questions as precisely how old frames beget new ones. Unless some basic mechanisms can be identified, rather than just situation-specific post hoc explanations, we have little hope of creating a public science. Perhaps more to the point, many of the above problems are not only addressed explicitly within the Structural Learning Theory but theoretical resolutions have been proposed and confirmed empirically (e.g., *Structural Learning: I. Theory and Research*. London: Gordon & Breach, 1973).

**References**


**Human Problem Solving: A Synthesis of Content, Cognition, and Individual Differences**

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Content, cognition, and individual differences in human problem solving are treated within a unified, operational theoretical framework. (1) Competence underlying given problem domains (content) is represented in terms of rule sets in which the rules are allowed to operate on other rules: relationships to formal systems and other competence theories, semantics, growing rule sets, global competence, and construction methods are discussed. (2) Human cognition and behavior in specific instances of problem solving are assumed to be governed by a simple goal switching control mechanism, associated with a fixed capacity information processor: this mechanism was shown to account for (solution) rule derivation, problem definition (subgoal formation), and rule selection (motivation) as well as memory storage and retrieval. (3) Rules of competence are shown to provide a basis for assessing individual differences in specific knowledge relative to given problem domains. In addition, relationships to simulation and experimental approaches to information processing are discussed both generally and with respect to human problem solving. Examples are cited showing how the theory may account both for experimental problem solving research and simulation protocols. It is concluded that, while the theory is compatible with contemporary information processing theories of human problem solving, and (potentially) is as precise as any, it has greater scope and parsimony.

**DISCUSSION**

Scandura: To provide some perspective for our discussion, let me briefly

mention some of my intellectual concerns as they relate to structural learning. The major results of my thesis work 15 years ago were the following: (1) Minor differences within instructional methods can have a much greater effect on the outcomes of experiments than molar differences between methods (e.g., between discovery and exposition). (2) The effectiveness of given information and individual problem solving ability depend on what the individual knows at the time.

Although this work was quite naive by present standards, I still believe the major results. Nonetheless, for a time (during the mid-1960s) I considered the more rigorous methods that experimental psychology had to offer. I suspect that most of us here would now agree that these methods leave something to be desired. They lead to the following kind of thinking—take the case of stochastic modelling. One makes assumptions about how individuals perform on certain tasks. Then, predictions are generated on the basis of those assumptions. Next, one collects data and checks out the predictions. If the theory accurately predicts means (group statistics), inferences are made about how (single) individuals do things. Well, one thing that the controversy between all-or-none and incremental learning theories taught us was that you can make opposed assumptions (about individuals) and get precisely the same predictions as far as group behavior is concerned. In short, the assumptions pertaining to individuals may or may not be related to group behavior.

Fundamental limitations of this methodology are that it does not deal with either individual differences or content within a common theoretical framework. One cannot, in my opinion, do work on cognition independently of considering individual differences, or independently of the particular content involved.

My own interests, then, have focused on developing a coherent theory that would take account of content, cognition, and individual differences. (The distinction between specific knowledge, e.g., including higher- and lower-order rules, and control mechanisms was also discussed with reference to goal switching in the Structural Learning Theory as contrasted with the production systems of Newell and Simon.)

Merrill: I would like to point out that rule-availability is not simply equivalent to the notion of control mechanisms. The latter details the order in which rules are used.

Scandura: Among other things—in the Structural Learning Theory, however, the order of rule is not fixed but is dynamically determined by goal switching control.

Shaw: One thing we should consider is how much of a control mechanism can be shoved into the rules themselves.

Kornfeld: Yes, for example, are the rules in the form of ordered or unordered statements? How are domains specified? And do the rules contain variables?

Scandura: In the Structural Learning Theory, rules are defined as triples; each consists of a domain (conditions that must be satisfied for the rule to be applied), a range (conditions the knower expects to be—what which are not necessarily—satisfied by applying the rule) and a restricted type of procedure. The procedures in rules may not generate new procedures and then (using computer terminology) "call them" during the course of applying that rule. This type of interaction is possible with unrestricted procedures of course.

In the theory, such interaction is effectively factored out of the (procedures in the) rules by the goal switching control mechanism. Why is it factored out in this way? Because in our experiments goal switching control seems to be uniformly available to essentially all of the people we have tested. It does not have to be taught. Most knowledge representable as rules, on the other hand, appears to be content and population dependent and must be learned. (I take no position here as to whether some primitive rules are "built into" the organism from birth or as a direct result of physical maturation. Something like this, however, must be assumed in any theory such as mine where the growth of new knowledge derives from existing knowledge.)

Merrill: One further question—are control structures innate?

Scandura: I take no hard line on the innateness controversy. My theory does not as yet deal with developmental factors. (Work in this direction is currently underway, with particular reference to the acquisition of concrete operations.)

Merrill: With respect to the field of educational design, maybe we should teach generalizable rules; that is, if there is a fixed hereditary development for control mechanisms, we should teach certain kinds of rules.

Scandura: My theoretical analyses indicate that a single control mechanism is sufficient to allow for the kinds of cognitive behavior we normally attribute to people. Moreover, our data shows that this mechanism is uniformly available to people generally, at least from about the age of 7.

Kopstein: My difficulty with your model is that you do not seem to distinguish the development of the theory from its empirical verification. You seem to forget to take learner-capabilities into account. You work with young children and generalize the results to all systems.
The rules are identified on the basis of observations, experimentation, and intuitions about how people in a given domain actually go about solving problems. (Since this was written, a whole new theory about how competence rules can be identified has begun to evolve under the rubric of “Structural Analysis”, which incidentally is not the same as Structured Programming.)

The important point here is that rules of competence provide a common basis (or measuring unit) for determining the specific knowledge available to individuals in the target population. Details as to how this can be done were worked out (and tested) some years ago.

Fox: In saying that we have to analyze the processes meant to control the control structure, you are putting two problems where there is only one. The first is that we have to understand the nature of standard rules that people use—they have tacit knowledge of them, in Chomsky’s sense. The second is that we also need to know how people manipulate that knowledge in a given situation. As I see it, you are trying to sell us the same problem twice.

Scandura: John, are you saying that there is no difference between processes (i.e., rules and higher-order rules) and control mechanisms?

Banerji: I think that there is a language problem here. I wish we had a common language to talk about things.

(After a brief discussion about problems of mutual intelligibility, the session adjourned for informal discussions at lunch.)

References


