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ABSTRACT

The book "Productive Thinking", by Gestalt psychologist Max Wertheimer, was published over 50 years ago, yet it continues to wield influence. The book's argument on productive thinking, and why it is still relevant today, are the focus of this paper. Productive thinking involves going from a situation of bewilderment or confusion about some issue to a new state in which everything about the issue is clear. The process involves a kind of reorganization, and marks a transition from a state that is meaningless to one that is meaningful. Aural and visual examples of productive thinking are presented, along with word games and the importance of problem reformulation. A number of logic problems are presented and the possibility of their solution is explored. Many scholarly reactions to the book's theme are presented in detail, and some of the research that has been initiated by productive thinking is explained. The ascendance of computer-based, information processing as a paradigm for cognitive psychology is discussed, as well as its application to productive thinking. Contains 50 references. (RJM)

A Contemporary Perspective on the Psychology of Productive Thinking

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Draft, August 16, 1996

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The book Productive Thinking by Gestalt psychologist Max Wertheimer was published just over a half century ago, two years after the author's death. A Japanese translation appeared in 1952, and a German one in 1957 (with a second edition in 1964); an enlarged English edition was published in 1959 in hard cover and reissued in 1971 as a paperback; and in 1982 the enlarged version was published again, with a new preface co-authored by several cognitive psychologists. A 1993 chapter on thinking in the Annual Review of Psychology, discusses Wertheimer's Productive Thinking at some length. A search of the Social Science Citation Index for only the years 1991 through 1994 yielded a dozen references to just the English editions of Productive Thinking each in 1991, 1992, and 1993, and 20 in 1994. Not every book published in 1945 was reissued several times in later years, was translated into other languages, or continued to be cited repeatedly in the social-science literature half a century later.

What is it about the book Productive Thinking that makes it continue to receive attention? Why are people still reading it, still citing it?

Wertheimer introduced his book with some simple but profound questions: "What occurs when, now and then, thinking really works productively? What happens when, now and then, thinking forges ahead? What is really going on in such a process?" He had been concerned with these issues for decades. In a journal article in 1912, more than thirty years earlier, he had provided example after example of fine thinking in the quantitative realm by indigenous people from many parts of the world. Two years earlier yet, he had published a paper in which he described the structural sophistication of the music of the Vedda, a tribe in what was then called Ceylon and is now Sri Lanka. What he admired in the music -- and the thinking -- of aboriginal people was its aptness: how their music followed strict esthetic principles and had a coherent structure -- and how their quantitative thinking followed strict functional principles and coherently fit the inherent structure of the concrete problems and situations to which it was applied. Gestalt theory emerged initially and primarily in areas that are now called cognitive psychology, and specifically in the fields of problem solving and what Getzels and Czikszentmihalyi (1976) have called "problem finding" -- as well as in music and the other arts. Indeed a number of the citations of the book Productive Thinking in the Social Science Citation Index during the last few years, not surprisingly, are in journals devoted to the arts, such as the Journal of Creative Behavior, the Creativity Research Journal, and Metaphor and Symbolic Activity -- as well as in such diverse other periodicals as Science Education, Human-Computer Interaction, Journal of Educational Research, and R&D Management, not to mention the Psychological Bulletin, Cognitive Psychology, and the American Psychologist.

But such lists are superficial; they miss the core, the essence, what Max Wertheimer called the "radix" or root, of the issue. What was the main point of Wertheimer's position on productive thinking -- and why is it still relevant and salient today?

What characterizes productive thought is its fit with the situation to which it is applied. Productive thinking involves going from a situation of bewilderment or confusion about some issue that is blind to the core structural features and properties of that issue, to a new state in which everything about the issue is clear, makes sense, and fits together. In the first page of his introduction, Wertheimer called it "the transition from a blind attitude to understanding in a productive process," a "surprising event," "the birth of a genuine idea," "when one has begun really to grasp an issue." At the core of the process is a kind of reorganization or restructuring, going from a state that makes no sense to one that does make sense, displays understanding or insight, is crystal clear. It is a transition from a state that is meaningless, nonsensical, befuddled to one that is meaningful -- a "good Gestalt."

In his many lectures on thinking, from the second decade of this century until his death in 1943, Wertheimer almost always used concrete examples to illustrate his principles. That is probably the most vivid way to introduce his ideas, so let me share with you a few illustrations of what he meant by "reorganization," "restructuring," "insight," "understanding." Not all modern cognitive psychologists would consider all of these examples as demonstrating the same underlying process or principle, and only one of these examples is one that Max Wertheimer used himself, but all do convey what he meant by the transition from what he called S_1, a state in which nothing really seems to make much sense, or things are seen in a rather humdrum manner, to what he called S_2, a state in which everything seems fully clear, makes sense, and can be grasped in its essence and in its relation to everything else in the total Gestalt.

While the transition to an insightful reorganization is characteristic of productive problem solving, it is perhaps most obvious in perceptual instances. To start with, consider this set of words. **(Transparency T1.)** Pas de l'y a Rhône que nous.
This example actually comes from William James, in his 1890 book, Principles of Psychology. What does it mean? For those of you who know some French, it might translate roughly as "Not of there is Rhône (a river) than we," which makes no sense at all. Try saying it out loud: Pas de l'y a Rhône que nous. Not much help. Maybe one

could read it with an American accent: "Pah de'l ya rown ke-new" or "Paddle your own canoe." Now I trust that many of you who haven't seen this example before have recognized it for the saying, "Paddle your own canoe," that is, the admonition that one should further one's own cause, should paddle one's own canoe. For those who have achieved the reorganization, there has been a transition from meaninglessness to a new structure, in which the sequence of sounds symbolized by the letters now makes some sense.

Or consider this simple drawing **(T 2)**. At first it might be seen as a rough profile of a squinting, smiling human face. But one can also reorganize it into a soldier and his dog passing by an archway; now the smile becomes the dog's tail and the squinting eye becomes the end of the soldier's rifle, complete with fixed bayonet.

Then there is a figure **(T 3)**, which is usually first seen as something like a ghostly creature on the right looking over a fence, perhaps with a dog's ears standing up above the fence on the left. But one can also see it as what might happen in this room three or four hours from now, if there is a particularly dirty spot on the floor. The custodian on the right is viewed from a somewhat compromising angle, scrubbing the floor next to a bucket or pail on the left; what had been the ghoul's eyes now are the soles of the janitor's shoes.

A rebus almost by definition cries out for reorganization. What does this **(T 4)** mean? Three common words are arranged vertically: the past participle of the verb "stand" over the word "well," both above the word "view." If one achieves a well-understood overview of the pattern, one has solved the rebus puzzle: "well" is under "stood," and both are over "view" -- which, slightly reorganized, becomes "well" under "stood" over "view," or well-understood overview.

A classic puzzle, which has been extensively studied in recent years by such investigators as Robert Weisberg, is the nine-dot problem **(T 5)**. The task is to draw four successive continuous straight lines, that is, without lifting one's pencil from the surface, such that each dot has a line going through it. When they first encounter this task, people make attempts like these **(T 6)**, always leaving out at least one of the dots. One analysis of the problem suggests that people implicitly, because of the square perceptual shape of the pattern, add a constraint that is <u>not</u> part of the problem conditions; they assume that the lines must stay within the outline of the square. The solution <u>does</u> require going outside that boundary, but the hint that one needs to go outside the square does not, alone, help much. The solution requires a particular structural way to "go outside the square," so as to capture, as it were, two "troublesome" dots in the same slanting line. Even this hint is not likely to help someone who has never seen the problem before. One sequence of lines that works is this **(T 7)**. The distance one needs to go "outside" the square in the upper right is specified by the end of the diagonal line going through the two lower-right dots just inside that corner; once one has understood that principle, one can generate the comparable solutions that begin at any of the square's corners.

Another widely-studied problem requires one to construct a chain out of a number of segments; this problem comes in several different versions. In one of the somewhat less familiar variants, you find the remnants of a gold chain in your Aunt Mathilda's attic **(T 8)**. There are exactly five pieces, each consisting of three links. You want to make the five bits of chain into one continuous line, consisting of a total of 15 circles or links. You go to your local jewelry store, and the jeweler tells you that the charge will be two dollars for each link that gets cut and then resoldered; come back tomorrow; the charge will be six dollars. Fine, you say, and leave the shop. But as you step out, you realize that something doesn't fit. Shouldn't the charge be eight dollars **(T 9)**, since four links will have to be opened and then closed again? Isn't it necessary to cut and solder, for example, the right-hand link in each of the first four remnants? When you go back in and ask whether there hasn't been a mistake, and that the charge should be eight rather than six dollars, the jeweler smiles and says, "No; I can do it for you for only six dollars." How can the jeweler do it? On first encounter with this problem, one typically remains stumped. But a kind of perceptual hint can help overcome the implicit assumption that the five remnants are not only perceptually but also functionally identical. The solution may become clear to those who have not encountered the problem before by a rearrangement of the remnants **(T 10)**. It requires a functional differentiation between one remnant and the remaining four. The four upper ones become the material to be joined, while the lower one becomes the material that does the joining -- and actually disappears, in a sense, in the process **(T 11)**. There are just enough links in it to fill the three gaps among the other four; all three of its links are opened and then closed again, in such a way that each fills the three gaps among the others.

Then there is the problem of the altar window, from an appendix added to the 1959 edition of Productive Thinking. The task is to cover an area **(T 12)** surrounding a round altar window in a church with gold paint. The circular window is exactly one meter in diameter. Vertical lines are drawn tangent to the circle, just as long as the window is high, and then semicircles connect both the tops and the bottoms of those tangent straight lines. If it takes half a liter of gold paint to cover one square meter of wall surface, how much paint will be needed to cover the area specified? The problem is sometimes approached by finding the area of the two half-circles at the top and the bottom, then trying to figure out the area of each of the four remaining "corners." This task turns out not to be trivial, especially for someone well versed in plane geometry. It can be a revelation to realize that such cumbersome procedures are superfluous, since a principle of using the "too much" in the figure to fill in the "too little" works here **(T 13)**: the two half-circles on the top and at the bottom will exactly fill in the area of the window; by placing them there one obtains the desired area: one square meter, of course; so one will require exactly half a liter of paint to gild the area.

A striking example of reorganization is an extension of a classic puzzle you may have heard before. A hunter with a telescopic sight on his gun sees a bear one mile due south of him. He aims his gun, shoots, and misses, and the bear ambles off. Then the hunter walks the one mile due south to where the bear was when he shot at him, then walks one mile due east, then one mile due north -- and finds himself standing exactly at the same place he had been standing when he shot his gun **(T 14)**. The classic version next asks, "What color was the bear?" For someone who has never heard this story, the question is astonishing. How could the information provided have anything to do with the color of the bear? It seems totally incongruous. The solution begins with reformulating the query into, "Where on the surface of the earth might it be possible to go successively one mile due south, then one mile due east, then one mile due north, and end up standing at the same place one started from?" This transformation may generate a meaningful connection between the information given in the problem and the request for the color of the bear. To save time, I won't take you step by step through the process of finding a solution; most of you probably already know it anyway: the north pole. If you are standing at the north pole, any direction is south. So you go one mile due south from there, then turn left 90 degrees and walk exactly one mile due east, then turn left again and go exactly one mile due north -- and end up standing on the north pole again. This spherical triangle that you have traversed looks a bit different from a plane triangle, in that the sum of its interior angles is 270 rather than 180 degrees, but the north pole clearly satisfies the specified constraints, because from it you can walk successively one mile due south, then one mile due east, then one mile due north and end up standing at the same place you started from. Is there any conclusion to be drawn about the color of the bear? Of course: any bear you encounter in the arctic is apt to be a polar bear, so the color of the bear's fur must be white.

But that is where the extension of this problem starts. Where else on the earth's surface, other than at the north pole, can one go one mile due south, then one mile due east, then one mile due north, and end up standing at the same place one started from? Ideally, I would stop here and let you think about the problem for a while, but let me add that the solution is not a trick; once you see it, it is elegant in its simplicity. Many people begin by thinking about starting at the south pole -- but that, of course, doesn't work, because every direction from the south pole is north. But -- and this could be a helpful hint --- the solution is actually on that part of the globe, very near the south pole. I'll return to this problem later, and maybe you can continue to think about it if the rest of this talk isn't too distracting.

Perhaps these examples have succeeded in conveying to you what Max Wertheimer meant by "reorganizing" or "restructuring." He argued that productive thinking requires an insightful revision of one's representation of the problem and of the problem domain, to use modern terminology. Let me paraphrase some of Wertheimer's general observations from his book Productive Thinking; while they may sound rather abstract, possibly the examples mentioned earlier will help clarify what he meant by them. He proposed three broad generalizations about productive problem solving which can be viewed as challenges to modern cognitive psychology; and they have indeed been addressed in one way or another by several contemporary writers. First **(T 15)**, to repeat a point from the introduction to this talk, productive thought involves transforming the representation of a problem from a situation S_1 (a vague, fuzzy, incomplete and confused representation that is blind to essential structural features of the problem), to a second situation S_2 (a representation that is clear, has no gaps in it, makes sense, and views each part of the problem in terms of its place, role, and function within the problem). Second **(T 16)**, such transformations are (a) hampered by blind search, "functional fixedness" or rigid set or "Einstellung," empty associations, "and-sums," conditioning, school drill, bias, and so on, and are (b) aided by open-minded exploration of the problem, searching for its essential, crucial features, and its "rho relations." By "functional fixedness" Wertheimer meant what his student Karl Duncker investigated in several well-known studies: if an object is viewed as fulfilling a particular useful function in one context, that makes it less likely that one will see that it could perform a rather different function as well in another context. An "and-sum" is a mere conglomeration of items that are arbitrarily connected, without regard to the attributes of those items or their meaningful relations to one another. The term "rho relation" was used by Wertheimer to indicate a feature that is crucial to the essence of a problem, its core or "radix." For example if you are to build a toy bridge of wooden blocks **(T 17)**, there is a rho relation between the distance separating the two uprights and the length of the horizontal member (it can't be shorter than the distance between the two uprights), as well as a rho relation between the heights of the two vertical blocks -- they must be at least roughly comparable if the bridge is to stand. But the <u>color</u> of the blocks bears no rho relation to whether the bridge can be stably constructed or not.

Third and finally **(T 18)**, this perspective generates several groups of potentially productive areas for research: (a) laws governing segregation, grouping, centering, and structural transposability, (b) how relations between parts and their wholes govern the possible operations on parts that take into account the part's place, role and function within the whole of which it is a part, and (c) the nature of "outstanding wholes," "good Gestalten," indeed of "rho relations" themselves.

In his book Productive Thinking Wertheimer illustrated these observations with numerous examples, in great detail and with analytical elegance; his examples ranged from finding the area of a parallelogram to how Albert Einstein formulated the theory of relativity. A number of these examples already had been used by Wertheimer in publications many years before, as early as 1920. To paraphrase Anders Ericsson and his colleagues in their preface to the 1982 edition of Productive Thinking, they set a challenge for the modern cognitive psychologist -- indeed for any thoughtful human being. They contrast pure memory, or reproductive thinking, which can be accounted for reasonably well by the associationist paradigm that prevailed fifty years ago -- and by its modern counterpart, the connectionist approach to computer modeling -- with productive thinking, or insight-based reasoning, or genuine understanding of conceptual problems and relationships, which are not so easily handled by an associationist or connectionist strategy. The issues of insight, understanding, and productive thinking were a major research focus for the Gestalt psychologists for several decades preceding the publication of Wertheimer's book; among contributors to these studies were Karl Duncker (1935, 1945), George Katona (1940), Kurt Koffka (1935), Wolfgang Köhler (1917, 1925), and Abraham Luchins (1942), all of whom worked closely with Wertheimer. Several contemporaries not primarily identified with the Gestalt school raised similar kinds of points: Otto Selz (1913, 1922) and Sir Frederick Bartlett (1932), to name only two. All of these writers generated descriptions of problem solving and thinking that compelled consideration of complex mental structures and processes, typically ones that are idiosyncratic to a particular problem and do not readily generalize from one problem domain to another.

During the 1950s and 1960s, with the advent of the computer and of information processing, began what is now called the "cognitive revolution." The computer became the model for the human mind. Newell, Shaw and Simon described a computer program in 1958 that could solve problems, and in 1962 their still more sophisticated General Problem Solver. In 1972, Newell and Simon, and Simon alone in a publication in 1978, formalized what has become the prototype of the kinds of paradigms that have been taken for granted by cognitive psychologists, computer scientists, and cognitive scientists ever since. Problem solving is conceived as goal-directed search among possible perceived solutions within a specified domain called the "problem space." Such a conception works well in simulations of the problem-solving efforts of novices who have little experience with attempting to solve novel problems, but cannot readily account for how experts like chess masters, physicists or designers, who have a thorough knowledge and an organized understanding of a domain, go about solving difficult problems in the area of their expertise. One consequence of this failure was the postulation by Walter Kintsch (e.g. Kintsch and van Dijk, 1978) and others of complex abstract knowledge structures such as schemas, scripts, or frames to account for text comprehension and other complex cognitive processes. From this perspective, as James Greeno (1977) put it, "insight" involves the discovery of the applicability of an existing general schema to a novel situation. But what processes generate genuinely productive thinking, that is, yield schemata or representations that can in fact be used successfully to solve a novel problem, remained -- and remains -- elusive. Blind schema-generalization cannot work; the restructuring and insight emphasized by Wertheimer are missing in computer models of cognitive processes. Ericsson and his co-authors in 1982 (pp. xv-xvi) concluded that while the information-processing tradition has made some modest progress on several issues raised in the book Productive Thinking, "it has by no means solved all of them. All of Wertheimer's examples raise serious problems for an associationistic paradigm of mental processes. Today, the information-processing psychologist considers the solution of the issues raised by Wertheimer central to progress in [the] understanding of problem solving and productive thinking. Many of the examples so lucidly discussed by Wertheimer remain only partially understood and continue to represent significant challenges to cognitive scientists."

Some time ago, I asked a number of colleagues for their suggestions on this talk. Lewis O. Harvey, Jr., an expert on psychophysics and behavioral neuroscience, referred me to the work of the Stuttgart theoretical physicist Hermann Haken and his colleagues (e.g., Haken, 1983, 1991; Haken and Stadler, 1990) on synergetics, the study of the behavior of dynamic systems containing many mutually interacting components; synergetic computer approaches have been applied in promising ways to some neural and perceptual phenomena, including "multistable figures" such as the Necker cube (Kruse and Stadler, 1990). Reid Hastie, a prominent cognitive scientist and social psychologist, gave me a number of recent relevant articles and references, and also raised a question that I consider directly to the point: What must a computer program that satisfactorily simulates productive thinking be able to accomplish? What would its essential features be? A decade ago (1985), I publicly concluded that the inherently blind connections that make up a computer and a computer program can never achieve the goal: insight, understanding, and meaning are in principle outside the capacity of any computer or computer program; to the extent that a program might be able to mimic or simulate productive thinking, the productive thinking or insight or understanding is not in the program or computer itself, but in the programmer.

Searches in the library, and the suggestions of my colleagues, yielded many recent books and articles that are clearly relevant to the issues raised by Max Wertheimer in the book Productive Thinking. People are still thinking about, writing about, and doing empirical work on these matters. The last part of this talk will sample broadly and briefly from among these publications. There are so many of them that I can only touch on a few. I expect that those of you who know the recent literature in this field will recognize some of them, and hope I haven't omitted too many of your favorite contributors or lines of research. The question about all these items, I believe, should be whether developments in the field during the last decade or two demonstrate real progress on the central problem that Max Wertheimer addressed in his analyses of productive thinking: the crucial role of reorganization, of restructuring, of insight. My old friend and colleague, Ward Edwards of southern California, a long-time systems analyst, recently wrote me in another context that he believes that one should let computers do what they do well, which is what he called the "intellectual" processes of evaluation, inference, and decision -- and let people do what <u>they</u> are good at, which is essentially the tasks required to structure the problem in the first place and to provide inputs to those three intellectual processes. Perhaps the time has come to recognize that computers and an information-processing model are, because they are inherently blind, excruciatingly literal, and incapable of processing meaning, in principle unable to simulate the most critical and central property of productive thinking, restructuring.

Consider first a work by the Swiss psychologist Hans Aebli, late of the University of Bern: his two-volume work, <u>Denken: Das Ordnen des Tuns</u> ("Thinking: The Arranging of Action," 1980). In it he refers repeatedly to Wertheimer's <u>Productive Thinking</u>. For example, he suggests (p. 33, vol. 1) that Karl Duncker's monograph and Max Wertheimer's book shed more light on the nature of creativity than all investigations with tests of creativity combined -- even though elsewhere (p. 39) he chides Wertheimer for using imprecise everyday language rather than the rigorous language of science. Later though (page 53), Aebli with approval cites Wertheimer's word "and-sum," as capturing the emptiness of sheer associations based on nothing more than contiguity. In his second volume, Aebli discusses at some length several of the examples from Productive Thinking, and admires the description of a problem as "a structure with a gap." Aebli uses the modern language of constructions, representations, and information processing, basically translating the classic Gestalt issues into the current terminology.

Keith Holyoak's and Barbara Spellman's chapter on thinking for the 1993 Annual Review of Psychology (pp. 265-315) contrasts what they call the production-systems approach of Simon and his colleagues, which handles "well-defined" problems that have clear goals, a clear starting state, and obvious operators reasonably well, with the approach to less well-defined problems on which the Gestalt psychologists Karl Duncker and Max Wertheimer worked, that typically require "restructuring" of the problem representation if solution is to be achieved. Holyoak and Spellman argue (p. 268) that Simon and his colleagues have been able to "accommodate many" -- if not all -- "of the empirical phenomena associated with such Gestalt concepts as 'intuition' and 'insight.'" They suggest that "some alternative approach might provide a computational realization of the Gestalt perspective on thinking," and cite a 1990 paper by Rock and Palmer which claims that there is "some affinity between Gestalt theory and current connectionist models," but no specifics are provided. Further on in their account (p. 269), they admit that "It is unlikely... that connectionism will undermine the traditional view that human thinking requires a symbol system," and (p. 273) give credit to Ryan Tweney (1990) for indicating that the complex interrelatedness of hypotheses provides a major challenge for computational theories of scientific reasoning. Later in their summary article, Holyoak and Spellman (p. 290) point out the crucial role that prior knowledge and contextual cues play in thinking. "Across a wide variety of tasks, the manner in which individuals reason and solve problems is intimately related to the content of what is being thought about as well as to the context in which the thinking takes place."

Further on (p. 293), Holyoak and Spellman point out that "A crucial question for theories of thinking concerns relevance," or what Wertheimer might have meant by rho relations. Holyoak and Spellman ask, "How do people access and exploit knowledge relevant to their goals when drawing inferences, making decisions, or solving problems? The problem of determining relevance emerges in many guises."

Yet another issue, only hinted at in my summary of the central theoretical issues of the book Productive Thinking, is transfer, the transfer of knowledge learned in one context to other related situations. As Holyoak and Spellman write (p. 297), "Essentially by definition, transfer is based on the perception that prior knowledge is relevant to the current context." How can a computer be programmed to make such metaphorical and analogical jumps? Another aspect of the relevance issue is stated as follows by Holyoak and Spellman (p. 302): "a crucial aspect of the general characterization of a representational system is that it involves specifying which aspects of the represented world are relevant." Once again: how do you program a computer so it will be able to recognize the difference between rho relations and trivial, superficial attributes of a problem?

That Holyoak and Spellman wrote a chapter on thinking for the Annual Review of Psychology so recently was, of course, useful for my purposes here today. More recent yet is a book edited by Robert J. Sternberg and Janet E. Davidson, entitled The Nature of Insight, published in 1995. It is full of references to Productive Thinking and to other relevant Gestalt publications. Yet another 1995 book, by David J. Murray, is in fact entitled Gestalt Psychology and the Cognitive Revolution. Its author claims, and documents in detail, that "the Gestalt psychologists... foreshadowed the cognitive revolution" (p. xi); he "emphasizes the value of the insights of Gestalt psychology for our understanding of cognitive psychology, and argues that we need to re-evaluate many of Gestalt psychology's ignored insights" (back cover). While concentrating on the contributions of Gestalt theory to perception and memory, Murray also treats in detail the work of Wertheimer, Köhler and Duncker on productive thinking. But let me comment briefly on a few other items that my computer-oriented information-processing cognitive friends and colleagues referred me to as possibly relevant to the current perspective on the psychology of productive thinking.

A paper by Allen Newell in 1980 discussed the virtues of the concept of a problem space, arguing that people construct and improve such spaces as they gain experience in a problem domain, and that the problem-space idea (p. 715) "has strong implications for the transfer of skill.... If a [person] maps a task into an existing problem space, then the transfer of this knowledge to the new task is implied." But Newell does not address the critical issue of rho relations: how does one know into which (already-familiar) problem space to transfer a new problem? Another article by Newell, in 1985, is essentially an appreciation of some of the classic problem-solving research of Wertheimer's and Köhler's student Karl Duncker. Newell claims that some progress has been made even beyond Duncker's pioneering work, but my reading of the article yields the impression that Newell does little more than translate the Duncker-Köhler - Wertheimer ideas into the modern jargon of information processing, without adding much else -- and hardly touching on the crucial issues of rho relations and insight. Newell recognized this to some extent, as when he wrote (p. 405) that his model uses a heuristic-driven but structure-blind search, while in the Gestalt conception "search in all its various forms was the indicator of blind meaningless activity."

A series of studies by Janet Metcalfe (e.g., 1986) and her colleagues provides an empirical, functional distinction between the processing of memory tasks and of problem-solving tasks, the same distinction that Wertheimer made between reproductive and productive thinking. It turns out that while people are generally able to predict their future performance on reproductive memory tasks (p. 292), they cannot predict future performance on productive problems that require transformation of the problem representation for their solution. Roderick Smith's recent doctoral dissertation (Kounios and Smith, 1995) provides additional comparable findings, using a sophisticated method to study the time-course of partial information accumulation during the processing of anagram tasks, which require some degree of reorganization, insight, or "illumination." Both of these lines of research imply that it may be inherently impossible for the current continuity models of information processing to account for the all-or-none or discontinuity features of problem solving that requires a changed representation. I have not yet seen any attempts to use the mathematics of chaos theory in computer models of cognitive processes; might some such notion -- similar to Thomas Kuhn's idea of paradigm shift, or a "Gestalt switch" -- have heuristic value? Of course, the issue of rho relations would arise here again: not any random radical transformation will lead to the solution of an "insight" problem; one needs to develop a transformed structure that fits the essential features of the problem situation.

A paper by Winston, Chaffin and Herrmann (1987) on a taxonomy of part-whole relations recognizes that such relations are not limited to logical inclusion or class membership -- indeed there are many kinds of part-whole relationships, some relatively empty and some relatively rich and pregnant. Rho relations again? The authors do not mention them, nor do they refer to an appendix in the enlarged edition of Productive Thinking, in which Wertheimer distinguishes at length between "arbitrary components" and "necessary parts."

In 1988 Clayton Lewis published a computer simulation of analysis-based learning and generalization of procedures in a task that requires making a variety of arbitrary connections between a set of commands to a computer and the computer's output. He managed to simulate at least some aspects of transfer of explanation-based procedures from one task to another (almost identical) task. Yet he admits that "none of the current analysis-based generalization methods fully captures Wertheimer's notion of understanding. Proper choice among different possible analyses of an example is crucial for Wertheimer, but... this problem may be beyond the reach of learning systems" (p. 24). One wonders how many of Lewis' colleagues in his department of computer science would agree with this pessimistic conclusion.

A 1990 paper by Kaplan and Simon, provocatively entitled "In search of insight," makes extensive reference to the Gestalt literature and then reports some empirical work with a classic mathematical puzzle, the mutilated-checkerboard problem. Attaining "insight," they write, requires discovering an effective problem representation, and the likelihood that such a representation will be discovered appears to be related to the search for invariants, what they call the "notice invariants heuristic." Yet it remains unlikely that such a heuristic could be generalized to other problems since it is specific to this particular problem -- and it also remains unclear how one should go about generating an appropriate problem representation in the first place. What commands could one give to a computer that would have this desired effect? Apparently even a Nobel Prize winning computer expert like Herbert A. Simon still can't tell us how to program a computer so that it can be sensitive to rho relations.

Finally, there is Sternberg and Davidson's book, The Nature of Insight, published just last year by MIT Press in Cambridge, MA. If I had lots more time, I should have discussed much of its contents. It is a rich resource; I recommend it heartily to anyone interested in the psychology of productive thinking and of insight. Most of its chapters, especially the earlier ones, are directly relevant to the title of this talk; I could have used several of them almost verbatim here instead of my own talk. Richard E. Mayer's opening chapter, for instance, is entitled "The Search for Insight: Grappling with Gestalt Psychology's Unanswered Questions." The next chapter, by Roger L. Dominowski and Pamela Dallob, "Insight and Problem Solving," is equally relevant, dealing with characteristics of problem solving, the difference between reproductive and productive thinking, the nature of insight, understanding, functional fixedness, restructuring, and so on. The "epilogue," by Jonathan Schooler and colleagues, entitled "Insight in Perspective," touches on the definition of insight, the causes of impasses during the process of solving a problem, how impasses are overcome, coherence, and other crucial issues. There are chapters by leading figures in modern cognitive psychology: Robert Weisberg, Mary Gick, Howard Gruber, Robert Sternberg, Janet Davidson, and many others. If you want "The Contemporary Perspective on the Psychology of Productive Thinking," the way to get it is to read the Sternberg and Davidson book. I wish I would have had the time to share its contents with you in detail -- but that could take days or weeks rather than just an academic fifty-minute hour or so.

Two things remain. First, does it look as though the modern computer-based information-processing paradigm that is dominating cognitive psychology will be able to deal adequately with the central issue of productive thinking? Let me not belabor my answer to that question. In any event, people today are still reading and pondering Max Wertheimer's book, Productive Thinking. Its striking descriptions and analyses of insights are as fresh today as they were a half century ago, and pose a serious challenge to any blind, automatic, or mechanical models of human thinking. No theory of cognition can afford to ignore that productive thought is often insightful, indeed sometimes exhilarating.

The other item concerns spherical triangles and the color of a bear (**T 19**). Where else on the surface of the earth, other than at the north pole, can one go one mile south, then one mile east, then one mile north, and end up standing at the same spot one started from? Try starting from a spot that is one mile north of the south pole. No; that won't do, because you can't go east from the south pole, only north. How about a little further north yet (**T 20**), say one mile north of a circle just north of and surrounding the south pole, that is exactly one mile in circumference? You go the one mile south to that circle, go east around the circle, and then head north again for one mile, <u>exactly retracing, in the opposite direction, the route you had taken south</u>. You can, of course, start from any point that is one mile north of that circle just north of the south pole that is one mile in circumference; the locus of points from which you could start is a circle. And: <u>that</u> circle is not the only solution. Because the critical circle on which you go east need not be exactly one mile in circumference; any <u>perfect fraction</u> of a mile would work just as well. If it were, say, one third of a mile in circumference, you would walk one mile due south to the circle, then go east around it three times, then head back north for one mile, exactly retracing the route you had gone south. It's a fascinating problem; you might enjoy thinking about it some more.

I wish you all productive thinking in all your endeavors. Thank you for your attention.

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Pas de l'y a Rhône que nous

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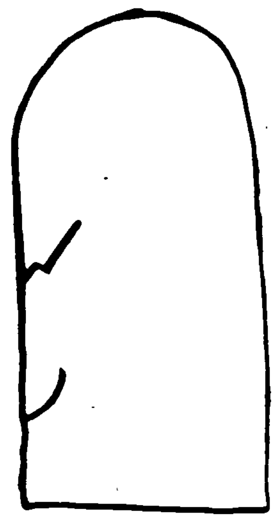

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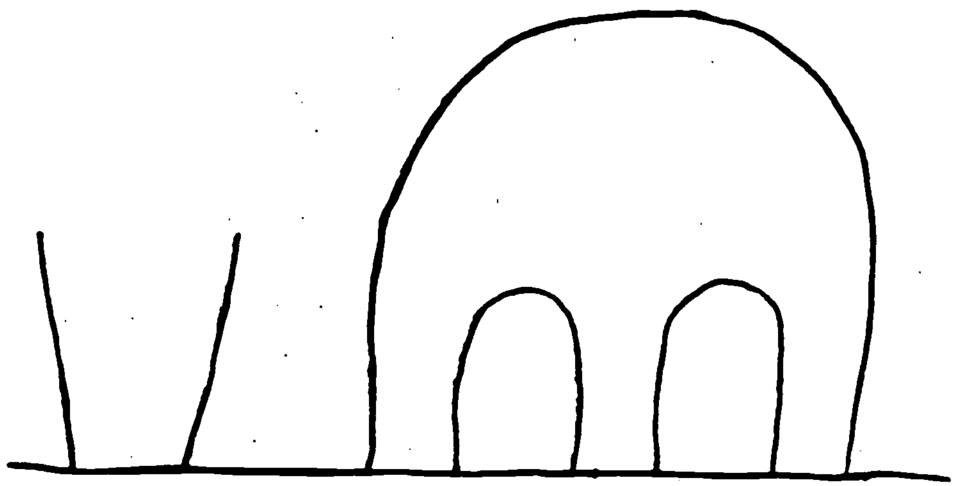

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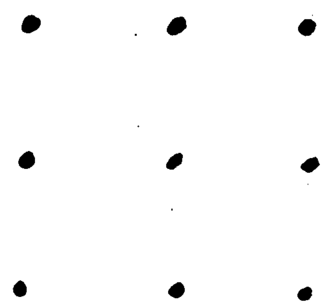

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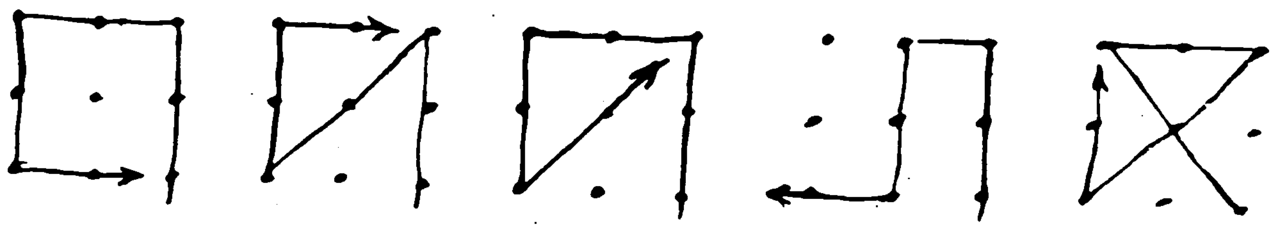

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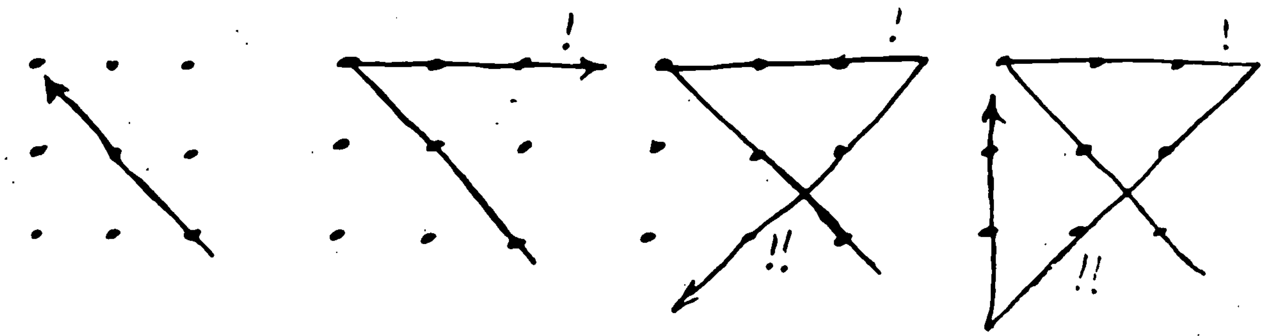

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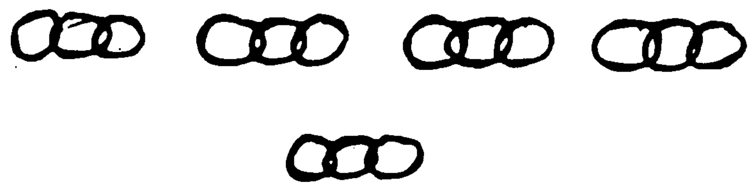

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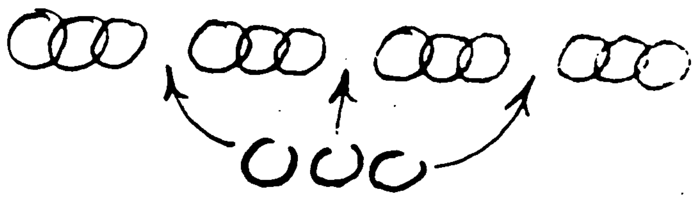

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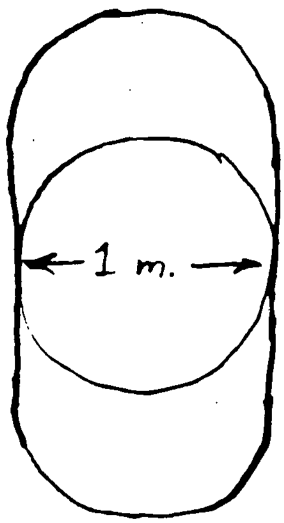

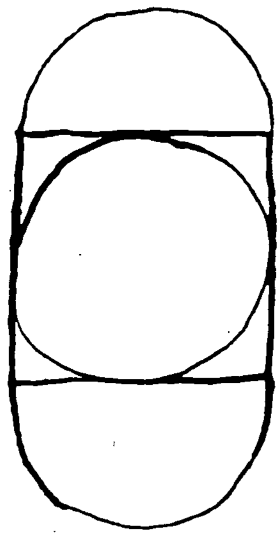

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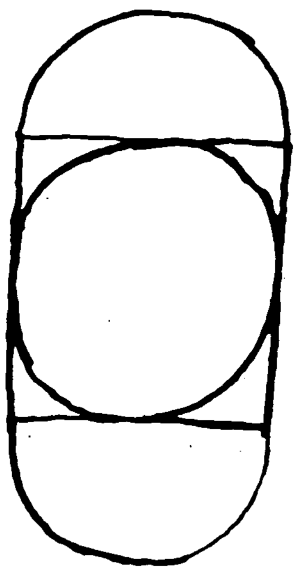

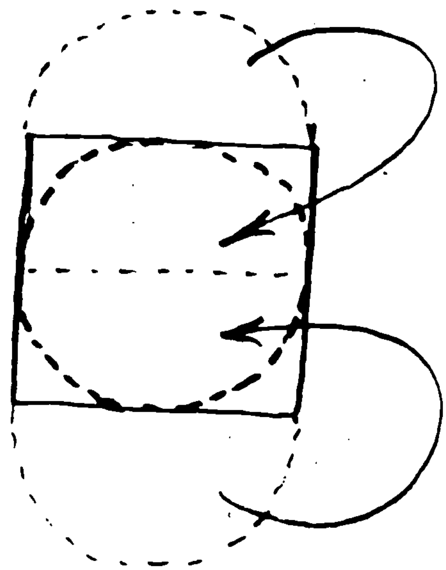

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one mile due <u>south</u>,

then one mile due <u>east</u>,

then one mile due <u>north</u>

14

Max Wertheimer's observations about productive thinking

1. Productive thought involves transforming the

   representation of a problem from
   "S1," a vague, fuzzy, incomplete and
   confused representation that is blind
   to essential structural features of
   the problem, into

   "S2," a representation that is clear, has
   no gaps in it, makes sense, and views
   each part of the problem in terms
   of its place, role, and function
   within the problem.

15

Max Wertheimer's observations about productive thinking

2. Such transformations are

   a) hampered by blind search, "functional fixedness" or rigid set or Einstellung, empty associations, "and-sums," conditioning, school drill, bias, etc. and are

   b) aided by open-minded exploration of the problem, searching for its essential, crucial features, and its "rho relations."

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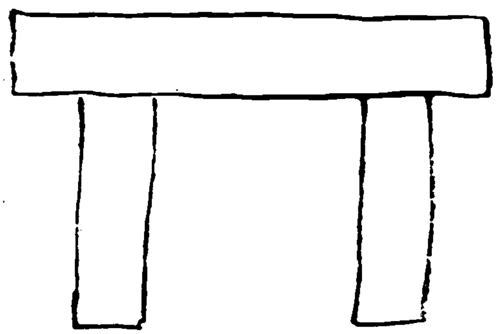

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Max Wertheimer's observations about productive thinking

3. This perspective generates several groups of potentially productive areas for research:
   a) laws governing segregation, grouping, centering, and structural transposability,

   b) how relations between parts and their wholes govern the possible operations on parts that take into account the part's place, role, and function within the whole of which it is a part, and

   c) the nature of "outstanding wholes," "good Gestalten," indeed of "rho relations" themselves.

18

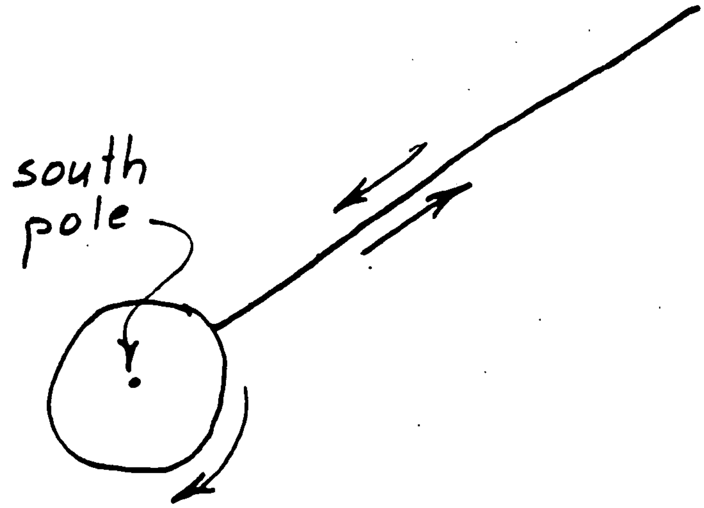
one mile due <u>south</u>,

then one mile due <u>east</u>,

then one mile due <u>north</u>

19

south, then
east, then
north



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