THINKING AND PROBLEM SOLVING

Peter A. Frensch
Department of Psychology, Humboldt University, Berlin, Germany

Joachim Funke
Department of Psychology, University of Heidelberg, Heidelberg, Germany

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Summary

Human thinking, and in particular, the human ability to solve complex, real-life problems contributes more than any other human ability to the development of human culture and the growth and development of human life on earth. However, the human ability to solve complex problems is still not well understood, partly because it has for a

long time been largely ignored by traditional problem-solving research in the field of psychology.

In this article, we present a definition of complex problem solving and describe a theoretical framework that accommodates the theoretical and empirical strides that have been made in understanding complex problem solving thus far and may serve as a guide for future research. We discuss the dominant methodological approaches that have been employed to study complex problem solving, and offer our own recommendations on which of the various approaches might be the most promising.

1. Introduction

March 28, 1979, Three Mile Island, Pennsylvania (Associated Press)
One of the Three Mile Island reactors was shut down for routine refueling on March 28. The other, Unit 2, was humming along quietly until, at 3:53 a.m., terrible events began with a whoosh. The fail-safe system failed. Three valves on auxiliary pumps that should have been open weren't. And the chain of human error and mechanical breakdown grew, multiplied, and turned a routine glitch into the worst nuclear accident in the 22 years since the U.S. nation began using nuclear power.
February 9, 2001, Long Beach, California (Associated Press)
Boeing engineers are working on an 800-seat airliner with wings that blend smoothly into the fuselage instead of protruding from its sides. The so-called blended wing-body aircraft will fly at the same speed and altitude as a 416-seat Boeing 747–400, but it will use 25 percent less fuel and generate less noise. The A-380, which will seat about 600, is expected to be in the air by 2006.

The breadth of human thinking is truly striking. As is evident in the examples provided above, human thinking can lead to catastrophic disasters. Yet, on the other hand, human thinking also makes possible the most wondrous achievements. Whatever "thinking" is, and scientists disagree heartily on the proper meaning of the term, there can be little doubt that human thinking determines human culture to an extent that is unrivalled by any other human ability. Of course, culture determines the way we think as well—as many scientists have pointed out in the past.

In this article, we describe some of the main properties of human thinking. To stay with the general theme of this encyclopedia, after providing a definition of thinking and briefly discussing the various categories or types thinking may be divided into, we concentrate on one particular type of human thinking that contributes more than any other to the development of human culture and the growth and development of human life on earth, namely, problem solving. Our discussion will focus on complex, real-life problem solving rather than on solving small and artificial laboratory-type problems, and will concentrate on both empirical research and attempts to explain the phenomenon theoretically.

2. Defining Human Thinking

Many of our daily activities involve thinking of some sort. For example, we decide what to wear in the morning, which route to take to get to our office, which job-related duties to perform in which sequence once we arrive at our office, what to have for lunch, and so on. Of course, not all thinking is alike. There is thinking that involves only a few mental steps, and there is thinking that requires many steps. Some thinking involves situations we have never encountered before, and other thinking involves familiar situations. Sometimes thinking is tied to clear goals, and sometimes it is not. “Thinking,” then, can be distinguished on any number of meaningful dimensions, and the mental processes—that is, the steps we engage in when thinking, as well as the mental representations the processes operate on—may differ widely for different types of thinking.

Given the multidimensionality of thinking, it may come as no surprise that different researchers, all claiming to study the phenomenon of thinking, have in the past differed widely in their definitions of the term thinking. On the one hand, thinking has often been defined in terms of its possible functions. For example, Aebli likens thinking to “bringing order into one’s doing,” and Johnson, Dörner, and many others define thinking in terms of problem solving. On the other hand, some researchers have attempted to define thinking in a manner that is independent of its assumed functions. We will follow the latter approach and for the purpose of this article define thinking as the “cognitive processing of internal memory representations that may occur both consciously and subconsciously and may not always follow the laws of logic.”

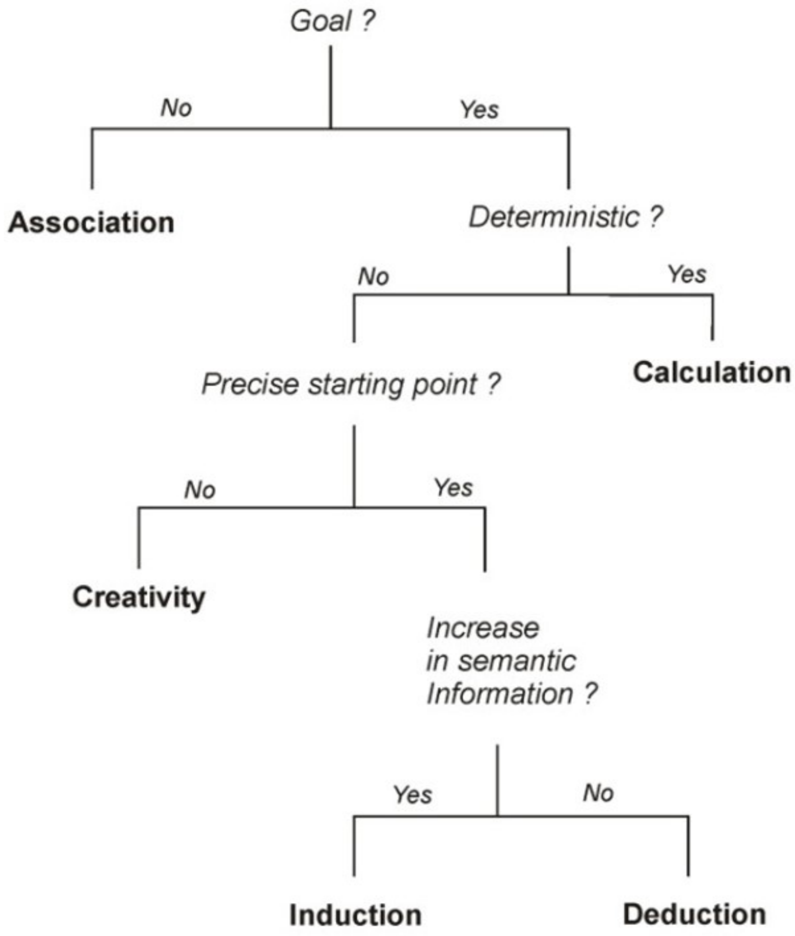

Figure 1. A taxonomy of thinking

Given this definition of human thinking, we can distinguish between various subtypes, or categories, of thinking. Figure 1 displays a taxonomy of thinking that has been developed by Johnson-Laird. According to Johnson-Laird, five different types of thinking can be distinguished. For example, thinking that is goal-oriented, does not follow a predetermined sequence of mental steps, and has no precise starting point is usually labeled "creative." Alternatively, thinking that is goal-oriented, does not follow a predetermined sequence of mental steps, has a precise starting point, and leads to an increase in semantic information in the human memory system is called "inductive." Inductive and deductive thinking together constitute the category of problem solving.

Readers should note that the taxonomy has more than just intuitive appeal. The questions used divide the area of thinking into truly distinct subtypes that differ from each other in terms of both the mental processes conducted and the mental representations involved. Thus, "association-based" thinking, for instance, differs from "calculation" both in terms of the underlying processes (i.e. mental steps) as well as in the mental representations that the processes operate on.

In the rest of the article, we focus primarily on one particular type of thinking that is inherent in the taxonomy, namely, problem solving (subsuming both inductive and deductive thinking). We will do so because we are convinced that this type of thinking is the most important in supporting and ensuring lasting local, regional, and global welfare.

In the next section, we summarize the currently dominant empirical approaches to studying problem solving, after first providing a brief historical background within which the development of the dominant approaches can be understood. Notice that we will concentrate almost exclusively on what is called complex problem solving (CPS), that is, problem solving that occurs in the context of real-world problems. We present a definition of CPS, and describe a theoretical framework that accommodates the theoretical and empirical strides that have been made in understanding CPS thus far, and serves as a guide for future research. Last but not least, we discuss the dominant methodological approaches that have been employed to study CPS, and offer our own recommendations on which approach might turn out to be the most promising.

3. Complex Problem Solving: Historical Roots and Current Situation

Beginning with the early experimental work of the Gestaltists in Germany, and continuing through the 1960s and early 1970s, research on problem solving was typically conducted with relatively simple laboratory tasks that were novel to research participants. Simple novel tasks were used for a variety of reasons: they had clearly defined optimal solutions, they were solvable in a relatively short time, research participants' problem-solving steps could be traced, and so on. The underlying assumption was, of course, that simple tasks, such as the Tower of Hanoi, capture the main properties of "real" problems, and that the cognitive processes underlying participants' solution attempts on simple problems were representative of the processes engaged in when solving real problems. Thus, simple problems were used for reasons of convenience, and generalizations to more complex problems were thought possible.

Perhaps the best-known and most impressive example of this line of research is the work by Newell and Simon.

However, beginning in the 1970s, researchers became increasingly convinced that empirical findings and theoretical concepts derived from simple laboratory tasks were not generalizable to more complex, real-life problems. Even worse, it appeared that the processes underlying CPS in different domains were different from each other. These realizations have led to rather different responses in North America and Europe.

In North America, initiated by the work of Herbert Simon on learning by doing in semantically rich domains, researchers began to investigate problem solving separately in different natural knowledge domains (e.g. physics, writing, chess playing) thus relinquishing their attempts to extract a global theory of problem solving. Instead, these researchers frequently focused on the development of problem solving within a certain domain, that is, on the development of expertise. Areas that have attracted rather intense attention in North America include such diverse fields as reading, writing, calculation, political decision making, managerial problem solving, lawyers' reasoning, mechanical problem solving, problem solving in electronics, computer skills, game playing, and personal problem solving.

In Europe, two main approaches have surfaced, one initiated by Donald Broadbent in Great Britain and the other by Dietrich Dörner in Germany. The two approaches have in common an emphasis on relatively complex, semantically rich, computerized laboratory tasks that are constructed to be similar to real-life problems. The approaches differ somewhat in their theoretical goals and methodology. The tradition initiated by Broadbent emphasizes the distinction between cognitive problem-solving processes that operate under awareness versus outside of awareness, and typically employs mathematically well-defined computerized systems. The tradition initiated by Dörner, on the other hand, is interested in the interplay of cognitive, motivational, and social components of problem solving, and utilizes very complex computerized scenarios that contain up to 2000 highly interconnected variables (Lohhausen project).

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Biographical Sketches

Peter A. Frensch studied electrical engineering, psychology, and philosophy at the Universities of Darmstadt and Trier, Germany, and at Yale University, USA. He received his M.S. in 1987, followed by his M.Phil. in 1988, and his Ph.D. in 1989, all at Yale University, and worked as an assistant and associate professor of psychology in the Department of Psychology at the University of Missouri-Columbia, USA, from 1989 until 1994. In 1994, he moved to the Max Planck Institute for Human Development and Education, Berlin, Germany. He is currently professor of psychology in the Department of Psychology at Humboldt University, Berlin, Germany. His research interests include learning, memory, and problem solving.

Joachim Funke studied psychology, philosophy, and German language at the Universities of Düsseldorf, Basel (Switzerland), and Trier. He received his M.S. in psychology in 1980 and his Ph.D. in 1984, both at the University of Trier. In 1985, he moved to the University of Bonn, where he was granted his habilitation in 1990. He is currently professor of psychology in the Department of Psychology at the University of Heidelberg, Germany. His research interests include memory and problem solving.