3 Universal trends and individual differences in memory development

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The study of cognitive development has been one of the most active disciplines within developmental psychology for some time. Within this discipline, the study of memory development has received much attention over the past 20 years. In the present essay, we will focus on the major achievements as well as some limitations of research into memory development conducted during that period.

Although we will concentrate on recent trends in memory development, there are earlier studies of memory development that were conducted before the information processing approach was introduced into developmental psychology about two decades ago. It is unfortunate that these studies, conducted almost a century ago, have been completely forgotten by contemporary European and American memory researchers. Although we do not intend to provide an overview of these studies, a summary of the main findings from that early period seems in order (see Schneider & Pressley, 1988, for a more detailed account). In our view, a juxtaposition of what was known then and what we know now may provide a more precise reading of the advances actually made.

Most early studies of memory development were stimulated by Hermann Ebbinghaus's pioneer work. One of its major goals was to obtain information about *general* or *universal* trends in memory development across the life-span. Thus, the main interest was in what Wohlwill (1973) called the "developmental function" of memory performance, or its value plotted over age. In many studies, memory performance was equated with achievement in memory-span tasks using meaningless syllables, words, or numbers as stimuli (cf. Braunshausen, 1914, for an overview). In other studies, the inclusion of meaningful materials (words, sentences) led to the insight that factors like word meaning and familiarity of material play a significant role in determining the amount of material recalled. For example, it was demonstrated that schoolchildren's memory for long sentences was considerably better than that for short lists of meaningless words, and that as a rule the "skeleton," that is, the core unit of the sentence, was retained best (Binet & Henri, 1894; Netschajeff, 1902). Comparisons of results from different assessment procedures (e.g., recognition vs. recall) clearly showed that the developmental function varied with the type of materials and the output demands used. Further major findings of that time can be summarized as follows:

1. In general, memory performance (immediate recall) improves over the school years and continues to increase until about the age of 25 years;
2. A particularly steep, linear increase in level of performance can be observed between the ages of 7 and 11, whereas a stagnation first sets in at the ages of 13 to 16 years;
3. A sharp distinction must be made between the developmental processes of immediate and long-term retention. Contrary to the findings for immediate recall, children's long-term retention skills are better than those of adults (cf. Radossawljewitsch, 1907).

Although this early period was characterized by a strong interest in general laws and universal developmental memory functions, this does not mean that the second realm of developmental inquiry, the study of individual differences, was totally ignored. On the contrary, the present-day reader is struck with the numerous studies on sex differences or on children of different "memory types" (e.g., acoustic, visual, tactile–motor). Interestingly enough, most of these studies were stimulated by the dominating issues of educational theory and practice. For example, many influential opponents of coeducation claimed that it would be "a sin against nature" to educate jointly boys and girls because of the girls' inferior intellectual aptitudes (see Braunshausen, 1914). Consequently, many studies compared boys' and girls' memory performances to test the assumption that girls cannot keep up with boys. The findings were unequivocal: regardless of the age group and memory function studied, girls' memory performance levels on the average tended to be higher than those of boys. Needless to say, these findings helped introduce the coeducation principle, at least in German schools.

Similarly, the study of "memory types" was mainly stimulated by the idea that children of different "memory types" should receive different instructional treatments, or optimal combinations of visual and auditory instructional methods (cf. Kirckpatrick, 1894). The major problems with this approach, however, were that it was difficult to find "clear-cut" or pure memory types (most subjects were classified as "mixed" types), and the individual differences detected were not stable over time (cf. Offner, 1924). Although the idea of "memory types" remained attractive during this early period, no changes in educational practices were made mainly as a consequence of these unsatisfactory results.

Thus, experimental research in memory development was active long before the term *memory* was rediscovered and developmental research was reestablished within the past two decades. What are the major differences between the early and the contemporary approaches? Although there are many, we think that the most crucial difference concerns the way the dependent variables were determined: Whereas the early studies focused on various aspects of memory performance and their developmental trends, the contemporary approach can be characterized as redirecting attention from overt memory products to the cognitive activities that generate them (cf. Flavell, 1985). Current research efforts concentrate on the identification of factors that "cause" variations in memory performance in different contexts or domains. Of course, one should not overlook the fact that the concept of "mechanisms" of developmental change was also used by theorists of the early period, particularly by those strongly interested in learning theory. Their assumption was that the organism provides the framework of mechanism within which learning and remembering occur (McGeoch & Irion, 1952). According to this view, changes in memory with age are primarily dependent on organic growth and decline, and less on previous learning. The problem of how factors like maturation and degeneration can change the framework of mechanisms remains unsolved within this approach (see Weinert, Schneider, & Knopf, 1988, for a more thorough treatment of this topic).

Theories of memory development derived from the information processing approach provide a much more detailed account of sources of memory development. In particular, four sources of memory development have received considerable attention within this approach: basic capacities, strategies, content knowledge (i.e., domain-specific knowledge), and metamemory. Most studies of memory development conducted within the past twenty years dealt with the role of one or more of these four sources in describing and explaining age differences in memory development.

In the following discussion, we will first give an overview of the major outcomes of this line of research. Given the multitude of empirical studies published in the past few years, we will not present a comprehensive picture of the state of the art, but rather focus on selected recent empirical findings and opinions concerning progress in this area. Although all these sources undoubtedly contribute to memory development, we think that there are still some issues that deserve special treatment that are typically neglected in the literature. Some of these central issues will be explicated in detail in this essay. In our view, one of the major shortcomings of most experimental studies is that it is almost impossible to determine the *relative* impact of the four sources and their interactions in predicting and explaining memory development. To achieve this goal, the experimental approach must be substituted or complemented by nonexperimental assessment procedures and more sophisticated data analysis techniques. A few examples will be given to illustrate how this can be done.

A further problem with the present view of memory development is that these four sources represent "within-the-child" parameters. A particular weakness of this approach is that it ignores possible explanatory factors in children's environments. As a consequence, the generality or universality of developmental trends is usually overestimated. This problem can best be illustrated by examining the impact of cultural factors like schooling or instructional differences on memory development.

Another neglected issue concerns the study of individual differences. Compared with research in memory development during the early period, only a few studies focus on interindividual as well as intraindividual differences. In our view, the few available studies seem suited to qualify the findings obtained from typical experimental studies on the "developmental function" sensu Wohlwill.

Our final point refers to the problem that more than 99% of the studies on children's memory have been cross-sectional in nature. Thus, all these studies must face the criticism that they are not truly developmental (Wohlwill, 1973). Development means change – more specifically, change over time within organisms. Developmental *changes* can only be assessed via longitudinal designs, whereas cross-sectional studies are restricted to the assessment of developmental *differences*. According to Appelbaum and McCall (1983), the phrase *individual differences* refers to the variability of performance between individuals about their group mean. Within a developmental perspective, the stability or instability of individual differences is of major interest. Individuals are stable if they maintain about the same relative ordering within their group at one age as they do at another age. This means that not only general developmental change but also the development of individual differences can be only observed within the framework of a longitudinal study. As a consequence, in the remainder of this essay we will present a series of arguments for a revival of longitudinal studies in the area of memory development, and also provide some empirical examples that seem suited to demonstrate the special relevance of such studies for our better understanding of memory growth.

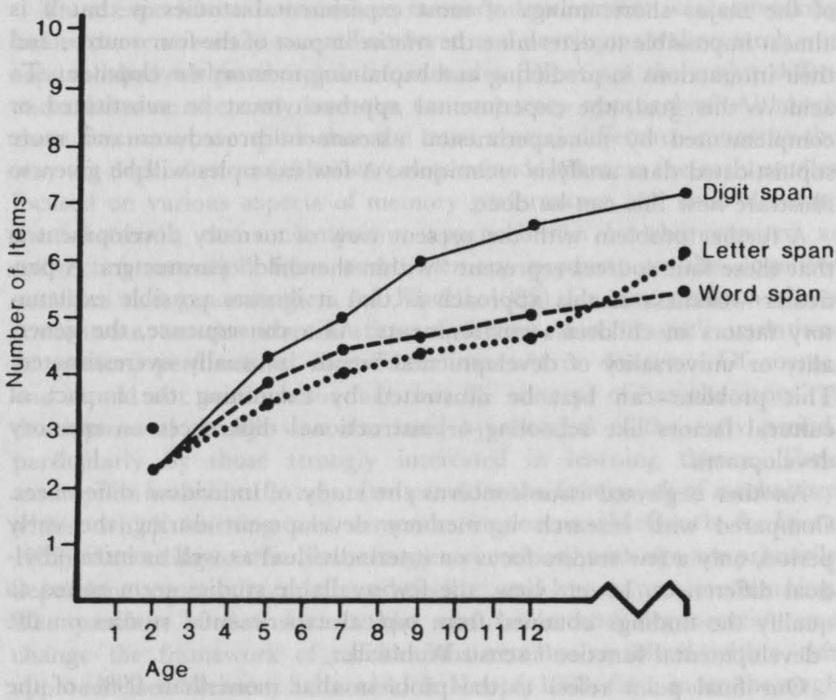

Figure 3.1. Developmental differences in digit span, letter span, and word span (data from Dempster, 1981, Figs. 1 to 3).

Sources of memory development: an overview

Basic capacities

One of the earliest views of memory development relied heavily on the concept of capacity. In its simplified version, memory development was exclusively seen as a function of memory capacity: According to this "container" model (Brown & DeLoache, 1978), young people have small boxes in their heads, whereas older people have bigger boxes. Translated into terms of a computer analogy, this model suggests that what develops is the *hardware* of the memory system conceptualized as absolute capacity, rather than its *software*, that is, the specific procedures to memorize material. At first glance, the data obtained from various studies concerning development of the memory span seem to support such a "container" model. For example, the data aggregated by Dempster (1985) indicate a continuous increase in different indicators of memory span from early childhood to adulthood (cf. Fig. 3.1). However, the major problem with this view is that memory span cannot be equated with "capacity" in the sense of memory "hardware"; there is evidence that performance in memory span tests is also influenced by "software" operations like rehearsal and grouping strategies (cf. Dempster, 1985) and by the familiarity and meaningfulness of the learning material. Thus, it does not make much sense to use the memory span as a measure of memory capacity.

Before analyzing the role of basic capacity in memory development, we should be more explicit about how basic capacity is conceptualized within the information processing approach. In general, this approach is based on the assumption that there are stable memory and processing limitations that individuals have to overcome by using either internal or external memory aids. According to this view, basic capacities are the building blocks of cognitive activity, in the sense that more complex cognitive activities are built up by combining them in different ways (Siegler, 1986). Given their frequent use, developmental differences in basic capacities could account for a number of developmental differences in memory performance. The memory model by Atkinson and Shiffrin (1968) with its division of memory into sensory, short-term, and long-term stores provided the first useful framework for describing basic capacities and their development. In short, experimental work conducted within this approach indicates that the absolute capacities of the three storage systems seem to be rather constant across childhood and adolescence. On the other hand, however, ample evidence indicates that parameters of information processing speed increase with age. This is true for the speed with which sensory representations are formed, and also holds for the speed with which objects can be represented in short-term memory or retrieved from long-term memory (cf. Keating & Bobbitt, 1978; Siegler, 1986). This finding seems in accord with Dempster's (1981; 1985) assumption that age differences in memory span are mainly due to nonstrategic factors like item identification speed or automatic item sequencing.

It follows, then, that we have to distinguish between an invariant total capacity of the memory system and basic operating functions that develop with age. There is an increasing tendency in the literature to accept the tentative model developed by Case (1985; Case, Kurland, & Goldberg, 1982) that tries to delineate these two constructs. In this model, a distinction is made between a storage space and an operating space. The term *storage space* refers to the hypothetical amount of space available for storing information; *operating space* refers to the hypothetical amount of space available for executing intellectual operations. Finally, *total processing space* is defined as the sum of an individual's storage space and operating space. The core assumption is that the total processing space available does not change over time, but just the proportions allocated to storage and operative processing. That is, as children grow older less and less memory space is necessary for the operative space, leaving more space for the storage of information. Case (1985) proposed that a child's ability to hold more information in short-term memory is mainly due to increasing automatization and perhaps biological maturation.

To illustrate the model's implications, Siegler (1986) used the analogy of a car trunk:

> The capacity of a car's trunk does not change as the owner acquires experience in packing luggage into it. Nonetheless, the amount of material that can be packed into the trunk does change. Whereas the trunk at first might hold two or three suitcases, it might eventually come to hold four or five. As each packing operation is executed more efficiently, trunk space is freed for additional operations. (p. 82)

According to this view, age-correlated improvements on short-term memory tests are due to shifts in the two space allotments rather than changes in total processing capacity. Does this mean, then, that basic memory capacities do not have any impact on memory performance? Of course, this is not the case. It is important here to note that the hypothesized invariance of total memory capacity is concerned with *intraindividual* characteristics. However, *interindividual* capacity differences are certainly not negligible when it comes to explaining differences in actual memory performance. Suppose, for example, that you want to predict young children's free recall for unrelated words by using a measure of basic memory capacity. Undoubtedly, a considerable amount of variation found in the memory performance measure could be explained by the variation in the memory capacity measure. In other words, individual differences in memory capacity are accurate predictors of individual differences in memory performance within and between age groups (cf. Schneider, 1986, for an empirical demonstration). It appears, however, that the predictive power of basic memory capacity depends on both the nature of the memory task and the age of the subjects. Its influence will be restricted whenever the task allows for compensatory operations (e.g., mnemonic strategies), or whenever the subjects are old enough to use mnemonic aids efficiently. It is thus reasonable to assume that the role of memory capacity in explaining age differences in memory performance generally decreases with the increasing age of the subjects.

Memory strategies

Since the early 1970s, numerous studies have investigated the role of strategies in memory development. According to these studies, strategy use was not only an important source of developmental differences but probably the major source (cf. Lange, 1978; Moely, 1977, for reviews). As will be noted, these researchers somewhat overstated the case. One fundamental problem typically neglected in the 1970s concerns a clear definition of memory strategies. In the 1980s, this question became a controversial issue. Whereas some authors defined strategies exclusively as *conscious* memory activities (cf. Naus & Ornstein, 1983; Paris, Lipson, & Wixson, 1983), others preferred a less strict definition that also subsumed *automatic* processes, particularly in the case of reading strategies (cf. Brown, Bransford, Ferrara, & Campione, 1983; Flavell, 1985). The detailed conceptualization provided by Pressley, Forrest-Pressley, Elliott-Faust, and Miller (1985) can be regarded as an acceptable compromise:

> A strategy is composed of cognitive operations over and above the processes that are natural consequences of carrying out the task, ranging from one such operation to a sequence of interdependent operations. Strategies achieve cognitive purposes (e.g., comprehending, memorizing) and are potentially conscious and controllable activities. (p. 4)

Although children's acquisition of memory strategies varies with the particular strategy, certain characteristics seem to be common to all strategies (cf. Brown et al., 1983; Waters & Andreassen, 1983). For example, memory strategies first appear under task conditions that are optimal for processing the to-be-remembered material (e.g., conditions that provide sufficient time to study the items). Further, strategies first appear with materials that encourage their use (e.g., semantically related materials that are particularly easy to interrelate in the case of organization strategies). The dependence of strategic behavior on task and procedural conditions changes with development. Older children are more active in initiating strategy use in different memory situations, including those that do not strongly encourage optimal processing, making the strategy difficult to execute. In short, they become more flexible in tailoring their strategy use to the demands of the particular situation.

The majority of studies of strategy use investigated children's use of rehearsal, organization, and elaboration strategies in laboratory tasks. Typically, these strategies were not observed in children younger than 6 or 7. This absence of strategic behavior was attributed to a "production deficiency" (Flavell, 1970); according to this hypothesis, young children do not engage in memory strategies because they simply do not know how and when to do so. Although evidence abounds for young children's production deficiencies concerning many memory strategies, more recent research has shown that the ages of strategy acquisition are relative, and variable between and within strategies. For example, it has been demonstrated that even preschool and kindergarten children are able to use intentional memory strategies, both in ecologically valid settings like hide-and-seek tasks (cf. DeLoache, Cassidy, & Brown, 1985; Sophian, 1984) and in the traditional context of a laboratory task (cf. Baker-Ward, Ornstein, & Holden, 1984; Sodian, Schneider, & Perlmutter, 1986). It appears, then, that very young children use rudimentary strategies whenever the task is either simply structured or extremely motivating for them.

It should be emphasized, however, that most developmental changes in children's strategy use can be observed during the elementary school years. In the remainder of this section, we will focus on the acquisition of the more prototypical memory strategies, namely, rehearsal and organizational strategies (see Pressley, 1982, for a detailed account on elaboration strategies). With regard to rehearsal, the typical difference between younger and older schoolchildren is that the younger subjects use a passive and inefficient single-item repetition strategy, whereas the older children put more items together in a "rehearsal set" and prefer cumulative rehearsal strategies (see Naus & Ornstein, 1983; Ornstein & Naus, 1985, for detailed reviews). Although young schoolchildren were able to use a cumulative rehearsal strategy when instructed to do so, they nonetheless did not employ this more complex strategy spontaneously. Recent work by Guttentag (1984; 1985) suggests that the main reason for this production deficiency is the "mental effort" requirement of the cumulative rehearsal strategy. Guttentag used a dual-task procedure: In addition to the usual "overt rehearsal" of to-be-recalled items, a motor task (key tapping) was performed simultaneously. The amount of interference was measured as the difference between the normal tapping during a baseline phase (without rehearsal) and tapping during rehearsal. Guttentag reported that the degree of interference experienced in motor performance was impaired more by simultaneous rehearsal among younger as compared with older children. However, age differences in interference did not occur when children used a passive, one-item repetition strategy. Thus, age differences in the spontaneous use of cumulative rehearsal strategies may in part be due to the enormous effort required of young children to employ complex strategies.

A subsequent study by Ornstein, Medlin, Stone, and Naus (1985) not only confirmed this assumption, but also provided a more exact indication of which components of cumulative rehearsal cause special difficulties for younger children. In this study the efficiency of second graders' cumulative rehearsal improved considerably when the previously presented items continued to be visible as they rehearsed. Apparently, a particular difficulty of cumulative rehearsal strategies for younger children is that the stimuli must be maintained internally during the repetition of learning material. Such maintenance requires great exertion, often exceeding the capacity of young grade-school children. In our view, this finding squares well with the proposal of several Russian investigators (e.g., Smirnov & Zinchenko, 1969) that a skill must be well developed in its own right before it can be effectively deployed as a strategic means to a memory goal.

Our second example concerns semantic grouping or categorization, one of the most frequently studied strategies. Developmental changes in children's organization of material parallel developmental changes in rehearsal, although it appears that the organizational strategy is acquired somewhat later in development. In its traditional form, the sort–recall task requires that a number of semantically related but randomly ordered stimuli should be remembered within a certain time interval. The subjects are usually instructed to do anything they want with the items in order to recall them better. The optimal strategy is to sort the items completely into categories and to use the category names as retrieval cues during recall. Thus, the amount of clustering during study as well as during recall is usually taken as an indicator of an organizational strategy.

Although this assessment procedure appears very elegant, there are nonetheless several problems with it. For example, the mere presence of clustering in subjects' recall does not prove that they indeed had intentionally used an organizational strategy when retrieving the items. We now have ample evidence suggesting that clustering during recall can represent automatic processes mainly stimulated by high interitem associativity (cf. Bjorklund, 1985; 1987; Frankel & Rollins, 1985; Lange, 1978). Similarly, sorting items into semantic categories is not always reflective of a conscious, deliberate organizational strategy. Instead, it may be that subjects are able to detect the categorical structure of an item list and sort items into categories, but do not know that this procedure enhances recall. These problems notwithstanding, the sort–recall task has generally proved valuable in demonstrating age differences in the intentional use of organizational strategies.

How can these age differences best be described? Recent studies (Schneider, 1986; Schneider, Körkel, & Vogel, 1987) have demonstrated considerable developmental differences during encoding of information. While second graders rarely sorted the items by categorical relations, fourth graders did so spontaneously. More important, whereas the majority of the younger children only looked at the items or labeled them when asked to learn the stimulus list, the older subjects used more sophisticated learning strategies like rehearsal or self-testing. Taken together, these developmental differences in encoding stimuli explain a considerable amount of age differences in recall. In addition, substantial developmental differences also appear in retrieval strategies, and encoding and retrieval strategies not only contribute independently to increased memory performance but also in interaction with one another (cf. Ackerman, 1985, for a detailed account on this problem).

Although the *interaction* of encoding and retrieval strategies and their joint effect on memory performance can be assessed through systematic manipulation in experimental designs, it is practically impossible to determine the *relative* roles of encoding and retrieval process, because comparable measures for the two do not exist. It should be noted that mathematical models for the separation of encoding and retrieval processes in memory tasks have been recently developed independently by several research groups (cf. Brainerd, 1985, for a review). Unfortunately, the results obtained for the various mathematical models are not consistent, and thus do not permit clear-cut conclusions. All in all, the results indicate that retrieval processes, unlike storage processes, seem to develop more from the early elementary school phase to adulthood; however, further research is clearly needed to validate this impression.

The impact of knowledge on memory

Recent theoretical statements have suggested that influences of the knowledge base or content knowledge are highly important for the development of strategic behavior and memory performance in children (cf. Bjorklund, 1985; Ornstein, Baker-Ward, & Naus, 1988; Ornstein & Naus, 1985). According to this view, the fact that children acquire specific information about particular content areas every day should influence their memorizing. It is an everyday observation that people who know more about an area than others find it easier to remember new information linked to that area. Although this fact is certainly recognized by most researchers in memory development, the measure usually taken to control for influences of prior knowledge – that is, selecting learning materials well known even to the youngest subjects – seems insufficient. The faulty logic of such an approach lies in the assumption that *knowledge* of stimuli names can be equated with *familiarity* with the learning material. As was impressively demonstrated by Chechile and Richman (1982), variations in meaningfulness of identical learning material in various age groups can explain age differences in memory performance: When meaningfulness values were equated, age differences in recall were minimized.

In addition, what a child knows about the materials to be remembered can have a strong impact on strategic manipulation of those items. This contention is supported by several experiments that systematically varied the meaningfulness of items across experimental conditions. For example, Tarkin, Myers, and Ornstein (cited in Ornstein et al., 1988), compared third graders' rehearsal in two experimental conditions. Although the stimuli of the word lists were all known to the children, subjects in one condition studied highly meaningful items – that is, words that elicited many associations – whereas subjects in the other condition rehearsed words that were low in meaningfulness. The data indicated marked differences in rehearsal as a function of condition. Rehearsal sets of the low-meaningfulness group were relatively small (fewer than two different items), whereas the high-meaningfulness group rehearsed more than three items together, a value characteristic of sixth graders. These outcomes suggest that the observed strategies are to some extent "stimulus driven": highly meaningful materials may facilitate rehearsal (and subsequently recall) because of an associative activation of the knowledge base.

Similar effects due to age-related increases in associative connections and the developing knowledge of hierarchical conceptual relations were demonstrated for the utilization of organizational (clustering) strategies in sort–recall tasks (Frankel & Rollins, 1985; Schneider, 1986). In both experiments, word lists were generated that varied in terms of strength of associations between category exemplars and the strength of category relationships. The combination of these two variables yielded four different list conditions: high category relatedness/high interitem associativity; high category relatedness/low interitem associativity; low category relatedness/high interitem associativity; and low category relatedness/low interitem associativity. Typical exemplars of the "high/high" lists were dog, cat, horse, and cow, and those of the "low/low" lists were beaver, walrus, squirrel, and giraffe. Frankel and Rollins (1985) reported that 10- and 16-year-old subjects evidenced high levels of clustering during recall under conditions of either high category relatedness or high interitem associativity; lower levels of clustering were only obtained when both variables were low in strength. On the other hand, 6-year-old children showed elevated clustering during recall only under conditions of high interitem associativity. These findings were basically replicated by Schneider (1986), working with 8- and 10-year-olds, and are consistent with the hypothesis that young children's clustering during recall is more a function of interitem associativity than of intentional strategy use. However, it is important to note that in Schneider's study, second graders demonstrated sorting strategies under conditions of either high category relatedness or high interitem associativity, with cluster scores approaching values usually obtained with fourth graders. In our view, this can be regarded as another example of "stimulus-driven" strategy use, that is, the impact of the knowledge base on the activation of memory strategies.

Probably the most dramatic demonstrations of the impact of the knowledge base on memory stems from experiments that focused on the relationship between domain-specific knowledge and memory performance. The most suitable way to demonstrate effects of the knowledge base is to contrast the performance of experts and novices in a specific domain. A now classical, clever experiment by Chi (1978) provided evidence for how greatly the knowledge base can influence children's memory performance. Chi compared the memory ability of chess experts and novices. Her twist was that knowledge was negatively correlated with age. That is, the 10-year-old children were the experts, whereas the adults were chess novices. Both groups were tested on two tasks. One was a standard digit-span task; the other was a chess reproduction task, which involved replacing chess pieces correctly in their positions. Chi (1978) found that her young experts outperformed the novices in the chess reproduction task, both in terms of actual memory performance and in predicting in advance how well they would perform. On the digit-span task, the adults, as expected, were better. Chi's conclusion was that differences in the knowledge base can outweigh all other memory differences between children and adults.

In a series of related experiments conducted in our laboratory (Körkel, 1987; Schneider, Körkel, & Weinert, 1987a; Weinert, Knopf, Körkel, Schneider, Vogel, & Wetzel, 1984), performances of soccer experts and of novices recruited from samples of third, fifth, and seventh graders were compared. Subjects read a story about a soccer game and were tested for their recall and comprehension of the text. Not surprisingly, soccer experts showed better recall of text details than novices, regardless of age. Moreover, experts were better at identifying contradictions in the text and in drawing text-specific inferences – that is, in reconstructing information that had not been explicitly included in the text. Younger experts outperformed older novices on all outcome measures, demonstrating the specific importance of a highly articulated knowledge base on text comprehension and recall.

In view of these findings, it seems that the knowledge base explains a great deal about why older children remember more efficiently than younger ones. The knowledge base not only influences the way children prepare for recall, but also what and how much they can recall. However, the question of *how* the knowledge base influences memory remains a controversial issue. For example, Ornstein and Naus (1985) emphasized the fact that an association between expert–novice status in a specific domain and differential patterns of recall of this material does not provide an explanation of how such differences arise. That is, findings of this sort do not tell us anything about the underlying mechanisms that could explain how experts are able to use their better-structured knowledge during remembering. According to Siegler (1986), two mechanisms – networks of association that link different items to each other, and the encoding of distinctive features – seem of major importance. Although empirical evidence from case studies (e.g., Chi & Koeske, 1983) supports such a view, in-depth analyses of the mechanisms by which the knowledge base mediates memory are still badly needed. In such analyses, the possible involvement of motivational and interest factors should also be considered. In our view, the work by Rabinowitz and colleagues (Rabinowitz & Chi, 1987; Rabinowitz & Glaser, 1985) represents a good starting point for more comprehensive theoretical and empirical analyses.

The impact of metamemory on memory development

As already noted, children's knowledge about particular domains increases as a function of daily experience. It also seems reasonable to assert that children's knowledge and understanding of memory processes develop simultaneously and that this kind of knowledge may be similarly related to improvements in strategy use and memory performance. Knowledge of this sort was labeled "metamemory" by Flavell (1971) and broadly defined as knowledge about different aspects of memory processing. Subsequent attempts to define this "fuzzy" concept more precisely (Wellman, 1983) led to the construction of taxonomies of metamemory that roughly distinguished between two basic types, namely conscious, verbalizable knowledge concerning memory, and implicit, probably unconscious knowledge about how to monitor and regulate memory (for more detailed accounts, see Brown et al., 1983; Flavell & Wellman, 1977; Wellman, 1983; 1985).

Factual knowledge about memory was further subdivided into knowledge about *persons*, *tasks*, and *strategy variables* that influence performance on a memory task, and the interaction of these variables. The person category refers to what children know about themselves and others as mnemonic beings, whereas the task category includes children's knowledge about what makes some memory tasks more difficult than others. The strategy variables category refers to children's verbalizable knowledge about various encoding and retrieval strategies, as distinguished from actual "on-line" strategy use in memory situations.

The second type of knowledge – regulation and monitoring of cognitive activities – refers to judgment of feelings about the ease or difficulty of remembering something. Here, the assumption is that children become more and more attuned to internal "mnemonic sensations" with development. They develop a sensitivity to the objective need for effort at present retrieval or additional storage activities for purposes of future retrieval. Examples of situations suitable to assess children's metacognitive experiences concerning memory include the prediction of one's own memory span or the decision about when one is ready to attempt recall of an item list.

Space constraints do not allow us to give a representative account of the development of declarative and procedural metamemory (for reviews, see Brown et al., 1983; Flavell, 1985; Schneider & Pressley, 1988). In brief, evidence from metamemory interviews and experimental tasks supports the general view that both components of metamemory seem to develop between preschool age and adolescence, with particularly rapid increases observable during the elementary school period.

Since the beginning of research into metamemory, a hypothesis that stimulated many studies was that children's metamemory is closely linked to their behavior and performance in various memory situations. For example, it was assumed that the "production deficiencies" frequently observed in younger children could be explained by their lack of specific strategy knowledge and a lack of knowledge concerning the appropriate conditions for controlled strategy use. Children's increasing knowledge about the memory system was thought to lead them to think and remember more and more effectively.

Early investigations into the metamemory–memory behavior relationship revealed only modest support for such a position, particularly where the relationship between declarative (factual) knowledge about memory and behavior in memory tasks was concerned (cf. Cavanaugh & Perlmutter, 1982; Schneider, 1985). Theoretically, several factors could contribute to the weak relations observed (cf. Flavell, 1978; Flavell & Wellman, 1977). For example, children who know that a strategy is useful might think that an alternative strategy is even better in a particular situation, or that the task is much too simple to use a memory strategy. Further, they may have abstract knowledge about strategies but not be very good at executing them. Finally, we can think of situations where strategy use is clearly needed for optimal performance, but where we decide that it is somehow not worth the effort. Flavell and Wellman (1977) termed this the "original sin" hypothesis.

Although it is intuitively reasonable to believe that these factors can attenuate the correlations among metamemory, memory behavior, and memory performance, they do not completely account for the negative findings. A major problem is that children's metamemory was only insufficiently and unreliably assessed in most of the early studies.

In the "second generation" of metamemory studies, precautions were taken to assess adequately the kind of metamemory relevant for the memory situation under investigation. As a consequence, closer relationships were found among knowledge, behavior, and performance (cf. Borkowski, 1985; Pressley, Borkowski, & O'Sullivan, 1985; Weinert, 1986). The findings further indicated that the intercorrelations among metamemory, memory behavior, and performance increased with age, probably due to the metamemory of older children. The aforementioned study by Schneider (1986) seems suited to illustrate this point. As noted, the second graders in this study sorted the items into semantic categories only when either category relatedness or interitem associativity was high, whereas the fourth graders were more flexible in using the organizational strategy. Additional metamemory assessments clearly showed that young children's knowledge about organizational strategies was generally poor and inconsistent across different assessment procedures. Thus, it was not surprising that rather low correlations between metamemory and memory behavior were found in this age group. On the contrary, most fourth graders knew about the efficiency of organizational strategies, and the metamemory scores obtained were highly consistent across measures. Even more important, significant intercorrelations among metamemory, memory behavior, and memory performance were found for this age group. Results of multiple regression analyses further indicated that fourth graders' recall could be best predicted by both their task-related metamemory and sorting strategies, whereas second graders' recall was not influenced by either metamemory or strategy variables. It suggests, then, that age differences in children's metamemory can be regarded as an important source of age differences in memory performance.

It should be noted, however, that we know too little about the developmental mechanisms involved. The question of how we should conceive of the functional and developmental connections between metamemory and strategies is a controversial issue. Although empirical evidence is still scarce, the so-called bidirectionality hypothesis (Flavell, 1978) has intuitive appeal. Accordingly, initial strategy use leads to some dim knowledge of the strategy's usefulness, which in turn stimulates more strategy use, which then leads to greater knowledge of the strategy's utility, and so on. This principle of reciprocal mediation is also central in the model of knowledge about strategies developed by Pressley, Borkowski, and O'Sullivan (1985) and depicted in Figure 3.2.

The fundamental elements of the model are the learner's strategies,

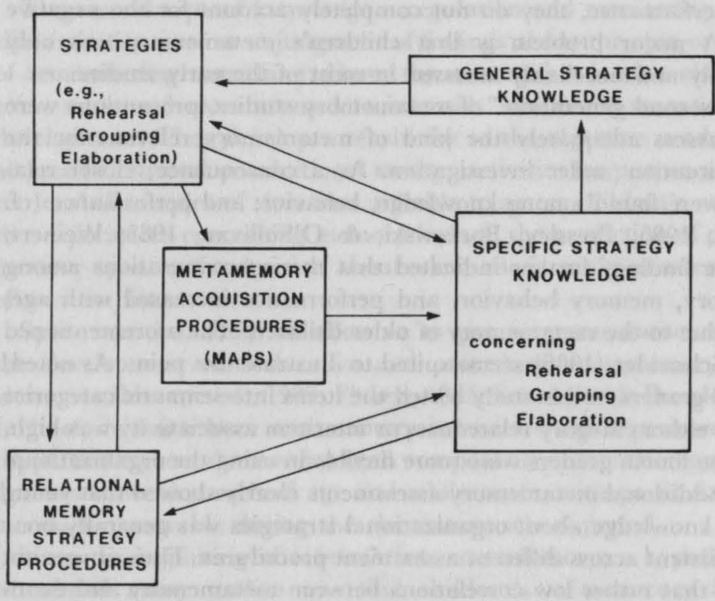

Figure 3.2. A model of metamemory about strategies (Pressley, Borkowski, & O'Sullivan, 1985; slightly modified).

which may share subprocesses. These commonalities among strategies are "detected" by a set of relational strategy procedures that are conceptualized as meta rules (Chi, 1987) in that they take other rules as input. Another important aspect of knowledge about strategies (MAS) is the general strategy knowledge component, consisting of general principles relevant to all or most strategies. The model implies that the reciprocal mediation process between strategy employment and specific strategy knowledge also adds to general strategy knowledge. We think that the inclusion of so-called metamemory acquisition procedures (MAPS) makes the MAS model particularly interesting. Like relational memory strategy procedures, they are conceptualized as meta rules in that they take as input other rules; their output is conceived of as an appropriate evaluation resulting in new knowledge. The various components of the model are not seen in isolation but in close interaction. Thus the MAS model is characterized as *dynamic* and *interactional*.

Although the validity of the MAS model has not yet been tested in detail, there is already promising evidence supporting the view that MAPS (e.g., self-testing procedures) play a central role in metacognitive approaches to strategy instruction (cf. Pressley et al., 1985; Pressley, Forrest-Pressley, & Elliott-Faust, 1988). In particular, the training of MAPS has been proved successful in young learners, teaching them to compare the efficacy of different strategies and to use that information to make strategy decisions. From this kind of intervention research, it can be concluded that MAPS not only feed in specific strategy knowledge, but also provide learners with more general monitoring skills, thus demonstrating that they are not tied to any particular strategy. Given the positive empirical evidence for at least some components of the model, one can be optimistic that future research will lead to theoretical refinements in the concept of metamemory and demonstrate its educational utility.

The four sources of memory development in a life-span perspective

It has been shown that memory development can be explained in four different ways: changes in basic capacities, in strategies, in the knowledge base, and in various components of metamemory. In the overview presented so far, we occasionally referred to the fact that some of these sources seem to have larger effects than others, and that some seem to contribute significantly in certain age periods but not in others. A systematic summarization of the types of contributions that these four sources make to memory growth during different periods of development was given by Siegler (1986) and is depicted in Table 3.1. According to Table 3.1, performance differences in the early developmental period (age 0–5) may be best explained by differences in memory capacity and content knowledge (the knowledge base). From age 5 to age 10, all four sources can account for developmental differences, with memory capacity declining in importance. Finally, from late childhood to adulthood, it seems that knowledge factors generally contribute more than both strategy and capacity components; Siegler (1986) assumes that factual (declarative) memory knowledge may exert most of its effect on memory performance within this later phase of memory development, whereas the impact of memory monitoring and regulation skills as well as of the knowledge base already contribute to memory development from early in life.

Although such a view is generally supported by the empirical evidence presented so far, it is nevertheless speculative in many aspects. For example, few empirical studies have directly investigated the relative impact of the four sources of memory on memory performance during different developmental periods, that is, for different age groups. Moreover, the summary given in Table 3.1 suggests a "natural," univer-

Table 3.1. *Contributions of four sources of memory development during different periods of development*

Source of development	Age 0–5	5–10	10–adulthood
Basic capacities	Many capacities present: association, generalization, recognition, etc. Absolute capacity already at adultlike levels by age 5	Speed of processing increases	Speed of processing increases
Strategies	Little evidence of strategy use	Acquisition of many strategies: rehearsal, organization, etc.	Increasing use of elaboration. Continuing improvement in quality of all strategies
Metamemory	Little factual knowledge about memory. Some monitoring of ongoing performance	Increasing factual knowledge about memory. Improved monitoring of ongoing performance	Continued improvement in factual knowledge, monitoring and regulation skills. Factual knowledge may exert increasing effects on memory behavior and performance
Content knowledge	Steadily increasing content knowledge helps memory where the knowledge exists	Steadily increasing content knowledge helps in acquiring new strategies, and helps memory where the knowledge exists	Continuing improvements as in the 5–10-year period

Source: Modified after Siegler, 1986.

sal course of development primarily caused by internal, "in-the-child" mechanisms. Indeed, most research discussed so far has completely ignored the problem of how external, environmental factors like cultural differences or instructional experiences can influence the impact of the four major sources of memory development. Finally, the literature summarized in Table 3.1 usually neglected the issue of individual differences. The importance of these neglected issues will be discussed in the following section.

Sources of memory development: neglected issues

Relative contribution of the four sources to memory development

It is not surprising that the problem of how to assess the relative or simultaneous impact of memory capacity, strategies, the knowledge bases, and metamemory has not been dealt with adequately in previous research. Appelbaum and McCall's (1983) criticism that developmental psychology has spent the past two decades in methodological narcissism is particularly true for the area of memory research. As most studies were devoted (or should we say restricted) to the experimental approach, the emphasis was on study memory development in a methodologically precise manner, and not on asking "bigger" questions requiring either many observed variables, or large samples, or both. In our view, exploring the relative contributions of those four sources to memory development as well as their complex interactional pattern means asking such a "bigger" question. Thus, to treat this problem appropriately, we need to replace the experimental approach by a methodological strategy that allows us to deal simultaneously with many variables and with large samples. We want to illustrate how the problem can be handled by using the causal modeling or structural equation approach based on correlational data.

One particular advantage of causal modeling procedures is that they can use latent variables instead of observed indicators. In causal models using latent variables, the measurement model defines the relationships between observed variables and the unmeasured hypothetical constructs via factor analytical procedures, whereas the structural equation model ("causal" model) is used to specify the causal links among the latent variables. Thus, a regression type of analysis is conducted on the basis of latent variables instead of manifest indicators, which means a more powerful explanatory approach.

The causal model developed by Hasselhorn (1986) may serve as an illustration of how this methodological approach can be used to integrate all variables considered relevant for the prediction of memory performance and to assess their relative impact on memory behavior and performance (cf. Fig. 3.3). The task chosen to illustrate the role of the four sources was the sort–recall paradigm. Various indicators of information processing speed were used to represent memory capacity, and several measures of semantic knowledge represented children's knowledge base. Sorting strategies in the sort–recall task indicated the strategy component (memory behavior) in the model. The two different components of metamemory – declarative and procedural metamemory – were con-

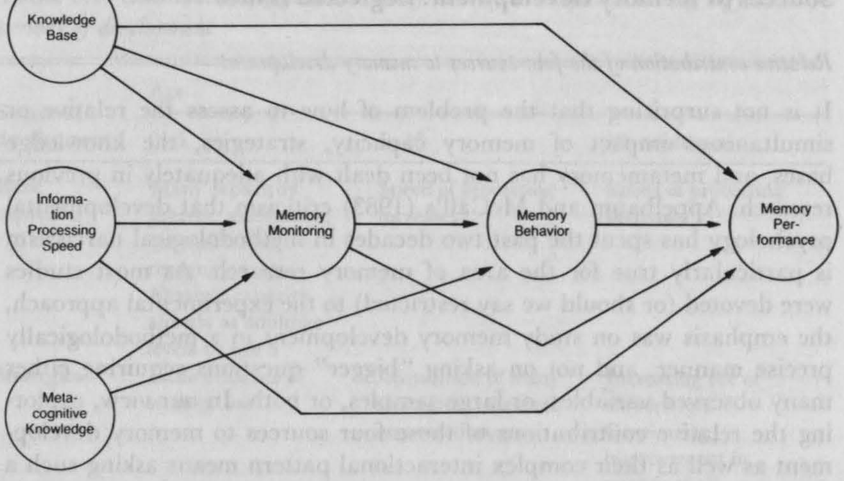

Figure 3.3. The structural equation model developed by Hasselhorn (1986) to illustrate the interplay of different sources in predicting memory performance.

ceptualized as two different constructs in Hasselhorn's model. Metacognitive knowledge included general declarative metamemory as well as knowledge concerning the sort–recall task. Memory monitoring, on the other hand, comprised measures tapping children's procedural knowledge (e.g., prediction of memory performance). As can be seen from Figure 3.3, the knowledge base, information processing speed, and metacognitive knowledge were used as exogeneous variables in the model, that is, they were not further explained or interrelated. They were assumed to influence memory monitoring in the sort–recall task, and also to influence memory behavior – that is, strategy use as well as memory performance. It was further assumed that memory monitoring should affect both memory behavior and performance, whereas memory behavior should directly influence the amount of recall. Hasselhorn (1986) estimated this model by using the data from 176 fourth graders. As a main result, metacognitive knowledge, information processing speed, the knowledge base, and memory behavior were shown to contribute independently to the prediction of memory performance. Moreover, in comparison with metacognitive knowledge and information processing speed, the knowledge base had by far the strongest impact on children's memory behavior.

Similar analyses based on structural equation modeling procedures and using data from third, fifth, and seventh graders and elderly adults (Schneider, Körkel, & Weinert, 1987b; Weinert et al., 1984) by and large confirmed these findings. In addition, it could be demonstrated in these studies that the structural patterns obtained in the analyses were similar across age groups in that metamemory always affected strategy use, which in turn significantly influenced memory performance. Although these models were not completely specified as they did not include the knowledge base, the striking similarity of interrelationships among metamemory, memory behavior, and performance obtained for the different age groups suggests that the basic structural or interactional relationship remains stable over time. As the empirical evidence is still confined to cross-sectional studies into the sort–recall paradigm, additional longitudinal analyses are needed to test the generalizability of these findings.

Of course, generalizability can only be expected if the problem of the specific "memory type" under investigation can be neglected – that is, if individual differences across various memory tasks do not matter at all. As already noted, the question of whether the memory concept represents a general, unitary human faculty or rather a variety of independent abilities certainly was a controversial issue a century ago, but it has not attracted much attention since then. The more recent empirical evidence will be summarized next (see Knopf, Körkel, Schneider, & Weinert, 1988, for a more detailed account).

The problem of individual differences

It should be noted that only a few studies conducted within the information processing approach have addressed the issue of intraindividual consistency in performance across several memory tasks. The hypothesis was that individual differences in memory reflect a general, strategic factor (Kail, 1979). According to this assumption, some people may use memory strategies consistently and perform well, whereas others may use strategies poorly, and thus show low levels of recall. Kail (1979) used a factor analytic procedure to test the hypothesis that third and sixth graders' memory performance in different tasks could be explained by a general strategic factor. Although he claimed to have found empirical support for such an assumption, a closer inspection of the intercorrelations among tasks and strategy measures revealed that they were generally small.

There is evidence, however, that the degree of intraindividual consistency across memory tasks strongly depends on the similarity–

Table 3.2. *Intercorrelations among various memory performance measures obtained for 4-year-old children (N = 185)*

Variables	(2)	(3)	(4)
(1) Memory span	.21	.20	.25
(2) Recall in a sort–recall task		.23	.36
(3) Text recall 1 (birthday party)			.64
(4) Text recall 2 (playing with friends)			—

Source: Data from Weinert, Schneider, & Knopf, 1988.

dissimilarity of task requirements. That is, high intraindividual consistency can be found for memory tasks tapping similar strategic skills. For example, substantial intertask correlations were found for free recall tasks that either used different stimulus lists or different procedures (Cavanaugh & Borkowski, 1980; Knopf et al., 1988). On the other hand, only weak intercorrelations were obtained when children's memory for text and memory for word lists were compared (Knopf et al., 1988; Weinert & Schneider, 1986; 1987). It seems important to note that this pattern of results holds for different age groups. In the study by Cavanaugh and Borkowski (1980), comparably high intertask correlations were found for kindergartners and first, third, and fifth graders. This was also true for the similar recall tasks in the study by Knopf et al. (1988), where high stability scores were observed for third, fifth, and seventh graders. Conversely, the correlations among dissimilar memory tasks (e.g., digit span and memory for prose tasks) were comparably low for all age groups in the study by Knopf et al. This finding can also be generalized to the four-year-old subjects of the Munich Longitudinal Study (Weinert & Schneider, 1986; 1987), as illustrated in Table 3.2. In this study, several memory tasks were presented to the children. While a word span task similar to that used by Case et al. (1982) tapped memory capacity, a simple sort–recall task was given to assess rudimentary sorting strategies and their impact on recall. Finally, two similar stories were presented to assess children's memory for prose. Given the large number of subjects, it is not surprising that all correlations shown in Table 3.2 are statistically significant. However, the data indicate that, with the exception of the interrelationship between recall for the two similar stories, intertask consistency of children's memory performance was reasonably low.

It appears, then, that subjects' memory behavior and performance differ as a function of the memory paradigm under investigation. Only for memory tasks belonging to the same class or type (e.g., free recall tasks, memory for prose tasks) can high intertask consistency be expected across a broad range of age groups. Obviously, there is no evidence for generally strategic or mnemonically sophisticated subjects. As a consequence, we doubt that a single structural model concerning the interplay of capacity, strategy, and knowledge variables can be constructed that is equally suited to explain performance in different memory paradigms.

The impact of cultural and instructional differences

One problem with our knowledge about memory development is that it is based on findings obtained in Western societies. In this connection, it is interesting to note that, according to these findings, the most active period in memory development coincides exactly with the period of formal education in Western societies. Thus, it has been pointed out many times that formal education may be significantly implicated in advanced memory development, and that the case is one of educational rather than maturational development (cf. Brown, 1977; Paris, Newman, & Jacobs, 1985). Schools represent cultural institutions in modern societies where remembering as a distinct skill is routinely undertaken in isolation from possible applications (Cole & Scribner, 1977). Although deliberate remembering as an end in itself rather than as a means to achieve a meaningful goal is an activity typical of Western schools, it may not play a major role in unschooled populations. The only way to test this assumption is to investigate cultures in which the degree of formal schooling and chronological age are not hopelessly confounded as in Western societies. Although the results from cross-cultural studies dealing with this problem are not always consistent (cf. Rogoff & Mistry, 1985; Wagner, 1981, for reviews), they give important information on the question of whether universal trends in memory development can be assumed.

First of all, they unequivocally support the position that the development of verbal memory strategies is closely connected to schooling. It has been repeatedly shown that verbal rehearsal and organizational strategies are not spontaneously available to subjects with no formal education. As a consequence, they usually show poor performance in verbal recall tasks. In fact, the impact of schooling on verbal memory tasks is so strong that it can easily outweigh factors like age or social class.

On the other hand, probably the clearest evidence for culturally invariant developmental trends was obtained for tasks where familiar, meaningful materials are used, and where the instructions focused on activities that are close to daily experiences in each of the widely differing cultures. In particular, the recall of stories or fairy tales whose structure seems comparable across varying cultures belongs to this category. Similarly, memory for location seems comparable in subjects with differing cultural backgrounds. In addition, the mediating effect of the knowledge base on children's memory performance seems to be comparably high in schooled and unschooled populations. As demonstrated by Kearins (1983), it is even possible that unschooled children can outperform schooled children in verbal recall tasks when the stimulus lists are highly familiar. In this example, Australian aboriginal children and white Anglo-Australian children recalled a word list consisting of the names of wild animals (known to both groups). Interestingly, recall of the aboriginal children was superior independently of whether only the names of the animals were read aloud ("name-only task") or pictures of the objects were given simultaneously ("picture–name task"). Subsequent interviews revealed that both groups in the "picture–name task" had mainly used imagery strategies, but that their learning styles differed in the "name-only task": whereas rehearsal strategies dominated in the Anglo-Australian children, the aboriginal children were apparently capable of spontaneously employing imagery. This seems to be a nice example of the compensatory effects that the knowledge base and interest factors can have on children's memory performance. Although an efficient verbal memory strategy was not available to the aboriginal children, their detailed knowledge and particular interest in wildlife led to superior performance in the verbal recall task.

Taken together, however, the findings from cross-cultural studies clearly demonstrate that the emergence of verbal memory strategies is a function of schooling. As a consequence, the development of memory strategies and their impact on memory performance is not a universal phenomenon but is confined to Western societies.

However, even within Western societies, differences in instructional practices can mainly determine the degree to which verbal memory strategies are spontaneously used. For example, mainly as a consequence of instructional differences, it may be observed that some children spontaneously employ strategies, whereas other children of their age do not. In a study by Schneider, Borkowski, Kurtz, and Kerwin (1986), substantial differences in the use of organizational strategies were found between American and German third graders. Whereas the German children clustered the picture stimuli almost perfectly according to their semantic categories, American subjects showed only low levels of spontaneous sorting. Interestingly, only a short training procedure was necessary to overcome the American subjects' production deficiencies. In a subsequent study (Kurtz, Schneider, Turner, & Carr, 1986), similar trends were found for American and German second graders. Here, the most important finding was that differences in children's strategy use covaried with the different emphasis put on memory strategies by teachers and parents. That is, the analysis of teacher and parent interviews clearly indicated that German teachers and parents spend more time teaching and explaining memory strategies to their children.

Additional evidence comes from recent studies by Moely and her research group (Moely, Hart, Leal, Johnson-Baron, Santulli, & Rao, 1986; Moely, Leal, Pechman, Johnson, Santulli, Rao, Hart, & Burney, 1986). In these studies, it could be demonstrated that individual differences in the use of memory strategies by elementary school children are substantially related to teachers' use of strategy suggestions in the classroom. Children whose teachers often suggested strategies were better able to maintain strategies and also improved recall performance more than children from classrooms with teachers low in strategy suggestions.

All in all, these findings indicate that the development of memory strategies does not follow a "natural" pattern predominantly caused by maturational factors. Instead, the speed and amount of developmental change clearly depends on the degree of formal education and other environmental factors (e.g., parental influences). Of course, formal education does not operate like a constant, invariant factor: Individual differences in educational practices have an enormous impact on when and how children acquire memory strategies. As a consequence, even in schooled environments, individual differences in strategy use are still observed.

Developmental differences versus developmental changes: the need for longitudinal studies

Usefulness and shortcomings of cross-sectional studies in research on memory development

Given the empirical findings reported so far, there is little doubt that research in memory development has made enormous progress during the past two decades. As a consequence, our knowledge concerning developmental differences in memory performance as well as the sources of those differences has increased considerably. However, such a positive evaluation of the state of the art must be qualified in several respects.

Research in memory development has been limited in that (a) only a few experimental paradigms (in most cases, short-term recognition or free recall of word lists and text materials) have been considered; (b) the focus has been on the assessment of (age-correlated) developmental differences in basic memory capacities, memory behavior, and performances, whereas developmental changes have been typically ignored; (c) most studies have examined linear relationships between developmental differences in memory performance on the one hand and developmental differences in memory processes on the other hand, which have typically been inferred from findings based on different age groups; (d) research has focused on universal aspects of memory development, thus neglecting intraindividual and interindividual differences in developmental changes, and possible causes for these differences; and (e) research has concentrated on the description of developmental differences in the relationship between memory processes and memory performance, and typically ignored the problem of how to conceptualize developmental (explanatory) mechanisms.

Because of these limitations, most contemporary theories and models of memory development appear *idealistic*. That is, the traditional research strategy of comparing average, isolated memory performances with average performance-related memory processes in two or more age groups supports a tendency to overestimate the universality, intraindividual homogeneity, and interindividual consistency of developmental sequences. Thus, according to this approach, memory development is viewed as a regular, rule-bound sequence of changes in cognitive competencies and related memory skills. Typically, deviations from this ideal sequence have been ignored. If not ignored, they have been either treated as error variance or interpreted as individual acceleration or retardation, compared to a prototypical developmental sequence.

Despite these problems, the research approach we have described has certain theoretical advantages that should not be overlooked. In particular, many recent studies conducted within the experimental paradigm were well suited to illustrate interrelationships among differences in memory performance and differences in specific mental capacities. Undoubtedly, this experimental approach can provide a solid basis for generating important hypotheses concerning memory development. However, the validity and generalizability of these hypotheses are restricted by the cross-sectional designs used. In our view, it is mainly because of the restricted range of experimental designs (used by most cognitive developmental psychologists) that the predominant models of memory development are idealistic in nature.

A different developmental pattern has emerged whenever the classical experimental approach is replaced by field-experimental studies using several memory tasks in identical samples. Here, a typical finding is that memory performance varies considerably within individuals and between subjects of the same age group. As mentioned previously, the intertask correlations are generally low. They are particularly low for different classes of memory tasks (e.g., word span, memory for prose), and somewhat higher when similar memory tasks (e.g., word lists using different stimulus materials) are used. It is safe to state that all efforts to establish a taxonomy of memory performances and their underlying dispositions based on factor analytical approaches have failed. Thus we have reason to adopt the conclusion provided by Campione, Brown, and Bryant:

> The picture is not as simple as had originally been thought, however, since no single, unitary learning or memory faculty of great generality has been revealed. Rather, both learning and memory are complex processes, incorporating a wide array of subprocesses, together with procedures for overseeing those subprocesses. (1985, p. 121)

Note that this conclusion is also in accord with the theoretical approach presented by Ericsson (1985), who inferred from his analysis of exceptional memory performance that "all systematic differences in memory performance are due to acquired memory skill" (p. 214).

According to Ericsson (1985), the skill hypothesis is not restricted to memory experts but also might describe the memory development of normal subjects. This hypothesis was confirmed through a series of training studies conducted by Baltes and his co-workers (Kliegl, Smith, & Baltes, 1986). In these studies, it was demonstrated that intensive training of elderly people in the utilization of complex but specific memory skills had impressive effects on their performance in a digit-span task. Do these results imply that memory development is best viewed as a function of several independent processes concerning the acquisition, improvement, and automatization of memory skills? Recent empirical evidence based on performances on various memory tasks does not confirm such a position. This evidence includes studies concerning the transfer of procedural knowledge (Brown & Campione, 1984), the (decontextualized) use of memory strategies (Naus & Ornstein, 1983), and the impact of general metacognitive skills on memory performance in different memory tasks (Campione et al., 1985).

Given the empirical evidence, realistic or "true" models of memory development should be located somewhere between the two poles of "the big picture of development" (Fischer, 1980) on the one hand, and a model representing memory development as the acquisition of many independent, specific skills on the other hand. Undoubtedly, memory development is much more variable and fragmentary than many idealistic models of development and intuitive developmental theories suggest. We believe that, in order to come to more realistic conceptualization of memory development, we must complement our cross-sectional data with empirical evidence from longitudinal studies.

Why longitudinal studies into memory development?

We would not go so far as to say that all those problems described in the previous section can be solved by focusing on the longitudinal approach. Nonetheless, it is indeed surprising that there are almost no longitudinal studies in the area of memory development. Of course, several disadvantages of longitudinal studies may have contributed to this situation (cf. Schneider, in press). They are extremely expensive and difficult to organize. Further, it is not an easy task to develop tasks that can be repeatedly used over a long period of time without producing floor and ceiling effects. Other methodological problems include the issue of how to substitute tasks with equivalent procedures at a later point in development, and how to control for retest effects. These problems seem particularly important in the context of learning and memory tasks, which are often repeatedly presented over a longer time period.

The lack of longitudinal studies may also be caused by the predominance of metatheoretical principles in the information processing approach: Most studies within this approach have been conducted in the area of memory development, an area that suggests the study of between-group differences (Kail & Bisanz, 1982). Despite these methodological and practical differences, however, an increasing number of social scientists consider longitudinal studies in the area of memory development to be a *necessary* complement to cross-sectional studies. In support of this judgment, the following reasons are frequently given:

1. In comparison with cross-sectional analyses, within-subject assessment of skill acquisition and performance changes are advantageous in that they allow for the description of developmental sequences. However, this advantage of longitudinal studies is of benefit only if individual data curves are considered instead of group means. Of course, the identification of typical or prototypical patterns of change is a major goal of developmental sequential analyses based on individual curves.

2. Longitudinal assessment of developmental change is particularly useful when there is evidence that cognitive competencies or performances do not continuously increase during childhood but may stagnate or even regress for a short period. Such U-shaped curves have been repeatedly observed (cf. Hoppe-Graff, 1985; Strauss & Stavy, 1982). According to Karmiloff-Smith's (1984; 1986) three-phase model of cognitive development, these U-shaped curves can be regarded as one of several "behavioral indices of representational change" (1986, p. 108).

For example, Lesgold (1984) observed such U-shaped performance changes when adult learners acquired domain-specific expertise, thus demonstrating the broad range of empirical examples for this phenomenon.

3. Longitudinal studies that not only include several memory measures but also additional cognitive indicators provide opportunities to go beyond the typical analysis of synchronous and asynchronous patterns of change. That is, they give information about interactional patterns in the development of different domains. According to Wohlwill (1973), this is the only way to assess homogeneity versus heterogeneity of individual memory development.

4. In our view, it is particularly informative to include specific training programs in the course of a longitudinal study because this allows the investigation of preconditions of successful intervention. Analyses of this kind are valuable as part of a comprehensive analysis concerning the preconditions and precursors of developmental changes in memory performance and the changes in related memory competencies (cf. Campbell & Richie, 1983). Although the longitudinal design is a necessary precondition, it may not be always sufficient for conditional analyses or prognostic studies of this type, mainly because of its nonexperimental character (cf. Hoppe-Graff, 1985). Given the very complicated cumulative or compensatory effects observed in the interactions among different sources of memory performance (e.g., domain-specific knowledge, general memory strategies, intelligent processing of information), it is probably difficult to identify necessary and/or sufficient conditions for memory development (see Hasselhorn, 1986; Kintsch, 1986; Körkel, 1987).

5. The assessment of stable interindividual differences in intraindividual change has been considered one of the most important tasks of longitudinal studies. As a matter of fact, these invariants are always masked by the effects of variable individual experiences; thus, it seems difficult to measure stable differences in operative abilities (e.g., differences in intelligence) and basic capacities in isolation, as emphasized by Estes (1982). Obviously, the only way to analyze the consistency of individual differences across tasks and their persistence over time is to use longitudinal designs.

To meet these theoretical expectations, longitudinal studies should be designed in a way that allows for the consideration of two different goals: On the one hand, the inclusion of a broad range of variables allows the empirical identification of complex interrelationships, isolated developmental trends, and age-dependent as well as age-independent developmental sequences (inductive approach). On the other hand, the hypotheses to be tested through longitudinal studies are best derived from theoretical knowledge about memory development obtained from cross-sectional studies (deductive approach). If it is also possible to vary conditions of development by using training programs or similar intervention procedures, then longitudinal studies could not only help in generating a broad descriptive knowledge, but could also provide conditional knowledge in the sense of theoretically postulated and empirically testable mechanisms of development. Given the present state of the art, however, this possibility seems restricted. The question of *why* changes occur cannot be adequately addressed by simply answering questions concerning which processes change how and under what conditions: Here, additional speculations are still needed.

Empirical evidence for developmental change: first results of longitudinal studies on memory development

We do not want to conclude without giving at least a short demonstration of how results from the few available longitudinal studies can enrich our knowledge about memory development.

In a short-term longitudinal study by Kunzinger (1985), the overt rehearsal and free-recall performance of 18 children was analyzed in two experimental testing sessions, initially when the children were 7 years of age and again 2 years later when they were 9. The impact of rehearsal frequency and rehearsal set size on subsequent recall was assessed in both sessions. The longitudinal results confirmed previous cross-sectional findings in that both rehearsal frequency and rehearsal set size increased with age, and that recall was more closely related to rehearsal set size than to rehearsal frequency. In addition, however, two interesting observations were made: First, it could be shown that rehearsal set size assessed at measurement Point 1 was not related to recall at measurement Point 1, but significantly predicted recall assessed 2 years later. This finding suggests that early differences in strategy use are better suited to predict future performance than to predict concurrent memory performance. According to Kunzinger, this finding may be due to the fact that production deficiencies dominant in the early assessment period were no longer a problem at age 9.

The second interesting finding concerns the relatively high stability over time observed for most memory variables. This stability was found for individuals' relative standing within their group between age levels (*group* stability) as measured with the correlation coefficient (*r* between .60 and .80) as well as for the level of *individual* stability. Here a "lability score" was computed to measure the amount of across-age variability shown in an individual's relative standing within the referent group. A high lability score indicated a high level of instability. The particularly high level of stability for rehearsal set size indicates that those children with initially larger set sizes were also those showing the largest set sizes 2 years later. Although these findings should be interpreted cautiously because of the small sample size, they give evidence of impressive interindividual stability over time, at least during the elementary school years.

However, as first evidence from our Munich Longitudinal Study (Weinert & Schneider, 1986; 1987) demonstrates, the picture of memory development may be different in preschool years. Our findings from the first two measurement points, when the subjects were 4 and 5 years of age, revealed considerable intraindividual inconsistency in performance across similar memory-for-prose tasks as well as individual instability with regard to the two measurement points. Lability scores were computed to assess the across-age stability in text recall, verbal intelligence, and motor skills. As a main result, we found that lability scores were almost three times as high as those obtained by Kunzinger (1985), and that they were absolutely comparable across the three tasks considered. It seems, then, that at that particular age high levels of instability are not only typical of memory performance but can be generalized across different domains. Although the reasons for the high levels of instability observed for most preschool measures of the Munich Longitudinal Study are not entirely clear, there are several possibilities (cf. Schneider, in press). For example, assessing true competence in preschool children is very difficult because situational factors seem to play an important role. That is, performance in a cognitive task may vary as a function of children's interest in the task, their familiarity with the experimenter, or their actual mood. On the other hand, it is also possible that the phenomenon under study is less stable over time than is typically the case for such variables in older children. This may even be true for traitlike variables (e.g., intelligence).

As a consequence, it is extremely important to make sure that variables are reliably assessed in order to evaluate the findings of considerable change over time. Whenever possible, coefficients of internal consistency should be obtained. If this turns out to be difficult, multiple measurements concerning the variable of interest should be available that allow for an evaluation of short-term stability.

Because sufficient internal consistency and/or short-term stability could be demonstrated for the measures in our longitudinal study, it appears that various memory phenomena indeed change considerably over time. Taken together, however, longitudinal evidence from memory studies is still too scarce to allow far-reaching conclusions. We believe that future longitudinal studies will be helpful in increasing our understanding of the emergence of how skilled remembering appears and develops.

NOTE

We would like to thank Beth Kurtz and Mitch Rabinowitz for helpful comments on the chapter.

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