use their available knowledge under idealized conditions. Does this say anything about actual behavior under nonidealized conditions? In fact, the answer is yes. We know the idealized conditions that must be satisfied in order for such a theory to apply. Hence, all we have to do is to consider the extent to which these conditions are not met in any given situation—say, on a 0–1 scale of probabilities. If a theory or hypothesis is valid under idealized conditions, then the theory will be valid in any given situation—just to the extent that the idealized conditions have been satisfied.

Perhaps surprisingly, this implied approach to testing is much closer to the classical approach taken in the physical sciences than it is to the standard approach in cognitive psychology. Figure 1 illustrates the classical and normative (standard psychological) approaches, with examples drawn both from elementary classical physics and from the study of problem solving. Notice in each case that the standard psychological approach to theory construction involves the specification of hypotheses relating independent and dependent variables. In the case of the inclined plane, corresponding predictions would take the form of computing expected values of functions of those independent variables that happen to be identified by the theorist. In the illustration, the function is left unspecified but the theorist is assumed to have identified the type of container and the angle of inclination as the crucial independent variables. The effects of incidental factors (error) also enter into the determination of expected values. Testing the theory (hypothesis) in this case, then, would involve varying the
NORMATIVE AND CLASSICAL APPROACHES TO THEORIZING AND EMPIRICAL TESTING

Illustration from Problem Solving

Problem: Determine whether subjects will succeed on verbal problems in arithmetic.

Illustration from Classical Physics

Problem: Determine the force required to move mass, \( m \), up the inclined plane.

NORMATIVE (STANDARD PSYCHOLOGICAL) APPROACH

Theory: Hypotheses concerning relationships between kinds of knowledge, etc. and actual problem solving performance.

Test: Provide given amounts of training on rules and randomize over all other factors (e.g., the particular problems chosen, the subjects, etc.)—because we do not know their effects.

Theory: Hypotheses concerning relationships between type of container (including but not limited to weight), angle of inclination, etc., and the required force.

\[ F = \text{Exp. Val. (} \text{Fn (} \text{container}, \theta, \text{error)} \text{)} \]

Test: Vary container (including its weight), angle of inclination \( \theta \), etc. and randomize over all other factors (e.g., the kinds of inclined planes, and masses, etc.)—because we do not know their effects.

CLASSICAL APPROACH

Theory: Hypotheses concerning relationships between various kinds of knowledge, etc. (e.g., with and without higher-order rules) and problem solving under specified simplifying (idealized) conditions (e.g., where the precise generative relationship between given knowledge and given problems is specified, the problems are understood as intended, the trained rules are in fact learned, and processing capacity is not exceeded)—because we either do not know their effects or want to obtain a more direct test of other hypotheses.

Test: Provide training on rules whose precise generative relationships to given problems are known in idealized situations where the problems are understood as intended, the trained rules are in fact learned, and processing capacity is not exceeded (i.e., where the effects of understanding, learning, and processing capacity are eliminated).

Theory: Hypotheses concerning the relationships between factors (e.g., mass and angle of inclination) and force under specified simplifying (idealized) conditions (e.g., where speed is constant and friction is eliminated) because we either do not know their effects or want to obtain a more direct test of other hypotheses.

\[ F = m \cdot \sin \theta \]

Test: Vary the mass, the angle of inclination, etc. in idealized situations where speed is held constant and friction (between the mass \( m \) and the plane) is eliminated (minimized).

FIGURE 1

container and the angle of inclination and randomizing over all other factors. We randomize over the other factors because we do not know their effects and want to ensure that they do not systematically effect the dependent variable.

Theories (hypotheses) in the classical view are concerned with relationships between independent and dependent variables as one might expect them to be in idealized situations. Ignoring gravitational constants, etc., the law governing forces involved in moving objects up an inclined plane has the well-known form, \( F = m \cdot \sin \theta \). Notice, in this case, that insuring constancy of speed and eliminating friction are directly analogous in behavioral science to ensuring that trained rules are in fact learned and that processing capacity is not exceeded.

The critical difference in this regard between elementary classical physics, and modern behavioral science, has been the apparent ease with which it has been possible to identify appropriate idealized conditions. In the case of classical physics, these conditions were almost "self-evident," so much so in fact that they seem to be glossed over in most contemporary discussions of the subject. Nonetheless, when one looks at the situation in contemporary behavioral science, at least those parts of it concerned with structural learning and behavioral regularities, the essential idealized conditions seem almost as apparent.

By way of contrast, oddly enough, the situation with respect to purportedly simpler behavior (e.g., as in learning pairs of nonsense syllables, remembering lists of digits, etc.) is considerably more complex (e.g., Scandura, 1973, Chapter 10). Could it be that the methods we routinely use in behavioral science today are largely a function of historical accident? It seems ironic indeed that "hard-nosed" behavioral scientists used physics as a guide in choosing to study simple phenomena before attempting to codify more complex behavior.

Theory construction in structural learning is a generalization of the classical approach in which idealized theories are complemented with observation theories that take into account deviations from idealized conditions (e.g., where trained rules are only learned with some probability and/or where processing capacity may be exceeded). In this view, for example, it makes sense not only to talk about how an information processor might use his available knowledge, if unencumbered by processing limitations, but also about knowledge use under realistic conditions. In the latter case, deviations from idealized conditions correspond to incidental factors.

Idealized theories, complemented with observation theories, may be tested against standard normative data as in the standard psychological approach. The major difference is that a sharp distinction is maintained...
between structural factors, associated with the idealized theory (e.g., the trained rules), and incidental factors, associated with deviations from idealized conditions (e.g., degree of learning-availability of trained rules at the time of testing, degree to which memory load may be a factor).

In the case of our inclined plane example, for instance, a structural learning type of theory might be represented by

\[ F = m \cdot \sin \theta + \text{Exp. Val. (incidental factors)} \]

This type of representation is used to emphasize the conceptual distinction between idealized and complementary theories. To the extent that the idealized theory is valid, predictions necessarily should approach those indicated by the idealized theory as deviations from the ideal (incidental factors) are diminished. To the extent that this happens, we can have confidence in the idealized theory. Notice, of course, that when there are no deviations from idealized conditions testing would be as in the classical approach.

Although this commentary is not the place to develop the ideas (this has already been done elsewhere, Scandura, 1977b, Chapters 1, 7, and 11), distinguishing between structural and incidental factors in behavioral theorizing/testing has several major advantages:

1) Thinking in terms of idealizations (i.e., separating structural factors from incidental ones) greatly simplifies the task of theory construction. In particular, once the role of a structural (fundamental) factor has been verified empirically, one can build theoretically with greater confidence than is true in the case of normative research. The former approach was used, for example, in developing The Structural Learning Theory (i.e., the class of structural learning theories; Scandura, 1971, 1973, 1977b).

2) This distinction also allows for more direct tests of theoretical hypotheses (e.g., see data in Scandura, 1977b, Chapters 5, 6, and 7). The effects of incidental factors are not averaged in with fundamental effects; they are either eliminated (in testing under idealized conditions) or manipulated independently of structural factors (in testing the latter under nonidealized conditions). As a consequence, it becomes possible to distinguish between variables that are fundamental to understanding human behavior and those that merely tend to co-vary with fundamental variables under typical (normative) test conditions. Experimentation, therefore, is more efficient than in the standard psychological approach where a variety of empirical tests are required to compensate for the possible confounding effects of incidental factors.

3) The relationship between laboratory findings and applications is much more direct. The laboratory is used to establish and test idealized theories/hypotheses, like the inclined plane law and goal-switching control, under idealized conditions. Applications, on the other hand, involve various but often specifiable deviations from the ideal. Any factor that affects individual behavior uniformly in precisely determined ways, under idealized conditions, will necessarily also affect behavior in the same way under nonidealized conditions. While deviations from the ideal may weaken such effects, they may not eliminate them. Put differently, laboratory findings may be applied with confidence in the real world without “field testing” (e.g., see Scandura, 1977b, Chapters 1 and 11).

Finally, I should emphasize that there is no one level of idealization. In the Structural Learning Theory, for example, there are any number of levels (e.g., Scandura, 1971, 1973; especially 1977b). In cognitive psychology, hypothesis theory, as developed by Levine (1975), deals with a more restricted range of phenomena but, nonetheless, has much in common with the memory-free Structural Learning Theory (cf. Scandura, 1973, Chapter 8). Indeed, even Piaget's epistemological theory is an idealization. This theory deals with the epistemic subject, and consequently divorces itself from the influence of specific knowledge. Unfortunately, to date, Genevans have not adequately specified the idealized conditions that must be satisfied in order for the theory to apply. Until this is done, the theory will remain nonoperational.†

In our laboratory, we are currently testing a reformulation of (a portion of) Piagetian theory in structural learning terms.

References


