Building a theory of problem solving and scientific discovery:

How big is N in N-space search?

Bruce D. Burns
(Symposium Organizer)
Institut für Psychologie
Universität Potsdam
14415 Postdam
Germany
burns@rz.uni-potsdam.de

The framework developed by Newell and Simon (1972) of problem solving as a search of a problem space, provides core concepts (e.g., representations, operators, heuristics, task analyses, etc.) that are used by many researchers studying complex tasks from the point of view of artificial intelligence, psychology, Human-Computer Interaction, and education. However, in recent years some researchers have tried to push beyond seeing tasks as search of a single problem space, and have instead suggested that many tasks can be better treated as a N-space search.

Dual-space search

The idea that there may be more than one type of problem space originated with Simon and Lea (1974), who suggested that problem solving and induction can be unified within a dual-space search framework. They suggested that problem solving was search of a single space, termed "instance space". This space consists of what is normally thought of as problem space, that is, instances of states of a problem (including the goal state). But induction required search of a qualitatively different type of space, "rule space". Search of rule space requires the formulation and testing of rules that may govern the behavior of a system. However, rule-space search is coordinated with search of instance space in that instances allow the testing of rules and provide the raw material for formulating new rules. In this way induction and problem solving, which have often been treated as different phenomena, can be unified into one framework. In fact, the same task could be treated by a solver as either a search of a single space or a dual-space. Even the classic Tower of Hanoi problem can be treated as a single-space search, find a sequence of moves leading to the goal, or a dual-space search, find a rule for transferring disks from one peg to another.

However, the idea of dual-space search received relatively little attention until Klahr and Dunbar (1988) extended it to scientific discovery with their SDDS (Scientific Discovery as Dual Search) model. For scientific discovery they conceptualized searching rule space as searching the space of hypotheses, and searching instance space as searching the space of experiments. Klahr and Dunbar found evidence that problem solvers learned more when they tested hypotheses. Vollmeyer, Burns and Holyoak (1996) found support for dual-spaces search theories by showing that the type of goals subjects have can affect learning.

N-space search

In recent years, both Klahr (Schunn & Klahr, 1995) and Dunbar have for empirical and theoretical reasons suggested that a broad range of tasks can be seen as search of more than two conceptually different spaces. Problem solving and scientific discovery may be better conceptualized as a N-space search, although the size of N is not clear and may not be fixed. Vollmeyer and Burns (1995) have presented evidence from protocols for a three-space search. Critics of the N-space framework have also emerged. Wolf, Beskin and Dietrich (1995) have argued that there is no need to postulate multiple spaces; instead, only the concepts proposed for a single space search need be used.

Given that a number of groups are starting to propose N-space models, now seem to be an opportune time to bring together different proponents and critics of these models so that some basic questions can be addressed. In particular: How strong is the empirical evidence for N-space models? Is there a theoretical need for such models? What distinguishes different N-space models? How can such models be tested, and in particular, what criteria should be used for proposing new spaces? How big is the N in N-space search and can it vary?

If the problem spaces framework can legitimately be extended into N-space search models, this may deepen our understanding of problem solving and scientific discovery. Such extensions may provide a way to unify diverse phenomena.

Speakers

Lisa M. Baker and Kevin Dunbar (McGill University).
Bruce D. Burns and Regina Vollmeyer (Universität Potsdam, Germany).

Chris D. Schunn and David Klahr (Carnegie-Mellon University).

David F. Wolf II (State University of New York at Albany) and Jonathan Beskin (State University of New York at Binghamton).

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