4

Strategic Development: Trudging up the Staircase or Swimming with the Tide?

As described in the previous chapter, children's thinking is highly variable. The present chapter focuses on implications of this variability for understanding development.

Thinking about a pair of visual metaphors may help facilitate recognition of these implications. The first, which I believe underlies most depictions of development, is the *staircase metaphor*. The second, which I believe offers a superior alternative, is the *overlapping waves metaphor*.

Two Metaphors for Cognitive Development

The Staircase Metaphor

Cognitive developmentalists have often phrased their models in terms that suggest that children of a given age think about a given task in a single way. *N*-year-olds are said to have a particular mental structure, a particular processing limit, a particular theory, strategy, or rule that gives rise to a single type of behavior. Change involves a substitution of one mental entity (and accompanying behavior) for another.

The basic conceptualization that seems to underlie these models is aptly captured in the title of Robbie Case's (1992) recent book *The Mind's Staircase*. The visual metaphor that this title evokes is, I believe, central to most cognitive-developmental treatments of change: Children are depicted as thinking in a given way for an extended period of time (a tread on the staircase); then their thinking undergoes a sudden, vertical shift (a riser on the staircase); then they think in a different, higher way for another extended period of time (the next tread); and so on.

This view of development is most closely identified with Piagetian and neo-Piagetian approaches, such as those of Piaget and Case. Thus, as shown in Figure 4.1, we see development depicted within Piaget's theory as involving sensorimotor activities from birth to about 2 years; preoperational thinking from 2 to 7 years; concrete operational thinking from 7 to 12 years; and formal operational think-

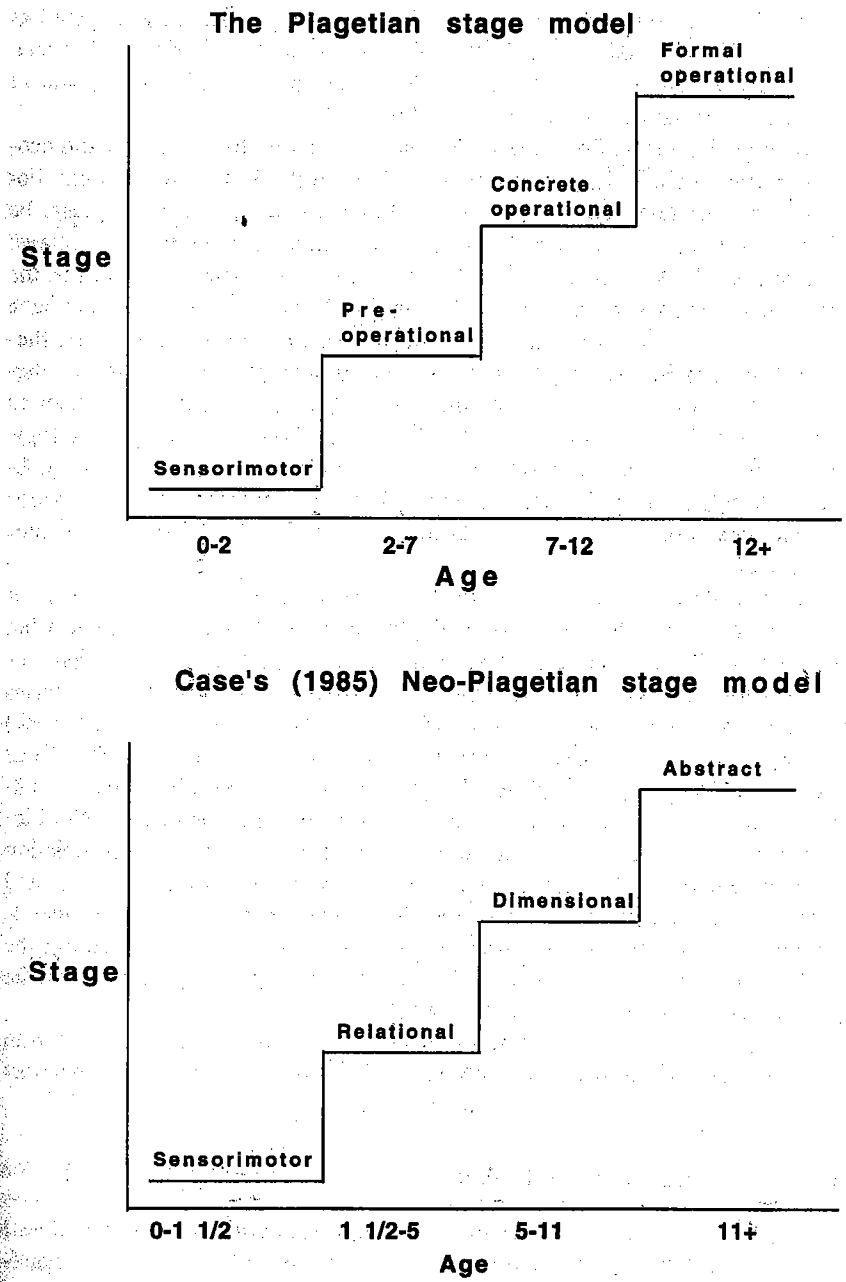


Figure 4.1. Piaget's and Case's (1985) staircase depictions of cognitive development.

ing from 12 years onward. Within Case's theory, we see thinking depicted as advancing from the sensorimotor level between birth and 18 months, to the relational level from 18 months to 5 years, to the dimensional level between 5 and 11 years, and to the formal level at age 11 and beyond.

Although this view of development is associated with the Piagetian and neo-Piagetian traditions, it is far from unique to them. Indeed, it is omnipresent. For example, researchers who try to identify children's implicit theories describe children's thinking in very different terms than Piagetians and neo-Piagetians; they also often look for and find much greater early competence. However, the form of their depiction of development is similar. Two-year-olds are said to have a desire theory of mind, whereas 3-year-olds are said to have a belief-desire theory (Wellman, 1990). Three-year-olds are said to have nonrepresentational theories of mind, whereas 5-year-olds are said to have representational theories (Perner, 1991). Four-year-olds are said to have a psychological theory of biology, whereas 10-year-olds are said to have a truly biological theory (Carey, 1985). As with the Piagetian and neo-Piagetian approaches, the staircase metaphor captures the basic idea about the course of development theorized in these approaches (Figure 4.2).

The depictions of information processing researchers differ from those of Piagetian, neo-Piagetian, and theory-theory researchers not only in vocabulary but in their emphasis on very precise descriptions of the cognitive processes that produce the behavior. Again, however, they usually portray development as a series of 1:1 equations between ages and ways of thinking. For example, Ashcraft (1987) depicted acquisition of expertise on simple addition problems (e.g., 3 + 7) as involving the following developmental sequence: 4- and 5-year-olds rely on counting from one; 5- to 8-year-olds rely on counting from the larger addend; older children and adults rely on retrieving the answer from memory. My own depiction of development of number conservation (Siegler, 1981) indicated that most 3- and 4-year-olds base judgments on the relative lengths of the two rows, some older 4-year-olds and most 5-year-olds base judgments on the results of counting the objects in the two rows, and 6-year-olds and older children base judgments on the type of transformation that was performed (Figure 4.3).

As discussed earlier, these staircase-like depictions are radically at odds with current understanding of children's thinking. This suggests that a different way of thinking about development may be more useful.

The Overlapping Waves Metaphor

Suppose we adopt alternative orienting assumptions about development that, I believe, are both more consistent with the data and more helpful in understanding change. Within this set of assumptions, children typically use multiple approaches over prolonged periods of time. Rather than development being seen as a stepping up from Level 1 to Level 2 to Level 3, it is envisioned as a gradual ebbing and flowing of the frequencies of alternative ways of thinking, with new approaches being added and old ones being eliminated as well. To capture this per-

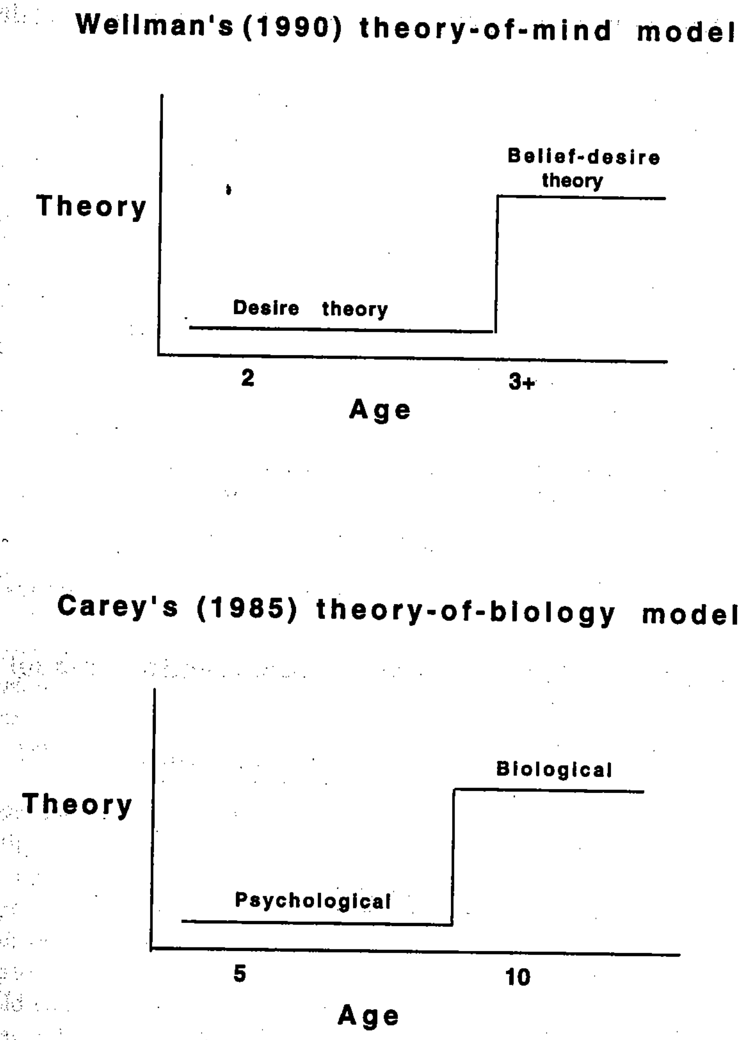


Figure 4.2. Wellman's (1990) and Carey's (1985) staircase depictions of development of theories of mind and biology.

shown in Figure 4.4, with each wave corresponding to a different rule, strategy, theory, or way of thinking. Contrasting the overlapping waves metaphor with the staircase progressions shown in Figures 4.1, 4.2, and 4.3 conveys some of the differences between the two approaches.

One immediately apparent difference is that rather than claiming that children use only a single way of thinking at each point in development, the overlapping waves depict the relative frequencies of multiple ways of thinking at each point in time (the vertical dimension of the figure). A second clear difference is that cognitive change is depicted as continuously changing frequencies of alternative ways

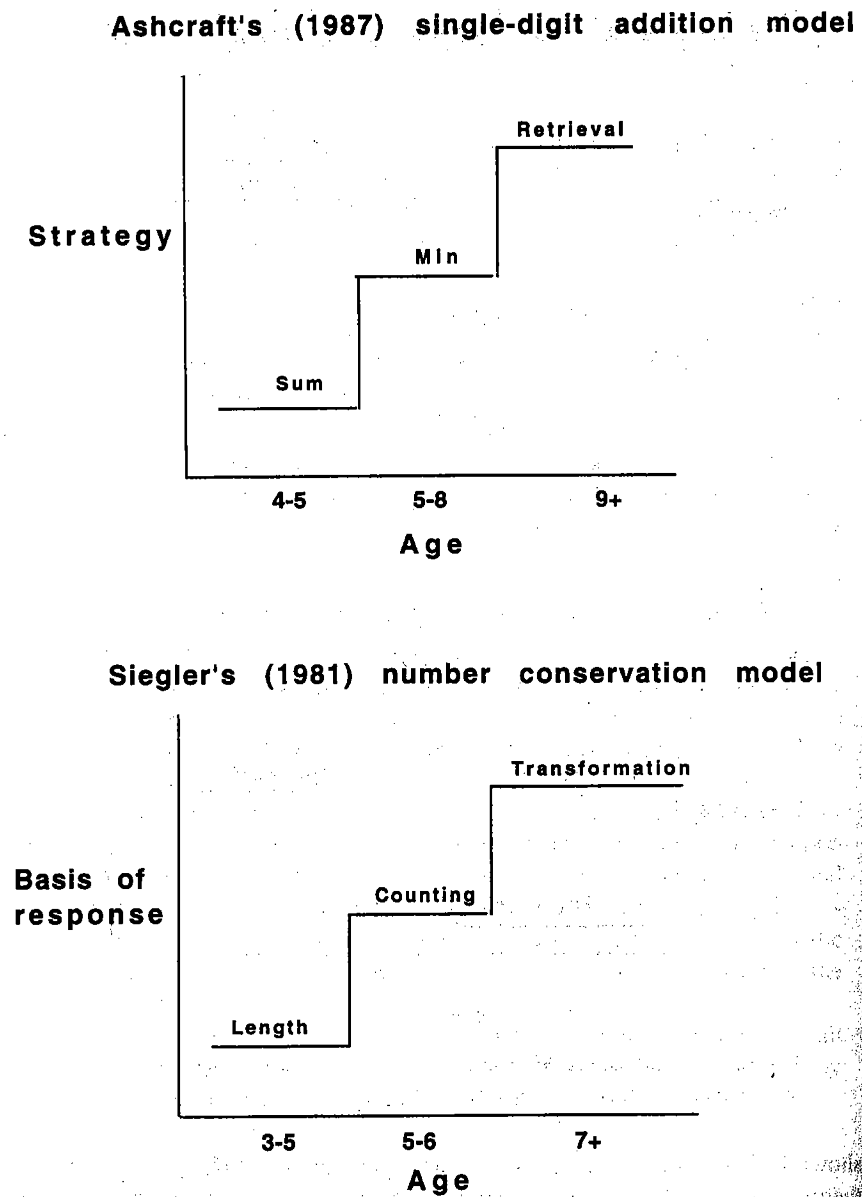


Figure 4.3. Ashcraft's (1987) and Siegler's (1981) staircase depictions of development of single-digit addition and number conservation.

If, on a given task, children think in only a single way at a given time, and occasionally suddenly shift to more advanced ways of thinking, the Figure 4.4 depictions collapse into staircase progressions like those in Figures 4.1 to 4.3. Thus, the overlapping waves depiction encompasses the staircase depiction as a limiting case

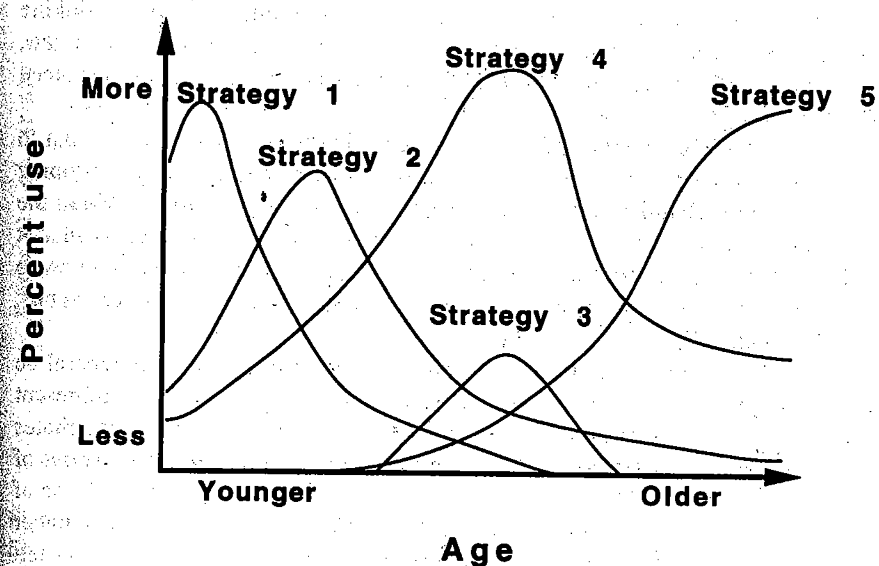


Figure 4.4. Overlapping waves depiction of cognitive development.

depiction of the situation that I believe is more typical, in which multiple ways of thinking coexist for prolonged periods, with development involving changes in their relative frequencies as well as introduction of new approaches.

The overlapping waves approach also opens up for investigation both descriptive and explanatory issues that would not otherwise be examined. Regarding description, knowing that children use varied approaches for substantial periods of time makes clear the need to examine separately developmental changes in the frequency, speed, accuracy, automaticity, and breadth of applicability of each approach. This can lead to a much more differentiated description of development than would be obtained by averaging over different approaches. For example, it can tell us whether age-related increases in speed of performance are due to older children acquiring new strategies that are faster than any previous approach, to their relying more often on the faster strategies from among those they already used, to their executing the same strategies more quickly, or to more than one of these potential sources of change.

Regarding explanations of development, the overlapping waves perspective moves to center stage a number of questions that have been backstage or offstage altogether in traditional approaches. What leads older children to choose different ways of thinking than younger ones? Is it that younger children don't have available the same ways of thinking as older ones? Or is it that they have the same ways available but use different algorithms for choosing among them? Or do they have available the same ways of thinking and use the same algorithms for choosing among them, but possess a smaller database that leads to the same algorithm generating different choices? This approach also raises the question of how new ways of thinking are discovered, and how, once discovered, they are integrated into the cognitive activity would be structured to give rise to multiple ways of thinking over periods of many years. Why, for example, when children discover a new, more advanced strategy, would they continue to rely heavily on old, less advanced strategies for prolonged periods of time?

This issue will be analyzed in greater depth in the next few chapters, but to anticipate the answer in a general way, consider the main task of the developing child: to learn. Childhood, especially early childhood, is a period in which the importance of high quality current performance is minimized relative to what it will be later in life. In contrast, learning new skills and competencies, and how to acquire yet greater knowledge, is absolutely essential. Learning is *the* central task of childhood.

The implication is that properties that facilitate learning may in general be especially prominent during childhood. Cognitive variability seems to represent one such property. Consider an example of how cognitive variability facilitates learning. Siegler and Jenkins (1989) examined 4- and 5-year-olds' discoveries of the min strategy for adding numbers. When the discoveries first occurred, use of the new strategy did not improve children's performance on the small number problems that were presented in this phase of the study. The min strategy was neither faster nor more accurate than counting from one. Thus, if new strategies were only generated when they benefited immediate performance, the children would not have discovered the min approach. For a substantial number of sessions after the initial discovery, the children used the new approach only occasionally on the small number problems that were being presented. Counting from one continued to be the children's predominant counting strategy even after they discovered the min approach.

However, when the preschoolers later were presented more challenging problems, such as 2 + 21, a disjuncture arose. Children who had previously discovered the min strategy used it often to solve the challenging problems, and thereafter used it considerably more often on all kinds of problems. In contrast, children who had not discovered the min strategy on the small number problems were simply overwhelmed by the new, more difficult problems. They neither solved them via the approaches they knew nor generated the min strategy in response to them. Thus, having available a variety of strategies can prove useful for adapting to new situations, even when one or more of the strategies is not used much and does not convey immediate benefits. The benefits parallel those of the immune system having available white blood cells that respond to a wide variety of antibodies, even though the cells may never have proved useful in the past (chapter 2, pp. 35–36).

Figures 4.5 and 4.6 illustrate how the overlapping waves model can be used to describe real-world empirical data. Figure 4.5 displays findings from Feldman's (1980) study of one child's map drawing on five occasions over a three-year period. During this time, Level II and III map drawings decreased in frequency; Level IV drawings first increased and then decreased; and Level V drawings gradually increased. At each time of measurement, the child produced four different levels of drawings, but the relative frequencies of the levels changed dramatically over time.

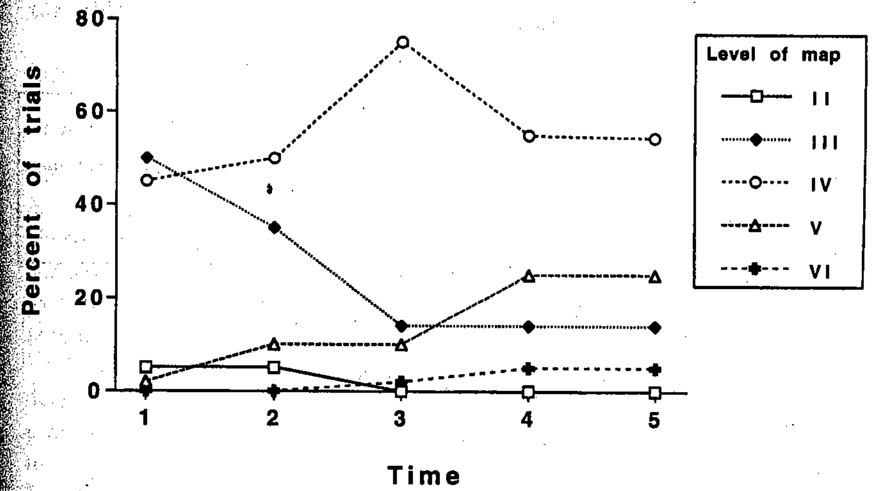


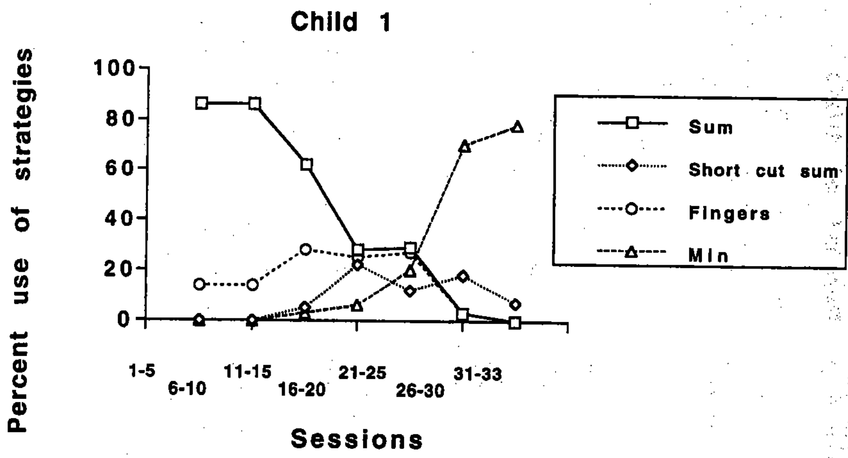
Figure 4.5. Variability of one child's map drawing over a 3-year period. Data from *Beyond Universals in Cognitive Development*, by D. H. Feldman, 1980, Norwood, NJ: Ablex. Copyright 1980 by Ablex. Reprinted with permission.

short-term longitudinal study, in which 4- and 5-year-olds were presented roughly 30 sessions of experience solving single-digit addition problems over an 11-week period. For each child, some strategies increased in frequency, others decreased, yet others increased and then decreased, and yet others stayed at relatively constant levels of use.

The remainder of this chapter reports data on cognitive change that have arisen from detailed analyses of a variety of types of development: arithmetic, language, motor skills, moral reasoning, and interpersonal interactions among them. The examples include data from infants, preschoolers, elementary schoolchildren, young adults, and old adults. These data, and the overlapping waves conception, allow us to describe development in a way that, I believe, is both more accurate and more interesting than the portrayal that emerges from the staircase depictions.[1]

Much of this chapter is devoted to a detailed portrayal of the development of addition skills. The area seemed worth-examining in depth because addition is a basic human competence, present in all societies; because its development covers a prolonged period from infancy through adulthood; because there is an extensive and high-quality database regarding it; and because that database allows us to distinguish six types of changes that contribute to strategic development:

1. Acquisition of new strategies
2. Changes in frequency of existing strategies
3. Changes in the speed of execution of the strategies
4. Changes in the accuracy of execution of the strategies
5. Changes in the automaticity of execution of the strategies



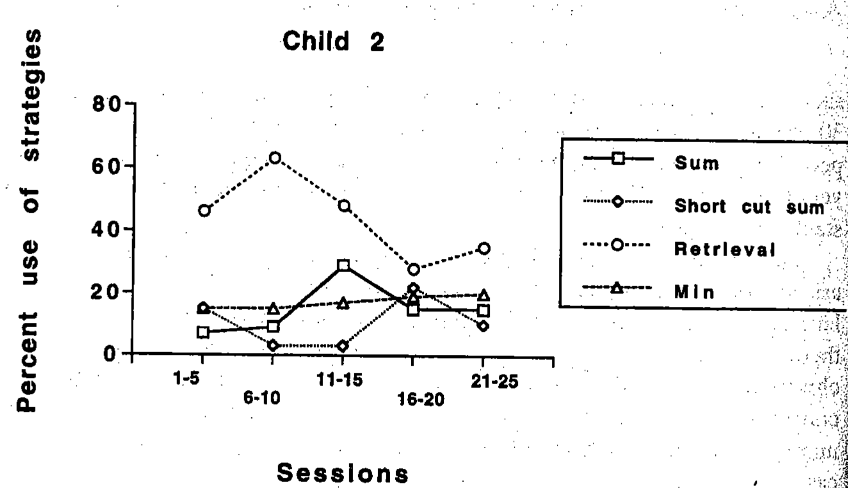


Figure 4.6. Variability in two children's simple addition strategies over an 11-week period (data from Siegler and Jenkins, 1989).

Thus the example illustrates two ways in which traditional portrayals of development can be enriched by the present approach: by depicting the strategic diversity that is present over prolonged periods of development and by differentiating among the multiple dimensions and providing data on each of them. As illustrated later in this chapter, most of the dimensions in this list also can be used to describe development in contexts where the unit of interest is not strategies, but rather beliefs, theories, rules, structures, or other units of cognition.

Development of Addition

Development in the Preschool Period

Strategy Use

From ages 2 to 4 years, children's knowledge of the sequence of number words and their ability to count objects to establish the cardinality of a set grows greatly (Fuson, 1988; Gelman & Gallistel, 1978). These acquisitions provide an essential base for the acquisition at ages 4 and 5 years of initial addition strategies such as counting fingers, putting up fingers but answering without counting them, counting imagined objects, and retrieval.[2]

During the preschool period, children increasingly use counting strategies and decreasingly rely on guessing. When young preschoolers are presented addition problems without physical objects present (as when asked "how much is 2 + 2"), they appear usually to guess. For example, the 4- to 4 1/2-year-olds observed by Levine, Jordan, and Huttenlocher (1992) did not use any overt strategy on 97% of trials, and answered only 9% of these problems correctly. The combination of absence of overt strategies and very low accuracy suggests that the children were guessing on these trials. Counting from one represented the leading edge of their competence; they always answered correctly on the 3% of trials on which they counted. Almost identical results were obtained when the problems were presented in story form ("Mike had two balls, he got two more, how many did he have then?").

With experience solving simple arithmetic problems, older preschoolers come to rely more heavily on overt strategies, particularly ones involving counting. The 4 1/2- to 6-year-olds studied by Siegler and Robinson (1982), who like the children observed by Huttenlocher, Jordan, and Levine were presented problems with addends of 5 or less, used overt strategies on 36% of trials versus 3% in Huttenlocher et al. In both studies, the counting that was observed consistently started with the number "1."

Speed and Accuracy of Strategies

Preschoolers' several approaches differ in speed and accuracy. Answering without generating overt behavior is by far the fastest strategy, putting up fingers but answering without counting them the next fastest, and the two counting strategies the slowest (Table 3.1, p. 62). Counting fingers and putting up fingers but answering without counting are generally more accurate than counting imagined objects or answering without any overt behavior.

Development in the Early Elementary School Period

Strategy Use

Children's proficiency changes dramatically when they begin to solve large numbers of addition problems in first grade. Virtually all children begin to use the *min strategy* (counting from the larger addend). S...