Children's Thinking

Developmental Function and Individual Differences

Third Edition

David F. Bjorklund

Florida Atlantic University

Wadsworth
Thomson Learning™

Australia • Canada • Denmark • Japan • Mexico • New Zealand • Philippines • Puerto Rico
Singapore • South Africa • Spain • United Kingdom • United States

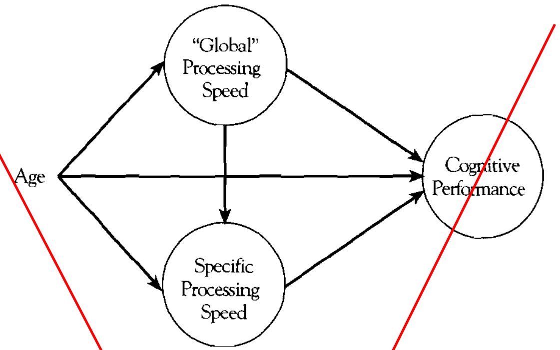

FIGURE 5-9 Model showing the possible relationships among age, global processing speed, specific processing speed, and cognitive performance. SOURCE: Adapted from "Processing Speed as a Mental Capacity," by R. V. Kail and T. A. Salthouse, 1994, *Acta Psychologica, 86,* 199–225. Copyright © 1994 by Elsevier Science Publishers BV. Adapted with permission.

cognitive architecture, much like the central processing unit of a computer is a basic part of the machine's hardware. Differences in this capacity change with age in regular ways and influence much cognitive functioning by limiting how much (or how quickly) information can be handled at any one time. Yet, age differences in speed of processing do not account for all age differences in cognitive performance. As Figure 5-9 shows, factors associated with age may directly influence cognitive functioning independent of processing speed, or age may affect task-specific processing speed. So although speed of processing is not everything, Kail and Salthouse (1994), like other capacity theorists, propose that it is perhaps the most important single factor underlying cognitive development.

Start here.

The Role of Strategies in Cognitive Development

Given that children have some mental resources available to them, what do they do with these resources to "think"? In other words, from an information-processing perspective, how do they process information? Information must be encoded or somehow represented in the cognitive system, and once it is in the mind/brain, something must be done with it. Perhaps the information—let's say the word *dog*—must be identified (a meaning must be found in memory for the visual stimulus), classified (as a small, four-legged, domestic mammal), compared with other stimuli or other items in memory (similar to cats; very different from sea slugs), or remembered for later on. Each of these operations (or set of operations) takes time and each requires experience to perform efficiently. Some may be executed automatically and unconsciously, whereas others may be executed only at the individual's discretion, with the mental operations and their results being available for conscious evaluation.

Much of the rest of this book will be concerned with developmental differences in these and other information-processing operations. In the present section, I would like to discuss a broad category of information-processing components—**strategies.** Strategies are goal-directed operations used to aid task performance. Strategies are usually viewed as being deliberately implemented, nonobligatory, and potentially available to consciousness (Harnishfeger & Bjorklund, 1990a; Pressley & Van Meter, 1993). And strategies develop.

Strategies are relevant to most aspects of cognitive development. For example, in memory development, commonly used strategies include rehearsing information or grouping to-be-remembered items by conceptual categories (for example, remembering all the outfielders on a baseball team in one group and all the pitchers in another). In mathematics, simple strategies of addition include counting on one's fingers or mental counting (for instance, for the problem 3 + 2 = ?, mentally starting with 3 and counting up two to arrive at 5). Strategies can be much more complicated and involve an evaluation component. For example, in reading, one must occasionally determine how well the recently read information is being understood. In all cases, the strategy is used to achieve some cognitive goal (remembering, adding, comprehending).

Although children often discover strategies on their own in the process of performing a task (Siegler & Jenkins, 1989), many important cognitive strategies are explicitly taught in school (Moely et al., 1992; Moely, Santulli, & Obach, 1995). In a classroom observational study, Barbara Moely and her colleagues (1992) reported that teachers in kindergarten through sixth grade taught a wide range of strategies that varied with the age of the child and the nature of the task. These included rote learning for simple repetitive tasks, elaboration, imagery, and self-checking, among others. Despite the diversity of strategies taught, Moely and her colleagues (1992) reported that the absolute frequency of strategy instruction was low. For example, specific strategy instruction was observed in an average of fewer than 3% of the teacher observations, with teachers providing some general instruction about how to deal with a task cognitively in 9.5% of the observations. In fact, 10% of the teachers observed in this study provided no strategy instruction at all. When focusing specifically on math instruction, however, second- and fifth-grade teachers were found to provide strategy or metacognitive instruction in nearly half of the observation intervals (Moely, Santulli, & Obach, 1995). Thus, strategy instruction in school varies with the teacher, the task, and the age of the children, with teachers generally providing children with instruction that is age-appropriate (that is, neither too simple nor too complicated for them to understand).

Mediational and Production Deficiencies

During the 1960s, it became obvious to cognitive developmental researchers that young children (usually preschoolers) typically do not generate and use the types of strategies that older children do. If strategies are so important to developmental differences in cognition, researchers reasoned, instructing a young child to use a strategy that is characteristic of an older child should result in changes in that child's cognitive performance.

Research using the logic of **training studies** flourished during the 1960s and 1970s and is still alive and well today. A three-step developmental progression of children's use of strategies was proposed. Early in development, children do not spontaneously generate a strategy to help them solve a task, and when children are shown a strategy, they are unable to use it effectively to guide their performance. This inability is called a **mediational deficiency** (Reese, 1962), meaning that a potentially effective strategy does not mediate task performance for young children. Presumably, these children do not have the mental apparatus to effectively use the strategy. For slightly older children (or for slightly simpler strategies), the imposition of a strategy results in improvement in task performance. In these cases, children do not *produce* the strategies spontaneously, but when shown what to do, they are able to follow instructions with corresponding improvements. Thus, they still have a **production deficiency** (Flavell, 1970); that is, they have the mental ability to use strategies but for some reason do not produce them without prompting. The stage of production deficiency is followed by a stage in which children produce strategies on their own without needing to have them imposed by an outsider.

Much cognitive developmental research through the 1970s focused on young children's production deficiencies (see Harnishfeger & Bjorklund, 1990a, for a brief history of research in strategy development). Many of the phenomena associated with concrete operations introduced by Piaget were examined from the viewpoint of production deficiencies. Demonstrations abounded, with researchers showing that 4-, 5-, and 6-year-olds could be taught to conserve (Gelman, 1969) and to take the visual perspective of another (Borke, 1975). Memory research used training studies extensively, demonstrating that under some conditions young children could be trained to use reasonably complex strategies such as rehearsal, organization, and imagery, although the effect of such training was often short-lived (see Schneider & Bjorklund, 1998; Schneider & Pressley, 1997; Chapter 8). It became clear that young children could be trained to use many of the strategies previously thought to be available only to older children. Tasks often had to be greatly simplified, and a trained 4-year-old rarely performed as well as an untrained 12-year-old, but younger children obviously had greater competence than psychologists had believed.

By showing that certain strategies could be taught to young children, researchers also illuminated something of the nature of what happens spontaneously in development. Thus, training studies were not done solely for their own sake (that is, to train children because they could be trained) but as a way of learning about the normal process of development.

What Are Production-Deficient Children Doing?

The emphasis on production deficiencies and their laboratory remediation resulted in a science that had a good deal to say about what older children do and about how to train younger children to resemble older children (at least in the laboratory). But it had little to say about what young children do spontaneously (Brown & DeLoache, 1978). If young children are not using strategies (unless we train them), what are they doing?

In recent years, developmental psychologists have concentrated on what production-deficient children do on their own. The answer is, basically, that they are also strategic. Preschool children, who do not spontaneously conserve liquid or organize sets of pictures according to familiar categories (such as animals, tools, and vegetables), nevertheless do things to help them perform tasks (see Wellman, 1988, for a review). These strategies often result in incorrect answers, but they are strategies nonetheless.

One simple but effective strategy used by 3- and 4-year-olds in trying to remember sets of pictures involves selectively attending to the pictures they want to remember (Baker-Ward, Ornstein, & Holden, 1984), including frequently re-attending to the stimuli, which reflects a form of visual rehearsal (Wellman, Ritter, & Flavell, 1975). Other early memory strategies include spontaneously labeling items presented for recall, a technique that is not very effective (Baker-Ward, Ornstein, & Holden, 1984), and using external memory cues. An example of the latter is found in the work of Heisel and Ritter (1981). Children were asked to hide an object in one of 196 containers, arranged in a 14 × 14 grid, so that they could remember the location. Children 5 years and older chose distinctive positions for hiding the items (for example, the corners), demonstrating a memory strategy. Three-year-olds did not use such techniques, although some of them did use the strategy of attempting to hide the object in the same location on all trials. Because the locations were not distinctive, this strategy did not help memory performance, but it does reflect the intent to do something to aid memory.

Assessing memory strategies in naturalistic settings (for example, children's homes), DeLoache, Brown, and their colleagues have reported strategies for children as young as 18 months (DeLoache & Brown, 1983; DeLoache, Cassidy, & Brown, 1985). The procedure involves a hide-and-seek game, in which a toy (a stuffed animal, for example) is hidden in one of several locations in a child's home. Following delays of several minutes, the child is asked to retrieve the toy. DeLoache and Brown reported that young children engage in strategic behavior during the delay periods, including looking or pointing at the hiding location and repeating the name of the toy. In more recent research by Cohen (1996), 3- and 4-year-old children played a game of "store," in which they had to fill customers' vegetable orders. To complete these orders, children could use a variety of strategies including addition (add a tomato to an array), subtraction (take a tomato away from an array), and recognizing that no changes in an array had to be made to fill the order. These young children used a full range of the possible strategies and became more efficient (that is, made fewer moves to fill an order) with practice. These results make it clear that production deficiencies are relative. Even very young children use strategies; the strategies that they use tend to be simple and to increase in efficiency with age.

Following the findings of DeLoache, Brown, and others, it seems clear that preschool children engage in some planning that warrants being called a strategy. Still, their strategies lack the effectiveness of the procedures used by older children and often may not aid task performance at all. However, Wellman (1988) asserts that preschoolers' strategies are every

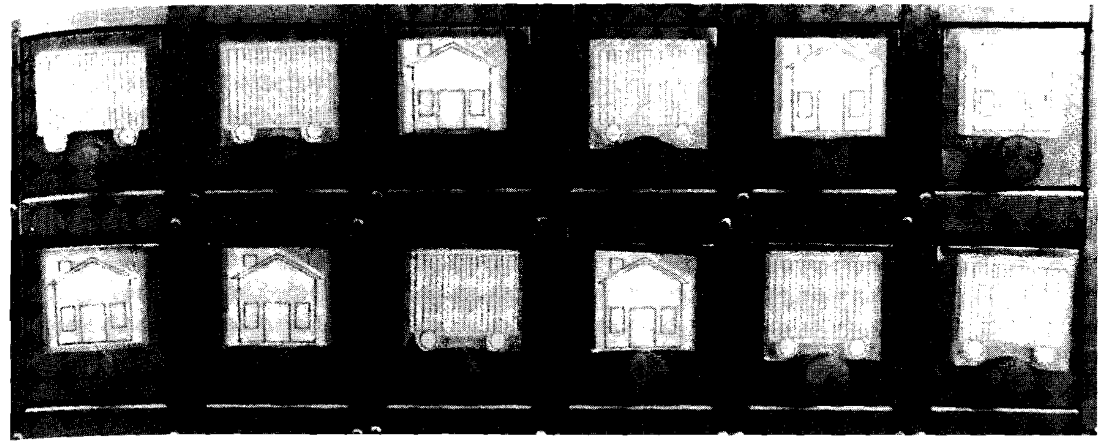

PHOTO 5-1 Apparatus used in studies of children's attentional strategies by Patricia Miller and her colleagues. (Courtesy of Patricia Miller.)

bit as goal-directed and performance-influencing as the strategies of older children are and that they are used in a wide range of situations. Recent findings support Wellman's interpretation, although we must be careful not to attribute too much in the way of strategic competence to the preschool child, for cognitive skills are clearly more effective and more easily observed in older children.

Utilization Deficiencies

Until recently, it was generally accepted that children progress from a mediational deficiency to a production deficiency and then finally are able to produce effective strategies on their own. But recent researchers have seriously questioned this progression and observed a phase in strategy development in which children use a strategy, sometimes as effectively as older children, but experience no benefit in performance. This phase in strategy development, first identified by Patricia Miller and her colleagues (Miller, 1990; Miller & Seier, 1994) has been referred to as a **utilization deficiency**. Most experiments performed by Miller and her colleagues involve children's use of a selective-attention strategy (DeMarie-Dreblow & Miller, 1988; Miller et al., 1986). Children (usually between the ages of 3 and 8 years) are shown a series of boxes with doors on top arranged into two rows of six columns (see Photo 5-1). On half of the doors are pictures of cages, meaning that those boxes contain pictures of animals. On the remaining doors are pictures of houses, meaning that those boxes contain pictures of household objects. Children are told to remember the location of one group of objects, either the animals or the household objects. They are also told that they can open any doors they wish during a study period. Children's attentional strategies can be examined by looking at the doors they choose to open during this study period.

The most efficient strategy, of course, is to open only those doors that have a drawing of the relevant category. In a series of experiments, Miller and her colleagues have found a developmental sequence in strategy development. In the first phase, preschoolers show no selective strategy, usually opening all the doors on the top first and then all the doors on the bottom, regardless of what picture is on the door. In the second phase, children use the selective strategy, but only partially: they still open many irrelevant doors. In the third phase, children use the strategy (that is, open mainly the relevant doors), but the strategy does not help them remember the locations of the items. This third phase constitutes a utilization deficiency. Not until the fourth phase, usually late in the preschool years, are children able to use the attentional strategy and also to benefit from its use.

Utilization deficiencies have since been documented in older children for more complex memory strategies, (Ackerman, 1996; Coyle & Bjorklund, 1996), reading (Gaultney, 1995), attention (Miller et al., 1991), and analogical reasoning (Muir-Broaddus, 1995), among others. Moreover, reviews of earlier research indicate that utilization deficiencies are very common, at least for memory strategies. For example, Miller and Seier (1994) reported strong or partial evidence of utilization deficiencies in more than 90% of all experiments examining children's spontaneous use of memory strategies. Similarly, utilization deficiencies have been found in more than 50% of memory training studies conducted over a 30-year period (Bjorklund et al., 1997). Earlier researchers typically dismissed their findings of young children using strategies but not benefiting from them, rarely discussing such results in their papers. It appears now, however, that such a finding is not a quirk or experimental error, but the typical pattern of strategy development.

The Cost of Strategy Use

One reason for researchers' reluctance to identify utilization deficiencies earlier is that in the prevailing theory, strategies, by definition, are implemented to facilitate task performance. Children's use of strategies in the absence of enhancements in task performance violated what everyone had come to believe was common knowledge. Why should young children who use a strategy not benefit from it? One speculation is that the execution of strategies requires substantial mental effort and that young children do not have enough information-processing resources to execute the strategy and still perform other aspects of the task as well (Bjorklund & Harnishfeger, 1987; Miller et al., 1991). That is, strategy use has a cost in mental effort, and young children exert so much of their limited resources executing the strategy that they do not retain sufficient mental capacity to perform other aspects of the task efficiently.

This possibility was demonstrated in a dual-task memory experiment by Bjorklund and Harnishfeger (1987). Third- and seventh-grade children were instructed in an organizational memory strategy (remembering all the words from a category together). In addition, the children were required to tap an index finger on the space bar of a microcomputer as fast as they could. Their tapping rate during the memory training was compared with their rate during a baseline period when no memory task was given and during a free-recall memory task for which no training instructions had been provided. Decreases in tapping rate during the memory tasks were used as an indication of how much mental effort the children were expending on the tasks. The more slowly the children tapped (relative to when they were performing no memory task), the greater the mental effort required to perform the memory task was presumed to be. That is, the more mental effort required for the memory task, the more interference (measured in terms of decreased tapping rate) there should be on the secondary, tapping task.

Bjorklund and Harnishfeger reported that both the third- and seventh-graders showed increased interference as a result of the training, relative to the free-recall task. Furthermore, both groups later used the strategy that they had been shown during training. This use was indicated by increased clustering in recall, with children remembering words from the same category together. Only the seventh-grade children, however, showed a corresponding improvement in the number of words they recalled, relative to the free-recall task. The third-graders remembered no more words as a result of the training than they did when no memory instructions had been given, despite the fact that they used the strategy and expended greater amounts of mental effort. We interpreted these results as indicating that the third-graders used too much of their limited mental capacity in executing the strategy to have enough left over for other aspects of the memory task, such as retrieving specific words. Strategies are supposed to provide greater efficiency in processing, and had the third-grade children mastered the strategy to a greater degree, their memory performance would probably have improved. Nevertheless, under the conditions of this experiment, the memory performance did not improve. Similar findings and interpretations have been reported for other memory strategies (Guttentag, 1984), simpler attentional strategies (Miller et al., 1991), and a more complex elaboration memory strategy (Rohwer & Litrownik, 1983).

Strategies are effortful. Young children process information less efficiently than older children, making them less likely to use a strategy spontaneously and less likely to benefit from the imposition of a strategy. Cognitive processing becomes more efficient with age, allowing children to execute more strategies and to use them with greater effectiveness.

Siegler's Adaptive Strategy-Choice Model

The foregoing discussion might give the idea that for any given task, children use one strategy and perhaps with time and practice eventually begin using another, more efficient strategy. Such a perspective reflects how a good deal of strategy research during the past 25 years has been done, looking at changes in a single strategy over relatively brief periods of time. This perspective is an overly simplified one, however. Recent research has shown that children use a variety of different strategies to solve a single problem, sometimes several strategies at a single time. Evidence for multiple and variable strategy use has been found everywhere it has been looked for, including arithmetic (Alibali, 1999), scientific reasoning (Schauble, 1990), memory (Fletcher & Bray, 1997), spelling (Rittle-Johnson & Siegler, 1999), and conservation (Church & Goldin-Meadow, 1986), among others (see Siegler, 1996).

This perspective of multiple- and variable-strategy use is best exemplified by the **adaptive strategy choice model** of Robert Siegler (1996). I discussed Siegler's model briefly in Chapter 2 in the section on "Selectionist Theories of Cognitive and Brain Development." Basically, Siegler adopts the idea of natural selection from Darwin's theory of evolution and applies it to cognitive development. Stated most simply, Siegler proposes that, in cognitive development, children generate a wide variety of strategies to solve problems and, depending on the nature of the task and the goals of the child, certain strategies are "selected" and used frequently, whereas others, that are less effective, are used less often and eventually decrease in frequency.

Siegler and his colleagues have demonstrated for a variety of strategies on a variety of tasks that children typically use multiple strategies, frequently switching from one strategy to another over repeated trials (Siegler, 1996; Siegler & Jenkins, 1989). The technique used by Siegler and his colleagues to assess children's multiple strategy use has been referred to as a **microgenetic method** and involves looking at developmental change within a single set of individuals over relatively brief periods of time—days or weeks, usually (see Miller & Coyle, 1999; Siegler & Crowley, 1991). For example, in learning to add, children frequently use a strategy that involves counting out loud both addends, called the sum strategy (for example, for 5 + 3 = ?, saying "1, 2, 3, 4, 5 [pause], 6, 7, 8."). A more sophisticated strategy, called the min strategy, is to begin with the larger addend (in this case, 5) and count up from there (for example, saying "5 [pause], 6, 7, 8."). A still more sophisticated strategy, known as fact retrieval, is "just knowing" the answer—retrieving it directly from long-term memory without having to count at all (for example, simply saying "8" to the question "How much is 5 + 3?"). When looking at group data, one gets the impression that children progress from using the sum strategy to using the min strategy to using fact retrieval. Yet closer examination reveals that individual children use a variety of these strategies at any one time: the frequencies with which these various strategies are used vary with age. (More will be said of children's arithmetic strategies in Chapter 12.)

Other examples of children's multiple-strategy use come from experiments assessing memory development. For example, in a study by McGilly and Siegler (1990), children in kindergarten, grade 2, and grade 4 were given a serial-recall task (to remember a list of digits in exact order). McGilly and Siegler observed the strategies the children used and later questioned them about their strategy use.

They reported that the children used a variety of different strategies on these tasks, with any given child using a combination of strategies over repeated trials. That is, multiple strategy use was the rule rather than the exception. In other research, Cox and his colleagues (Cox et al., 1989) demonstrated that third-grade children given instructions to sort words into groups by meaning not only improved their memory performance but also used more sophisticated rehearsal techniques. That is, improvements in one strategy (organization) led to improvements in another strategy (rehearsal), which in turn led to greater levels of memory performance. Moreover, children use a variety of different strategies on a single trial, often switching the combination of strategies they use from trial to trial (Coyle & Bjorklund, 1997).

Basically, Siegler sees multiple strategies existing within a child's cognitive repertoire at any one time, with these strategies competing with one another. Early in development or when a child is first learning a new task, relatively simple strategies will "win" most of the time. With practice and maturation, the child will use other, more effortful but more efficient strategies more frequently. Thus, Siegler believes that development does not occur in a steplike fashion but, rather, as a series of overlapping waves, with the distribution of those waves changing over time. Figure 5-10 presents Siegler's wave approach to cognitive development. Multiple strategies are available to children at every age, but which strategies are used most frequently changes with age.

More will be said about Siegler's account of strategy development later in this book, particularly in Chapter 12, examining age differences in arithmetic strategies. Siegler believes that age differences in how strategies are selected and used reflect an important way of viewing cognitive development that differs from conventional Piagetian and information-processing models. Perhaps the most important message from Siegler's work is that at any point in time and for any given task, children have a variety of strategies available to them. The issue facing cognitive developmental psychologists is not whether children are being strategic. Rather, we are seeking to discover what strategies and combination

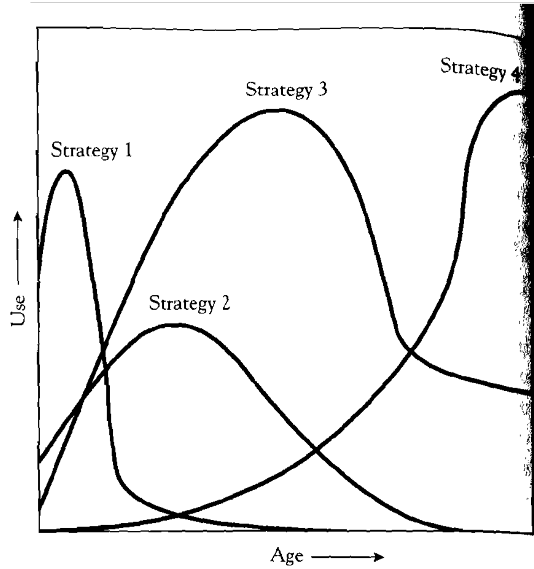

FIGURE 5-10 Siegler's adaptive strategy choice model of development. Change in strategy use is seen as a series of overlapping waves, with different strategies being used more frequently at different ages. SOURCE: Adapted from Siegler, R. S. (1996). *Emerging minds: The process of change in children's thinking*. New York: Oxford University Press.; thanks to Robert Siegler.

of strategies children of different ages use and how the simpler strategies used by young children develop into the more sophisticated and effective strategies used by older children and adults.

Stop here!

Implicit Strategy Use

Can strategies ever be implicit, out of our conscious awareness? We may not always be aware of the strategies we are using, but part of the definition of strategies I provided earlier made it explicit that strategies are at least *available* to consciousness. Recent research, however, has caused a reconsideration of this aspect of strategies, and this is illustrated by a recent experiment by Siegler and Stern (1998).

In their experiment, second-grade children were given a series of arithmetic problems of the following form: $a + b - b = ?$, for example, $37 + 16 - 16 = ?$ Most of you will recognize that there is a shortcut to