Children's Thinking: What Develops?

EDITED BY

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CHILDREN'S THINKING: WHAT DEVELOPS?

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In questions of science, the authority of a thousand is not worth the humble reasoning of a single individual.

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Preface

In 1963, John Flavell posed one of the truly basic questions underlying the study of children's thinking; his question was simply "What develops?" The 13th Annual Carnegie Cognition Symposium, held in May 1977, seemed to me an appropriate forum for considering what progress had been made toward answering this question in the past 15 years. Therefore, when I invited participants for the Symposium, I asked them to explicitly consider the issue as it applied to their areas of greatest current interest. Both the range of the answers they produced and the quality of the evidence they marshalled to support their views attest to the continuing importance of Flavell's original question; they also attest to the vitality of the field of cognitive development.

I have arranged the chapters within the book into three sections: memory development, development of problem solving skills, and development of representational processes. The first section concentrates on the area of memory development. In Chapter 1, Brown and DeLoache present an overview of current research in this field. Of particular interest is their contrast of memory development research with research on problem solving; they argue strongly that the two areas have exactly opposite sets of strengths and weaknesses. Brown and DeLoache also review Soviet research indicating that young children may have far greater memorial capacities than they usually are given credit for. Finally, they nominate their prime candidate for what develops: metacognition.

In Chapter 2, Case presents a new general theory of memory development. The theory is applied to a very broad range of childhood, from the first years of life through adolescence. Ideas of Piaget, Pascual-Leone, and Newell and Simon are given prime roles within it. M-space and executive strategies emerge as especially important sources of development within Case's theory.

In Chapter 3, Chi addresses directly the question of what causes developmental differences in memory. She indicates that there are three likely possibilities: changes in capacity, changes in strategies, and changes in knowledge about the material that is being memorized. In one of the most dramatic experiments reported in the volume, Chi demonstrates that 10-year-olds who are knowledgeable about chess outperform mildly knowledgeable adults on both mnemonic and metamnemonic tasks involving chess configurations. This was not due to the children having better memories in absolute terms—when tested on standard digit span tasks, the adults showed the usual superiority over the children. Thus, it is not surprising that Chi emphasizes sheer amount of knowledge as an important component of development.

Flavell discusses the three memory development articles in Chapter 4. As with all of the discussions, his comments are too diverse and demand too much understanding of the articles to be easily summarized here. They definitely should be read carefully, though; "What develops?" is his question, after all.

The next section of the book concerns the development of problem-solving skills. In the first chapter in this section, Chapter 5, I explore the origins of scientific reasoning. Children seem to acquire initial systematic strategies on a wide variety of scientific problems during the period between age three and age five. Their ability to learn systematic strategies that they do not already possess also improves dramatically during this period. The question is how we can explain these developments. Within the research that I present, improved encoding emerges as an especially important explanatory factor.

In Chapter 6, Trabasso, Isen, Dolecki, McClanahan, Riley, and Tucker review what is known about children's understanding of class inclusion; they also present a large number of new experiments of their own. The chapter is organized around a task analysis of what children would need to know to comprehend the class inclusion concept. This analysis indicates eight separate components. Represented among these are the physical display, interpreting the question, finding referents for the subordinate and superordinate classes, quantifying them, comparing the quantified symbols, and deciding on the correct amounts. Interestingly, when all the evidence is in, Trabasso et al. conclude that all eight components may be important sources of developmental change.

Klahr, in Chapter 7, examines three- to five-year-olds' ability to plan ahead. The task he uses is a variant of the familiar Tower of Hanoi, beloved to all students of problem solving. Klahr finds that children pass through a number of knowledge states on their way to understanding how to solve such problems. These knowledge states are reflected not so much in how many moves children can make without erring as in the types of moves they can make. Klahr also finds that at least some young children are capable of

planning surprisingly long and complex sequences of activities. He nominates procedural knowledge as an especially important source of development.

In the final chapter in the problem-solving section, Gelman analyzes the development of counting skills. Her focus is on very young children, two- to four-year-olds. She ingeniously demonstrates that even before their performance is entirely accurate, such children often have considerable understanding of the principles underlying counting. Gelman sees development as occurring primarily in the range of situations in which these counting principles are correctly applied.

After Greeno's discussion, in which he considers what Piaget, Binet, Thorndike, Wertheimer, and Dewey might have to say about the problem-solving papers, we turn to the third and final section of the book, the development of representational processes. In Chapter 10, Nelson considers one type of representational development, the development of language skills. Nelson uses the script formalism to examine children's understanding of mealtime routines in three situations: home, the daycare center, and McDonald's. She finds that children as young as three and four years understand what is constant and what is variable within each setting. Elaboration of scripts emerges as an important aspect of development in this report.

Gregg, in Chapter 11, examines children's exocentric representations, their ability to take perspectives other than their own. The experimental situation involves three- to five-year-olds in guiding the Turtle, a computer-controlled robot, through a maze known as Turtle Town. The child always sits in the same place and uses a button box to make the Turtle turn left or right or go straight ahead; thus, he is forced to adjust his spatial perspective to that of the Turtle. Gregg suggests that development on this task is dependent on increasingly elaborated frames. This formalism emerges as quite similar to the scripts Nelson speaks of.

In Chapter 12, Kosslyn examines the development of another representational process, visual imagery. Taking seriously the metaphor that the child is father to the man, Kosslyn describes how he has worked back and forth between research with children and research with adults to derive theories of both mature and developing imagery systems. Among other accomplishments, Kosslyn has written a running computer simulation of how people form images and how they use them. The article includes both descriptions and prescriptions concerning how to develop psychological theories.

In Chapter 13, Dorothea and Herb Simon use protocol analysis and computer simulation techniques to analyze the transition from unskilled to skilled problem solving in physics. Their article focuses on the performance of two individuals on high school level kinematics problems. One of the subjects is a novice at such tasks, the other a relative expert. The contrast in the equations they use on different problems points to the importance of physical

intuition in this domain. Physicists and others have often spoken of such intuition as crucial to skilled performance, but few attempts have been made to specify exactly what the term might mean. The Simons' chapter is a step toward this goal.

Finally, in the last discussion of the book, Bower critiques each of the representational development articles in turn, and then suggests that rather than playing the role of Grand Inquisitor, he would prefer to have been the Grand Cheerleader for the Symposium.

Scanning over all of the articles, several themes emerge; I think that these are quite revealing about current directions within cognitive development. One of the themes concerns the increasing age range that is coming under scientific scrutiny. Numerous investigators (e.g., Gelman, 1978; Neimark, 1975) have commented that cognitive developmentalists have concentrated their attention disproportionately on the age range between five and ten years. This situation appears to be changing rapidly. No less than six of the 11 articles in the volume (Brown and DeLoache, Gelman, Gregg, Klahr, Nelson, and Siegler) focus primarily or exclusively on children below the age of five. At the other end of the spectrum, there is also increasing appreciation of the relevance of research with adults to the study of development. This is most directly manifested within the chapters written by Chi, Kosslyn, and the Simons, but to varying degrees it is seen in almost all of the contributions.

Another apparent trend is the increasing focus on what children of given ages *can* do rather than on what they cannot do. This is especially evident in the work with very young children. Traditionally, children below age seven seem to have been included in cognitive development experiments primarily to provide a baseline against which cognitive growth could be measured. Yet, in the present volume, we hear Gelman speaking of the counting principles three- and four-year-olds understand, Nelson speaking of the scripts they know, Klahr describing the plans five-year-olds can formulate, Gregg indicating the nonegocentric perspectives they can take, and me describing the systematic rules they can use. Brown and DeLoache point out in Chapter 1 that it is much more informative to be told what children of any age are doing than to be told what they are not doing; the subsequent chapters in the book indicate how right they are.

Another trend evident in this volume is an emphasis on using more natural, nonlaboratory-oriented tasks. There have been many recent calls for more ecologically valid investigations in all domains of psychology (e.g., Charlesworth, 1976; Neisser, 1976). These calls seem to be having a substantial influence on students of cognitive development. Some of the tasks described in this collection are taken directly from the day-to-day lives of children: remembering a grocery list (Brown and DeLoache), counting (Gelman), and mealtime routines (Nelson). Others are tasks that many children encounter in school: balance scales, projection of shadows,

probability problems (Siegler), and kinematics problems (Simon and Simon). The game of chess (Chi) would also seem to qualify for the ecologically valid seal of approval.

A final direction in which the field seems to be going is toward increasing use of formalisms to represent what children know. The formalisms are quite diverse, ranging from computer simulations (Klahr, Kosslyn, Simon and Simon), to frames and scripts (Gregg and Nelson), to principles, rule models, and flow charts (Gelman, Siegler, and Trabasso et al.) and to M-space models (Case). In all instances, there seems to be a recognition that verbal descriptions are often vague and ambiguous and that more explicit languages are necessary if we are to build rigorous and testable theories; it therefore seems that the representation of knowledge will become an increasingly important issue in the coming years.

I would like to thank a number of people for their work on this Symposium. Elaine Shelton contributed greatly to the editing of the book and took care of a million and one details that arose during its preparation; without her help, putting together the book would have been far more difficult. Ed Sieger did the bulk of the typing and did it extremely well. Greg Long took care of arrangements during the Symposium itself, and made everything run more smoothly. Finally, Betty Boal, who has shepherded through all 12 of the previous Symposia, contributed her considerable experience and expertise to this one as well. I owe her a considerable debt of gratitude.

A different type of contribution was made by my wife Alice and my children Beth and Todd. Alice took over many responsibilities while I was working on the book, gave me good advice, listened patiently, and, in general, helped keep me on an even keel. Beth and Todd never hesitated to remind me that from some perspectives, at least, whether Daddy will play horsie is more important than whether a manuscript gets sent off on Thursday or Friday. It is difficult to argue with them.

Robert S. Siegler

To My Mother and Father

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MEMORY DEVELOPMENT

1 Skills, Plans, and Self-Regulation

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I. INTRODUCTION

In thinking about memory development, we have rarely questioned the essential similarity of the processes studied under the rubrics "problem-solving skills" and "memory strategies" (Brown, 1975a, 1977, in press a). A general class of information-processing models, with their emphasis on routines controlled and regulated by an executive, seems suitable for describing the major psychological processes of interest in both domains. However, because our charge is to function under the memory development heading, we have decided to refocus our thinking from our usual position of regarding the problem-solving and memory people as those who study the same processes on different tasks. Instead, we have begun by looking for any interesting differences between the major emphases and accomplishments in one field that could intelligently aid the development of the other. There do appear to be some psychologically interesting differences, not only in the tasks and skills studied but in the depth of the analyses of those tasks and skills and in the commitment to addressing instructional goals. In the first part of this chapter we highlight some of these differences between the two approaches and try to illustrate a weakness in the current mainstream of memory-development research. In the second part we concentrate on an area of concern to both the problem-solving and memory-development literatures: self-regulation and control, our candidate for the most fundamental difference between the experienced and the naive. In the final section we indicate new problem areas and new ways of considering what it is that develops with age and experience.

II. DIFFERENCES BETWEEN THE MEMORY DEVELOPMENT AND PROBLEM-SOLVING APPROACHES TO COGNITIVE DEVELOPMENT

Because our task is to consider what memory theorists have to say about development, we approach the issue from the perspective of the memory-development literature. Studies of a few aspects of memory dominate the field at this time, at least in number if not in content. Before we address the issues central to such research, a brief history of the way developmental psychologists interested in memory have approached the question of "What develops?" is illustrative.

A. Early Studies

Prior to the 1960s, the question "What develops?" would not have been raised. Obviously, memory develops. Lacking a fine-grained analysis of memory processes, early researchers selected tasks and age groups somewhat randomly. They found that on most tasks older children remembered more than younger ones, and slow learners had more difficulty remembering than those of average ability! The predominant explanation, when one was offered at all, was that immature learners have a limited memory "capacity." As they mature, this capacity increases, allowing them to retain more. The underlying metaphor, whether implicitly or explicitly stated, was of the mind as a container: Little people have little boxes or jars in their heads, and bigger people have bigger ones. Any demonstration of inferior performance on the part of the smaller person proved the capacity limitation "theory," not surprisingly since such a theory was merely a restatement of the data (Chi, 1976). The same general state of affairs also characterized the problem-solving literature, where early studies also showed poor performance by young children on a variety of tasks. Explanations of why the young did poorly were either not forthcoming or involved a circular argument: Little people have little problem-solving capacity, a restatement of the data masquerading as a theoretical explanation.

More sophisticated, or simply more adventurous, theorists subdivided the metaphorical containers. They attributed the deficits in memory or problem-solving performance to a limitation in the space available in one of the main architectural structures of the information-processing system, with space defined in terms of the number of slots, spaces, or buffer units available to the system at any one time. It was thought that as a child matured, his available space increased. The correlation of digit span with age, intelligence, and general problem-solving efficiency was taken as firm support for this notion of increasing space with increasing age, and short-term memory was cited as the most likely culprit in the young child's mental overpopulation problem. It should be noted, however, that most developmental psychologists avoided the issue of architec-