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DUNCKER ON THINKING:
An Inquiry into Progress in Cognition

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NOTE: This is a first accumulation of material for this paper.
It will be seriously revised, shaped and compressed.
But it does give the general flavor of what I intend to do.
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A Century of Psychology as Science:
Retrospections and Assessments

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DUNCKER ON THINKING: An Inquiry into Progress in Cognition

1. INTRODUCTION

How shall we cast light on what we have learned about cognition in the last 100 years? It is a pleasant enough task I have, as part of the American Psychological Association's centenary celebration of the establishment of Wundt's Laboratory in Leipzig. Yet, as in so many tasks, it is pleasant initially to accept and contemplate; pleasant also in the final delivery. Yet, anxious difficulties arise in bridging the gap between the acceptance and the delivery -- a gap that arises for this as for every other problem.

Cognition is only a part of Psychology and for much of the century a pretty minor part. This derives from a larger history -- of how associationism and then behaviorism gave a particular cast to the study of the mind, how that cast emphasized learning, how the reactions to that, especially Gestalt psychology, found their main ground in perception. All this is oft recounted. The last quarter of this century has witnessed the return of the oppressed to a position of prominence: The phrase "the cognitive revolution" graces multiple introductory paragraphs. There is a story to tell about that revolution, though it too is generally familiar in its major outlines. But our problem is not the recounting of history. Science celebrates its history, not by recounting, but by critical appraisal. Our task is to find out what we have *learned*. At least, that is the agenda for this occasion.

I have selected a way. I will consider a particular scientist, Karl Duncker, and indeed a particular work, *Zur Psychologie des productiven Denkens*, originally published in 1935 and translated as *On Problem Solving* in 1945 as a *Psychological Monograph*. Duncker studied how human adults solved various mathematical and practical problems. The most well known is probably the X-ray problem, which asks how a beam that destroys all tissue, healthy and diseased alike, can be used to destroy only a tumor, sparing the healthy tissue. Duncker used *thinking-aloud* protocols as a source of data, analyzing in detail the processes that his subjects went through and how the solutions they found (or failed to find) reflected the structure of the task. The concept of *functional fixity*, familiar to all psychology students, at least up to a decade ago, originated in this study.

I will ask what have we learned since Duncker. What did he know and what were his scientific tasks? What does cognition now know, what are its scientific tasks and where does it stand on Duncker's tasks?

You have a right to know why I selected this way. It certainly solves my problem -- transforming an open and unstructured task of how to deal with the whole of the history of cognitive psychology into a closed and finite task. To you, the solution must certainly appear sudden. How did I ever think of *this*!

Actually, I thought of this a long time ago. I do not recall exactly when I first read Duncker, sometime in the late fifties.[1] Having had no formal training at all in Psychology, I was digging around understanding what was known as my interests deepened in problem solving and cognition. I did purchase my own copy of Duncker's monograph, which I still have. It's full of marginal notes -- a rare thing for me, since I never have quite thrown off the guilty feelings about actually writing in a printed book. But Duncker made an impression on me. I made a note to myself then that Duncker would make an interesting topic for a paper, one that would be at once an appreciation and a critique. Now, in 1979, the opportunity has arisen and I have seized it.

Having chosen a focal point, my first obligation will be to provide its historical context. I must put Duncker in place so you see why this choice of mine is appropriate to understanding what we have learned about cognition, over and above being a working out of my own personal agenda. Only then can we settle down to see what Duncker knew about problem solving.

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[1] It was after the initial work on the Logic Theorist program (Newell, Shaw & Simon, 1958), for we did not cite Duncker in that paper, but soon thereafter while working on GPS (the General Problem Solver) (Newell, Shaw, & Simon, 1960).

2. The Historical Context

Lets start with the hundred year time line, which is layed out in Figure 2-1. First, note that Duncker (1935) occurs at about the halfway mark in the century; we have also noted a direct predecessor (Duncker, 1926) and the translation to English (Duncker, 1945). Duncker was a student of Max Wertheimer and Wolfgang Kohler; he dedicates his work to them jointly. This monograph was essentially the only thing Duncker wrote about problem solving, at least that made it into the scientific literature.[2] Duncker did a few things in perception, but only this one on thinking. This may have been because he died early, in 1940 when he was only 37 (he was then at Swarthmore with Kohler). In any event, our inquiry can be neatly localized to this one work.

Second, observe the great cluster of events that occur in the second half of the fifties, below the dotted line. This signifies the start of the shift to an information processing viewpoint -- the start of the revolution in cognition. It can be seen in the variety of different strands -- Broadbent, Miller, Bruner-Goodnow-Austin, Chomsky, Tanner-Swets, etc. All of them were generated out of a rapidly shifting conceptual base growing out of the development of communications and computer technology, and the use of mathematics to deal with the operation and behavior of systems, as in game theory and operations research. These strands are quite separate in many ways, and this will claim our attention in a moment. Their confluence -- their *unity in diversity* to use a well worn phrase -- in reflecting a common underlying view, while dealing with many separate aspects of human behavior, produced almost literally a conceptual explosion. We have documented our assessment of this critical period (Newell & Simon, 1972); recently a short note by George Miller agrees (Miller, 1979).

The major sense of the question, "What have we learned in cognition?", must be, "What has this shift to the information processing paradigm wrought in comparison to what we knew before?"

I draw your attention next to three textbooks on thinking, written just before the '58 tsunumi (Humphrey, 1951, Vinacke, 1952, Johnson, 1955). These provide as neat a fix as one

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[2]The only other reference on problem solving and thinking I have been run across is Duncker (1935b), and this only by Duncker himself (1935a). I have, however, not conducted an exhaustive search.

1880's

1890's James, Principles of Psychology, 1890.
Thorndike, Animal Intelligence, 1898.

1900's

1910's Dewey, How We Think, 1910.
Selz, Zur Psychologie des productiven Denkens und des Irrtums, 1922 (1913).

1920's Kohler, The Mentality of Apes, 1925 (1917).
Duncker, A qualitative study of productive thinking, 1926.

Maier, Reasoning in humans, 1930,31.
1930's Tolman, Purposive Behavior in Animals and Men, 1932.
Duncker, Zur Psychologie des produktiven Denkens, 1935.

Kohler 1940
Luchins, Mechanization in problem solving, 1942.
1940's Duncker, On Problem Solving, 1945 (translation of Duncker, 1935).
Wertheimer, Productive Thinking, 1945.

Humphreys, Thinking, 1951.
Vinacke, The Psychology of Thinking, 1952.
Johnson, The Psychology of Thought and Judgment, 1955.
1950's ----------
Bruner, Goodnow & Austin, A Study of Thinking, 1956.
Miller, The magical number seven, plus or minus two, 1956.
Chomsky, Syntactic Structures, 1957.
Broadbent, Perception and Communication, 1958.
Newell, Shaw & Simon, Elements of a theory of human problem solving, 1958.

1960's Newell, Shaw & Simon, GPS: A program that simulates human thought, 1961.
Neisser, Cognitive Psychology, 1967.

Johnson-Laird (ed), Thinking, 1975.
1970's Estes (ed), Handbook of Learning and Cognition, 6v, 1975-78.

Figure 2-1: Key events in one hundred years of the study of cognition.

could want on what had been learned to that point.[3] They show that the work of Duncker was indeed an important and accepted component of the then current view of thinking. It needs to be stated immediately that the "then current view" was not exactly a coherent one. With due regards to their respective authors, these books make dull reading, providing a congeries of assorted experimental facts, tenuously related theoretical ideas and historical notes on different schools. Duncker's work is not scattered in itself, nor is it dull; but his work resides as one strand among a number of others.

Duncker was a Gestalt psychologist, as noted. Though the principle focus of the Gestalt work was in perception, both his mentors had worked on thinking: Kohler with the apes at Tenerife in 1914-17 (Kohl25); Wertheimer with children in the classroom (Wertheimer, 1945). Both of these efforts emphasize the *understanding* of relationships and the suddenness with which such insight came. Both efforts were justly famous. Given that Kohler and Wertheimer were also two thirds of the Gestalt triumverate, it must be said that Duncker is a minor character on the stage of scientific history. Boring (1950) allots him just two sentences, followed immediately by the plaint that the mere listing of names is the bane of scientific histories. That did not keep Duncker's work from being extremely well known and giving impetus to much subsequent research, most especially on the scientific problem that Duncker had called *functional fixity*.

Duncker is therefore part of what the textbooks called "the Gestalt theory of thinking". Gestalt psychology was a reaction to associationism and its behavioristic follow-on, and it never gave up its rhetoric of protest, even when, as Boring (1950) believes, it was "dying of success", its main points assimilated. However, in the study of higher mental processes it had the field somewhat to itself. Certainly the Behaviorists didn't make other than occasional forays into the area and engage in their own reductionist rhetoric about thinking and problem solving being nothing but learning. Thus Duncker's work bears strong kinship with others (Luchins, 1942, Katona, 1940) and this group in total occupied a prominent position in a non-prominent province of psychological study. Duncker himself, by the way, exhibits little of the Gestalt family's need to score on the Behaviorists. He finds good things in everybody, even Thorndike with his studies on cats in puzzle boxes (Thor98), taken by most to be the hard rock on which the Behaviorists cast out meaningful insightful problem solving and replaced it with trial and error.

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[3]For those interested, these authors have also each written a book on thinking well after the shift to an information processing viewpoint had occurred (Humphrey & Coxon, 1963, Johnson, 1972, Vinacke, 1974); these provide lovely data on the extent to which new paradigms are universally perceived and taken up. It is barely apparent in these later works that anything specifically of an information processing nature has happened, though both Johnson and Vinacke speak in terms of the explosion of work on thinking and problem solving.

By selecting out Duncker, it is apparent that I jump in at midcentury, and neglect the earlier history of work on thinking, though I have recorded a few of the antecedents in the figure. This is mainly because I want the cumulated knowledge about cognition as it existed just before the advent of information processing psychology. I do not need to ask how psychology arrived at Duncker; I am taking him as a given, not as something to be explained. The issue, of course, is not quite so simple. The gap between Kohler in 1917 and Duncker in 1935, almost twenty years later, is not all that great. Thus there is a judgment on my part that the important question about what we have learned in cognition is the one I am posing, not what did Duncker learn that was was not known before him. Moreover, it turns out that the earlier period has been treated in a very neat fashion by the Mandlers (Mandler & Mandler, 1964) in a book entitled *Thinking: From Association to Gestalt*, which starts with Aristotle and ends with Duncker. I recommend it.

I need to add one side note. Otto Selz (1881-1943) is the repeatedly rediscovered skeleton in cognitive psychology's closet. Selz was a psychologist educated under Kulpe who wrote an immense work on thinking (Selz, 1913, Selz, 1922). He has had essentially no impact on psychology; yet he understood a number of essential elements of a processing explanation of thinking, especially the notion of methods.[4] Almost none of his work has been translated (a short piece now exists in the Mandlers, 1964), though chapter length treatments exist (Humphrey, 1951, DeGroot, 1965). I could have selected Selz for this occasion, but Duncker constitues my unfinished business.

Lets us return to the post-fifties development. It is called both the information processing approach and the new cognitive psychology; it is perhaps soon to be called *Cognitive Science*, if the nascent movement to provide an umbrella name for linguistics, artificial intelligence and cognitive psychology takes firm root. We need to understand a bit about it before we can finally go to work on Duncker.

Substantively, the underlying proposition is that theories of human voluntary behavior are to be sought in the realm of *information processing systems*. This is to be understood in the same sense that theories of macrophysics are to be sought in the realm of *differential equation systems*. That is, there is a type of system -- called an information processing system -- that consists of *memories* and *processors* (also *transducers*, *switches*, *controls*, *data operations* and *links*, to be complete, but no matter). The system works on an internal medium

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[4]We did pay our respects to him (Nowell, Shaw & Simon, 1958), having been introduced to him by De Groot, the Dutch psychologist who studied thinking in chess (DeGroot, 1946); though it cannot be said that Selz had any real impact on our work.

of *data structures*, which represent things; and the operations it performs on these representations is such that is can compute new representations and thereby generally manage its affairs in the world. This is an immense class of systems, all with a family resemblance -- active, autonomous, a central inner-life, rule-governed, limited structural and resource capacities, discrete, etc. To repeat: The central agreement is that a human is this kind of a system, it being open and the object of empirical investigation to find out the particulars. Such an agreement is often phrased by saying that there is a common *language*, but I find it preferable to emphasize the substantive aspects of the type of system to be used to model the human.

Important aspects of other major attempts to understand human nature can also be described in terms of the type of underlying system they posited. The *stimulus-response* systems of behaviorism, the *fields* of Gestalt psychology, the *hydraulic* systems of Freudian psychology, even some minor ones such as the *Markov* systems that mathematical psychology briefly toyed with. One can often show some equivalences between such general classes of systems, as in Suppes attempt a few years ago to demonstrate that any information processing system could be modeled by an SR system (Supp7x). Such demonstrations, while interesting, have only minor significance. What counts is how the scientist thinks with a given system view -- what sort of simple versions he is led to posit to explain some phenomena, etc.

The information processing revolution has in common this fundamental system view. It is otherwise importantly diverse, as the cluster of work in 1958 in Figure 2-1 indicates. Broadbent (1958) represents the line from control and communication engineering; it has focussed on working out the structure of the basic preceptual and processing mechanisms. Miller's paper on chunking and the limits of short term memory can be taken as part of that, as can the introduction of signal detection theory by Swets & Tanner (1956). Our own work (NeweS58) can be taken to represent the line from programming and artificial intelligence. This is the *symbolic* level of information processing and is to be distinguished from the *register-transfer* level considered by Broadbent and company, exactly as software to hardware. These would be considered two entirely distinct system views -- except the study of information processing systems has welded them into a single view. [MORE] This symbolic level, represented also by Bruner, Goodnow & Austin (1956), is what provides the notions of *plans*, *programs*, *procedures*, and *strategies*. Later on it also provides the issue of the organization of knowledge in long term memory (AndeB73, Quil68). Chomsky (1957), of course, represents the line from linguistics, with the view -- new to linguistics as well -- of rule-governed generative systems. This oversimplified picture I am giving does most violence here, since strong elements of the so-called structuralist tradition exist in Chomskian linguistic, which can be clearly distinguished from the engineering and mathematical traditions

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