A person is confronted with a problem when he or she has a goal but does not immediately know the series of actions that can be taken to attain it. The study of problem solving is the study of the cognitive process that an organism uses to achieve a goal, particularly when the process requires thought.

To be considered as problem solving, an activity generally must involve a series of steps, operations, or intermediate states. Simple retrieval from memory does not qualify as problem solving. Instead, problem solving involves overcoming an obstacle to get from the current state to the goal state. It can involve reformulation of the problem, transformation of the task, or the decomposition of the goal, as well as the recombination of old ideas into new patterns or the transfer and application of an old solution to a new context. Because this goal-directed behavior relies on more basic processes of perception and memory, problem solving is considered a higher order cognitive process. Along with decision making, reasoning, and comprehension, problem solving is often classified under the umbrella term of thinking.

As a higher order process, problem solving was one of the areas of cognitive inquiry most affected by the domination of behaviorism, which caused it to be written out of psychology textbooks for most of the 20th century. A resurgence of interest began in the 1950s when the cognitive revolution prompted new attempts to study the complex mental activities that had been ignored by behaviorists. The topic received increasing attention as information-processing approaches gained traction in the 1970s. Thus, this entry will start by describing the early work done in the Gestalt tradition and then will provide an overview of several contemporary thrusts, including the information-processing approach, research on expert problem solving, mathematical problem solving, analogical problem solving, and creative problem solving.

The Gestalt Tradition

Behaviorists explored problem solving as either a reproductive process wherein organisms applied a specific response that had been used successfully on a previous occasion or as a process of chance discovery through trial and error. For example, Edward Thorndike observed that cats learn how to escape from cages by engaging in random behaviors that are gradually reinforced by success. By contrast, Gestaltists defined problem solving as a productive process. They attempted to detect processes underlying problem solving by asking human solvers to report their thoughts out loud. Gestaltists attempted to understand how thinking developed over the course of a solution, including transformation of the task by reformulation of the problem and goal statement.

They also described problem solving as being a search through a solution space, suggesting that from the start, the solver works within a narrow space of possibilities that can be expanded and redirected as necessary properties of the solution are realized or demanded by failure. Using protocols and experimental methods, the Gestalt tradition documented several theoretical barriers to successful problem solving, including mental set, functional fixedness, and unnecessary assumptions. The Gestalt movement was also frequently characterized by its interest in the roles of insight and incubation in problem solving.

Mental Set and Functional Fixedness
Mental set, or *Einstellung*, is a form of difficulty that occurs when a problem solver becomes fixated on applying a method that has worked previously. The classic demonstration comes from the water jug experiments performed by Abraham Luchins in which participants completed a set of practice problems that could be solved only by using a lengthy formula, followed by a problem that could be solved using a simpler method. Participants who were exposed to the practice problems tended to use the lengthy technique despite the possibility of using the simpler alternative. Even when given an extinction problem where only the simpler solution worked, participants exposed to practice were less successful at finding that solution than naive participants were.

*Functional fixedness* is a specific form of mental set in which individuals fail to recognize that objects can be used in nontraditional ways. The classic examples of this effect come from N. R. F. Maier’s two-string problem and Karl Duncker’s candle problem in which experience with usual uses of objects such as boxes and pliers prevents solvers from finding creative solutions. Both mental set and functional fixedness describe the inclination to rely on previous experience.

The two kinds of fixation can also be combined, such as by having individuals use an object for its usual purpose immediately before attempting a problem where the solution requires it to be used in a nontraditional manner. Priming of misleading responses can exacerbate fixation on ineffective solutions. In the extreme, fixation can blind participants to finding alternative solutions that others may discover easily.

**Unnecessary Assumptions**

Difficulties arise when the solver places unnecessary boundaries, constraints, or assumptions on the task at hand. The most well-known case is the nine-dot problem, where a solver is presented with a 3 × 3 grid of dots with the goal of connecting all nine dots by drawing no more than four lines and without lifting the pen or pencil from the paper. The participant typically makes many attempts by drawing lines that stay within the grid of dots. This self-imposed constraint inhibits the solver from thinking “outside the box” and finding the solution. In response to failures, attempting to reformulate the problem or starting over in a new way may prompt a solver to question her or his assumptions, expand boundaries, and remove constraints.

**Insight and Incubation**

Another emphasis in Gestalt theory was on the characterization of solution as being the result of a reorganization of the elements of the problem into a new whole, which resulted in sudden flash of *insight* or Aha! moment. Wolfgang Köhler asserted that such flashes of insight were preceded by periods of intense thinking. Alternatively, Graham Wallas suggested that insight might be most likely following a period of *incubation*, as, according to his theory, thought proceeds through five stages: preparation, incubation, intimation, illumination, and verification.

**After the Cognitive Revolution**

**The Information-Processing Approach**

In 1972, Allen Newell and Herbert Simon published *Human Problem Solving*, which detailed the solution processes for relatively simple and well-defined problems, such as
DONALD + GERALD = ROBERT, the Hobbits/Orcs problem, and the Tower of Hanoi. They provided an information-processing account of how people may solve problems by searching in a problem space. The problem space consists of the initial state, the goal state, and all possible intermediate states in between.

The actions that people take to move from one state to another are known as operators. A main theoretical contribution was in identifying the principles that govern how people navigate their way through a large number of possibilities, given the limited capacity of working memory. Newell and Simon proposed that navigation is guided by shortcuts, known as heuristics. One heuristic is hill climbing, whereby people take the action that seems to move them forward—that is, toward greater similarity between current state and goal state.

Another useful approach is problem decomposition in which the solver considers the subgoals that must be reached, or obstacles that must be overcome, on the way to achieving the main goal. This can be part of a more sophisticated heuristic, means-ends analysis, where the solver looks for the action that lead to the greatest reduction in difference between the current state and goal state but also specifies what to do if that action cannot be taken.

A particular strength of the Newell and Simon approach was the development of a computer program, the General Problem Solver (GPS), as a testable model of their theory. When the GPS was programmed to use these heuristics, a close match was found between the steps taken by the program and those observed in the protocols of human solvers.

**Expert Problem Solving**

Spurred by the early success of the information-processing approach, researchers began to investigate problem solving in domains such as physics and engineering and in strategic games such as chess. Modern theories of expert problem solving emphasize the important role of an accessible, large, well-organized store of domain-related knowledge that (a) allows experts to circumvent working-memory limitations, construct problem representations that capture key structural features or relationships, and allocate attention to important or relevant information and (b) provides the opportunity for strong methods of solution such as forward search. Some negatives of extensive, prior experience have been discovered as well, as experts may also be susceptible to mental set, which may make them less likely to find creative solutions.

**Mathematical Problem Solving**

Theories of mathematical problem solving have generally attempted to explain difficulties that students experience, particularly in the problem representation phase. Students are commonly derailed in their solution attempts by irrelevant information or by ambiguous or confusing language in problem statements. Working-memory limitations also cause difficulties during solution when problems require representing more than one state at a time or the maintenance of intermediate results. Theories about the development of mathematical problem-solving skills have distinguished between teaching students to solve problems procedurally versus conceptually. Instructional approaches that emphasize why particular formulas or methods provide solutions to a class of problems—including explanation, comparison of example problems, or
invention tasks—generally lead to greater success in applying these skills in novel contexts.

**Analogical Problem Solving**

Several lines of research on analogical problem solving have explored solvers attempting to use solutions from old problems to solve a new one. Much of the theorizing in this area has focused on explaining why solvers, even when given the solution to an isomorphic (i.e., identical in form) problem minutes before reading the new one, fail to transfer the given solution without a hint. One major obstacle that has been identified is the tendency for solvers to focus on superficial similarities between cases instead of on structural similarities or patterns of relations among problem elements.

A popular test that requires the solution of figural analogy problems is Ravens Progressive Matrices. This test was developed as a test of intelligence in the psychometric tradition, but it has become a theoretically important task for understanding how problem solving may depend on working-memory capacity. Success at solving matrices problems tends to correlate highly with other forms of analytic problem solving, as well as with measures of executive control, because of the need to inhibit irrelevant information during solution and to deal with the novelty and complexity of the task.

**Creative Problem Solving**

Although success at many problem solving tasks relies largely on making systematic progress through a solution space toward a particular solution and focusing on relevant problem elements, success on other tasks requires the ability to think divergently. *Divergent-thinking tasks* prompt the generation of novel uses, improvements for everyday objects, or consequences of hypothetical scenarios. These tasks have been used in assessments of individual differences in creative problem-solving skills and also to study the possible benefits of collaboration during group brainstorming.

Theoretical approaches have generally focused on explaining why collaborating groups might outperform individuals. Other approaches to creative problem solving have explored contexts that cause fixation or conformity, factors that allow individuals to overcome impasses imposed by misleading problem representations or solutions, and how solvers may achieve insights or highly creative solutions during problem solving. There has been much debate about whether qualitative differences exist between solution processes for analytic and creative problem solving.

**Ill-Structured Problem Solving and Problem Finding**

Problems can be classified along a continuum from well defined to ill defined, depending on whether they have clear goals, solution paths, or predictable solutions. Although most research has focused on well-defined problems, in addition to work on creative problem solving, there has been some headway into less structured domains, such as international relations, art, and writing. Research using computerized microworlds has explored complex problem solving that incorporates difficulties, such as a lack of clarity in starting states or operators, multiple or competing goals, large numbers of interconnected variables, and several kinds of uncertainty or unpredictability.
Finally, although most research on problem solving starts by providing the solver with a statement of the problem to be faced, to fully explain successful problem solving in real-world contexts, one needs to examine the problem-finding stage. The ability to recognize or formulate when there is a problem to be solved may be critical for achieving the moments of greatness that problem-solving theories ultimately seek to explain.

See also Creativity; Exceptional Memory and Expertise; Human Information Processing; Intelligence Testing; Reasoning and Decision Making

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