Individual Differences in Memory Development Across the Life Span

Franz E. Weinert, Wolfgang Schneider, Monika Knopf
MAX-PLANCK-INSTITUTE FOR PSYCHOLOGICAL RESEARCH, MÜNCHEN, F.R.G.

Abstract

Experimental research on memory development has typically focused on the description of universal development trends across the life span and the identification of major sources of development within this domain. However, there is a lack of studies investigating the preconditions and effects of interindividual variability within age groups across different memory tasks. Similarly, our knowledge

about the stability of interindividual differences across the life span as well as the sources and the amount of intraindividual variability across memory tasks is scarce. In the present chapter, we concentrate on these neglected issues. First, theoretical assumptions concerning the interindividual and intraindividual variability of memory development are discussed. Next, empirical evidence is presented that seems suited to document the importance of these neglected issues. While we try to give a representative account of the literature, the emphasis is on more recent studies of memory development in children and elderly adults conducted in our laboratory.

The results demonstrate that age-related changes and individual differences in the knowledge base are particularly important for describing and explaining individual differences in memory development. In comparison, the role of stable individual differences in basic memory capacities in explaining variations in memory development is less clear given the conflicting empirical evidence. In the final section of the chapter consequences for future research are discussed.

Research in memory development is focused on universal changes from childhood to later childhood. A review of the literature makes clear that individual differences tend to be neglected although they characterize age-related changes and they are the result of such changes in memory development. This dual function holds for intraindividual differences in the mastery of various memory tasks, for interindividual differences within the same age group as well as for differential memory changes in the course of development.

The analysis of individual differences in memory development poses a number of fundamental questions: Is the course of memory development identical for all individuals, differing only in developmental speed and performance levels, or is it possible to identify highly disparate courses of development for different individuals? What conditions or factors are responsible for the course of memory development?

Another such question is whether the variables that can serve to explain universal changes can also account for interindividual differences in the memory performance of persons within the same age group at different times across the life span. Can developmental and individual performance differences be explained as resulting from differences in the acquired memory skills or do memory capacities have an impact both on actual memory performance and on the long-term acquisition of memory skills? What is the role of the domain-specific knowledge base on memory performance as against that of general memory strategies and that of metamemory? Can the same variables predict/explain individual differences in memory performance and memory development in children and in (older) adults or must explanations/predictions of individual variations in memory performance also consider age-related differences?

These then are some of the basic questions that arise for the analysis of individual differences in memory development across the life span. In the present state of research only some of these guiding questions can be answered adequately. The main concern of this chapter therefore is to examine whether the explanatory variables for universal changes in memory performance can be used in order to explain and predict individual differences.

I. Historical Background

More than 100 years ago, Hermann Ebbinghaus described some of the tasks, and at the same time anticipated many of the difficulties, that a differential psychology of human memory and its development across the life span would face: "How differently individuals behave, one good, the other bad, even compared to oneself each different in different phases of life, different in the morning and in the evening, in youth and in old age . . . infinite differences are found" (Ebbinghaus, 1885, p. 2). Thus, Ebbinghaus soon gave up the attempt to systematically analyze general laws of individual differences. In the first version of his manuscript "On Memory," he admitted with resignation, "My efforts in this respect have failed" (Ebbinghaus, 1880/1983, p. 68).

Hermann Ebbinghaus' decision to study general laws of memory and to neglect individual differences had a long-lasting impact on experimental research in learning and memory, no matter how widely the competing functional, behavioral, and cognitive approaches differed. Despite isolated efforts, intraindividual and interindividual differences in memory performance were neglected as error variance.

This tendency is not found to such a degree in the history of developmental psychology, a subdiscipline of scientific psychology which—since its beginnings at the end of the 19th century—was as strongly (maybe even more strongly!) influenced by the biological theory of evolution as by experimental psychology. This, of course, also influenced memory research (Binet & Henri, 1894). From the beginning, three research goals could be differentiated:

Study of Specific Attributes of Memory Performance and Their Change as a Function of Age. Although (or perhaps because) developmental curves were not based on longitudinal data, but were reconstructed from age-correlated performance differences in cross-sectional studies, a wide consensus was reached after only a few decades of research on memory development. McGeoch and Irion (1952) summarized: "The increase. . . . of learning (and memory) with age over the years to early maturity, its relative constancy during the next decade, and its low decline thereafter appear over a very wide range of conditions and are among the more general facts of the psychology of learning" (p. 544).

Study of Individual, Age-Correlated Variations in Memory Performance Explained by Stable Characteristics of the Person. Intraindividual memory differences (as a function of memory faculty under study) as well as interindividual differences (concerning the rate of development, gender, intelligence) were prominently considered in early research. As a rule, the suggestion of Binet and Henri (1894) that individual differences are easier to study in complex processes than in simple ones (memory of ideas versus memory of simple elements) was followed in these studies. The results, however, were empirically inconsistent and theoretically unsatisfying. Memory abilities identified by factor analysis proved to be highly task-dependent. All efforts to produce a taxonomy of primary memory abilities failed. Sex differences in memory performance were generally trivial or noninterpretable. Finally, the correlation coefficients of the relation between memory and intelligence varied from 0 to .80 and proved to be strongly dependent on the task. The hypothesis "mental age, not chronological age is a basis of the learning curve" (Hollingworth, 1920, p. 181) could also not be generally confirmed (Johnson & Blake, 1960; Stevenson, 1972). What, then, is the resumé of this initial period of intensive study of individual differences in memory performance? Despite great efforts, no satisfactory method was found to systematically pursue individual differences in memory, even though performance variation in developmental studies was always large and usually remained so when chronological age was controlled.

Identification and Analysis of Developmental Mechanisms Explaining Age-Correlated Changes in Memory Performance and Their Individual Differences. This line of research was particularly influenced by the classical maturation-degeneration hypothesis, which maintains that changes in memory with age are primarily dependent on organic growth and decline, and less dependent on previous learning. "The organism provides the framework of mechanism within which learning occurs and by which learning bounds are set. Maturation and degeneration probably change this framework in many now unknown ways which subtly effect rate of learning. Within these bounds set by the organism, the psychological conditions of learning change and have their influence" (McGeoch & Irion, 1952, p. 550).

After much data had been collected from a large number of different studies using chronological age as the only measure, and aggregated person variables as indicators of individual differences, the results became increasingly redundant, inconsistent, or both. As a consequence, interest in the development of learning and memory diminished rapidly between 1930 and 1960. This situation did not change before new theoretical models were presented in the 1960s which drastically changed the aims of research and the empirical methods.

II. A New Look in Studying Individual Differences in Memory Development

In the 1960s the traditional question of how memory develops as a function of age was replaced by the question of what develops when memory changes across the life span. "What is memory development the development of?" therefore became the guiding query of research in cognitive child psychology. The theoretical framework for this reseach and many analytical tools were adapted from the quickly expanding field of cognitive psychology. The empirical studies addressing this question did not represent an integrated research program. The studies can be classified according to five basic assumptions, each of which makes different hypotheses on the cognitive changes responsible for improvement of memory achievement.

These assumptions were all influenced by the observation that age-related changes in memory performance differ as a function of the task considered. For example, it was shown that age-correlated performance increases in childhood were observed especially in complex tasks in which strategic behavior is necessary or helpful in learning and recalling relevant information (Naus & Halasz, 1979). While only small age-related changes were found in incidental learning and recognition tasks, much progress was observed in intentional learning and free recall tasks during childhood. The following main assumptions guided research into this developmental trend conducted during the last 2 decades:

1. It is assumed that memory performance depends on how intelligently input information is encoded, represented, and retrieved. The development of memory in childhood thus becomes part of and a consequence of growth in intellectual competency. This corresponds to the opinion of William James that has stood the test of time: "All improvement of memory consists of better thinking" (1890, p. XII). Although the relation between intelligence and memory was often analyzed in the following years, it only gained theoretical importance with Piaget's and Inhelder's (1968) work. Here, it was not only postulated that specific coding processes are influenced by the development of intellectual functions, but that the memory code itself (and consequently the structural possibilities and limitations of mentally representing informations) can be regarded a function of the level of cognitive operations achieved by the individual. According to this approach, individual differences are considered solely as variations in the speed of passing through the sequence of cognitive development.

2. It is assumed that memory performance depends on the availability of memory strategies which can be used across different memory tasks. It may often be the case that solving a memory problem as intelligently as possible is dysfunctional. Instead, it may be more effective to use a routine strategy which is suitable for many learning and memory situations (e.g., rehearsal, elaboration, organization of the material to be learned). According to Pressley, Forrest-Pressley, Elliott-Faust and Miller (1985), such a strategy is "composed of cognitive operations over and above the process that are a natural consequence of carrying out the task, ranging from one such operation to a sequence of interdependent operations. Strategies achieve cognitive properties (e.g. comprehending, memorizing) and are potentially conscious and controllable activities" (1985, p. 4). Strategies become increasingly available in the course of childhood, especially between the ages of 4 and 12, and strategic behavior can increasingly be better tailored to the specific requirements of a task. Furthermore, strategies can be trained to a limited extent, that is, they can be taught to young children who do not yet spontaneously use them. With the help of behavioral algorithms, children are thus enabled to organize input such that learning is facilitated, storing takes place economically, and retrieval of material in different contexts is facilitated.

3. It is assumed that memory performance depends not only on the availability of appropriate memory strategies, but additionally depends on the effective use of it which is influenced by metamemorial knowledge and skills. Young children often do not use appropriate strategies (although available) spontaneously in learning and remembering, but do use them when they are prompted. They are also often not able to maintain a newly acquired strategy over a period of time, and to generalize it to new tasks. Flavell (1971) explained this behavioral deficit by a lack of individual knowledge of a given strategy and a lack of knowledge concerning the appropriate conditions for their controlled use. He labeled this type of action-orienting knowledge as well as the related executive skills "metamemory" (Flavell & Wellman, 1977; Yussen, 1985). Isolated insights into the functioning of one's own memory are less characteristic for this type of knowledge than the total organization of memory-related knowledge in the form of intuitive memory theories (Wellman, 1985). Between the 5th and 12th-years-of-life, the structure as well as the content of this knowledge changes greatly and can thus explain some of the performance improvements in memory tasks observed in this age span (Schneider, 1985). The theoretical status of the concept of metamemory is, however, still unclear and problematic and does not correspond to its frequent use and usefulness in empirical studies.

4. It is assumed that memory performance depends on the available knowledge base for a specific task. The everyday observation that people who know more than other people about one area learn, understand, and remember more, better, and faster in this field, has only recently been integrated into theoretical concepts of developmental psychology. For a long time, cognitive development referred to formally defined abilities, general concepts, and mental structures. This has changed drastically in the last few years. The development of the individual knowledge base, defined as the richness, variety, degree of organization, and the accessibility of the relevant knowledge has vastly gained importance as a theoretical explanation for changes and differences in cognitive achievement. This is true for domain-specific knowledge in the novice-expert approach (Chi, 1984; Voss, Vesonder, & Spilich, 1980) as well as for general world knowledge if one assumes that children are "universal novices" in comparison to adults (Carey, 1985). Although the relationship between the knowledge base and cognitive performance could be convincingly demonstrated in empirical studies, microanalyses for studying mechanisms and processes suitable to explain the acquisition of new knowledge from the currently available knowledge appear not to exist (Resnick & Neches, 1984).

5. It is assumed that memory performance depends on basic capacities of the memory system. Do the four assumptions mentioned above really describe the main parameters used in explaining memory development? This is a controversial issue. Many developmental psychologists believe that to fully explain individual differences in memory performance, features of capacity (e.g., speed of processing, working memory) indicating general limits of the memory system's hardware must be additionally considered. The available empirical data are scanty and contradictory. This holds true for the definition of capacity features, for the dependence or independence of capacity measures on the knowledge base, for the development of memory capacity features across the life span, and for the stability of interindividual differences over longer periods of development.

In theoretical discussions of memory development, the five assumptions are occasionally seen as competing approaches to explaining memory performance, and occasionally as components of a multiple explanatory model (Hasselhorn, 1986). Both views appear problematic. Understandably, sufficient content knowledge is a necessary condition for adequate behavior and performance in difficult memory tasks. It is only in simple memory tasks that insufficient knowledge can be compensated by the use of general memory strategies, by intelligent encoding of the new information independent of content, and by metacognitively planned actions (see Schmalhofer, 1982, and Kintsch, 1986). Thus, depending on the type of memory task, there are difficult performance criteria in which lack of content knowledge cannot be compensated and less difficult criteria in which lacking knowledge can mostly be compensated for by intelligent behavior. Given the considerable changes the knowledge base undergoes during childhood, the relations between task-specific memory performances and individual learning skills are invariant for a limited time only. The theoretical model could be further complicated by the assumption of stable individual capacity limits. These capacity limits not only influence, under otherwise comparable conditions, the type of acquired knowledge and the mental representation of this knowledge but also have a direct impact on how the available cognitive resources are used in solving the memory task.

In developmental psychology, componential models of memory performance have the advantage of explaining both interindividual differences in a given age group as well as age related changes in memory performance and their individual differences. According to this conception, substantial intraindividual differences are to be expected in memory performance. In other words, the common everyday assumption of general memory differences (good versus bad memory) should be an exception. It is presently not clear if in addition to the above conditions, further parameters of ability as stable individual constraints of knowledge acquisition and use are necessary to explain performance variance in memory tasks. Ericsson (1985) disputes this and concludes from his data that "most of all variability in memory ability can be accounted for by differences in acquired memory skills" (p. 189).

If one considers memory development in a life-span-perspective and not only in childhood, then the question is if the theories describing and explaining performance changes are equally valid in different time periods. To answer this question, current research concentrates on childhood and later adulthood, two periods in which considerable changes in memory performance can be observed. It is of great theoretical interest for life-span developmental psychology to see if the developmental changes in the two age groups show conformities, parallels, or analogies. Denney (1982) takes a radical, but traditional, position in assuming that "the development during the later part of the life span mirrors development during childhood" (p. 818). On the basis of such an assumption (for a criticism of this position see Rabbitt, 1981), it is not surprising that all descriptive and explanatory hypotheses concerning memory development in children have also been tested for older age groups. We are thus in a position to clarify several important problems: Are the typical developmental courses and patterns of individual differences comparable in both groups? Can changes and differences be explained by the same proximal conditions? Is it useful, under these circumstances, to draw on different or similar theoretical models to explain and describe individual differences in childhood and later adulthood?

In the following review of the literature we present the most important findings for childhood, followed by those obtained for later adulthood. These findings can be backed by data from some of our own studies, in particular from one study which compared memory development in childhood with memory development in the elderly. It should be noted that it is not the intention of this chapter to give a comprehensive review of the literature and existing empirical findings; instead, the focus is on theoretical conclusions from present knowledge concerning memory development and individual differences in childhood and in older age.

III. Individual Differences in Children's Memory Development

A. TYPICAL DEVELOPMENTAL PATTERNS IN MEMORY PERFORMANCE IN CHILDHOOD

Undoubtedly, our view of age-related changes in memory development has changed over the past few years. Due to the strong influence of the pioneer work of John Flavell and his colleagues (cf. Flavell, 1971; Keeney, Cannizzo, & Flavell, 1967; Moely, Olson, Halwes, & Flavell, 1969), most studies conducted in the 1970s focused on the role of strategies in memory development. According to these studies, strategy use was regarded as the major source of developmental differences (cf. Lange, 1978; Moely, 1977 for reviews). The empirical evidence suggested that strategies like rehearsal and categorization emerged in the early school years but were not sophisticatedly and consistently employed before the end of elementary school. The notion of "production deficiencies" was introduced to describe failures of younger children to use memory strategies. Given the finding that such deficiencies in strategy use typically correlated with poor memory performance in different domains, strategy development was postulated as the basic source of cognitive development.

The aforementioned change in view based on more recent empirical findings concerned (1) the generality of the strategy development hypothesis, (2) the additional relevance of concepts like subjects' metamemory, and (3) the fundamental role of the knowledge base for processes of understanding, learning, and memorizing. With regard to the strategy development hypothesis, recent research suggested at least two changes in view: First, contrary to the conclusions of earlier work, it could be demonstrated that even preschoolers and kindergarten children were 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 (e.g., sort-recall task; cf. Baker-Ward, Ornstein, & Holden, 1984; Sodian, Schneider, & Perlmutter, 1986). Thus, the traditional view that intentional memory strategies do not emerge before the elementary school years was no longer tenable: Younger children are able to use rudimentary memory strategies whenever the task is either simply structured or extremely motivating for them.

Whereas this means an extension of the earlier perspective, the second change in view aims at restricting the generality of the strategy development hypothesis. Recent studies consistently found that the impact of deliberate strategies on memory development has been usually overestimated: On the one hand, children's memory performance did not necessarily improve when memory strategies were provided for them. Age differences in recall were not always related to age differences in the use of deliberate strategies, particularly in the case of preschoolers and kindergartners. On the other hand, effects originally attributed to deliberate strategy use were shown to result from automatic processing; for example, whereas clustering during recall in sort-recall tasks was considered an indicator of strategic behavior in earlier studies, more recent studies have demonstrated that clustering during recall is largely determined by the degree of inter-item associativity in the item-lists, particularly in young children. Thus, the amount of clustering depends more on automatic processing (i.e., the ease of access to semantic memory) and *not* on the use of intentional strategies (see Bjorklund, 1985; Chi, 1985; Ornstein & Naus, 1985; Rabinowitz, 1984; Schneider, 1985 for a more detailed treatment of this topic).

Hence, the increasing use of deliberate strategies with development seemed to be an inadequate explanation for memory development. As Chi (1985) pointed out, a more productive research approach would be to assess the representations of strategies at different stages of development and explore their changes over time, the conditions under which they can be elicited, how they generalize across contexts, and how they interact with the knowledge base (i.e., domain-specific knowledge as well as so-called world knowledge). However, before we begin investigating the role of strategies and the knowledge base in explaining memory performance, it seems useful to give some information about the typical course of memory development in the elementary school years and beyond.

Figure 1 depicts the typical age differences in memory performance obtained for various age groups in a sort-recall task using clusterable items (cf. Körkel, Schneider, Vogel, & Weinert, 1983). In the Körkel et al. study, 3rd, 5th, and 7th graders were administered a sort-recall task twice within a period of 15 months. As can be seen from Fig. 1, the well-known improvement in memory performance with age appeared both in the longitudinal and cross-sectional data. Similarly, indices assessing sorting behavior during study and clustering during recall as well as metamemory scores showed pronounced increases with age. Intercorrelations among knowledge, strategy use, and memory performance were also shown to increase with age. Taken together, the empirical evidence leads us to assume that different factors contribute to memory development, and that developmental patterns of memory performance can be typically described as follows: In contrast to recognition abilities, which appear to be at a high level from early childhood on, children's ability to recall verbal material increases regularly with age, starting from a generally poor level of performance in the preschool and kindergarten years where memory seems to be predominantly guided by children's world knowledge and natural activities. This pattern changes when chil-

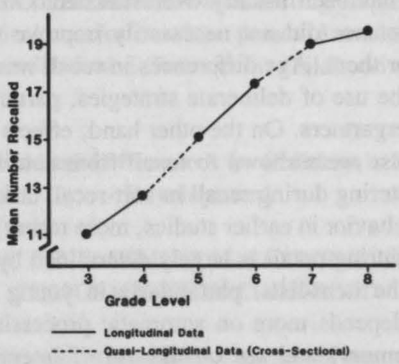

Fig. 1. Mean number of items recalled from a taxonomically clusterable word list, separated by grade (N=105 in each grade; data from Körkel et al., 1983).

dren enter elementary school: Due to the impact of practice, school, and training, children's repertoire of strategies and their knowledge about strategy use increase dramatically from 7- to 12-years-of-age, with both components positively influencing performance in a variety of memory situations. It appears that the degree of sophistication in strategy use is influenced by metamemory as well as by domain-specific knowledge, and that interindividual differences in these variables increasingly contribute to individual differences in memory performance.

As it stands, this description still contains several speculative assumptions. Therefore, in the following section, we report on selected empirical studies that addressed the issue of how age-related differences in memory performance can be explained by differences in basic memory processes, strategy use, and the knowledge base. In addition to discussing analyses conducted with random samples, analyses for specific subgroups are also included to control for the generality of findings.

B. THE IMPACT OF BASIC MEMORY PROCESSES, STRATEGY USE, AND THE KNOWLEDGE BASE ON MEMORY DEVELOPMENT IN CHILDREN

Most of the more recent studies on individual differences in memory development have concentrated on the main effects and complex interactions among domain-specific knowledge, strategy knowledge, strategy use, and memory performance in various age groups. From these studies, it can be concluded that, depending on the type of memory task, knowledge influences memory performance either directly or indirectly, that is, via the use of sophisticated strategies. The class-recall task (cf. Bjorklund & Zeman, 1982) can be regarded as a typical example of the first case: Even young children spontaneously used classroom groupings (i.e., assigned reading groups, seating patterns) to recall the names of their classmates, and recall was uniformly high for 7-, 9-, and 11-year-olds. Subsequent metamemory interviews indicated that subjects were not aware of their strategies. Bjorklund and Bjorklund (1985) further demonstrated that the induction of deliberate strategies (children were told to remember according to seating groups) influenced clustering but not recall. Thus, in that kind of task, the available knowledge automatically affects memory performance to such a degree that it is difficult if not impossible to further increase levels of performance by intentionally using grouping strategies.

A different pattern of results was obtained for more traditional memory tasks like rehearsal and sort-recall procedures. Here, it could be repeatedly shown that the knowledge base and metamemory influence memory performance predominantly via strategy use: Whenever the necessary domain-specific knowledge was available, even younger school children were not only able to use appropriate memory strategies, but also used them more efficiently than they normally did. For example, Tarkin, Myers, and Ornstein (see Ornstein & Naus, 1985) asked 8-year-old subjects to rehearse item lists that differed with regard to meaningfulness (high vs. low). The data indicated clear differences in rehearsal as a function of condition. The low meaningfulness group included fewer than two items in a rehearsal set (thus showing the age-appropriate behavior in such a task), whereas the high meaningfulness group rehearsed more than three items together, a value more typical of 11- and 12-year-olds. Similar effects of list meaningfulness on subsequent strategy use and recall in a sort-recall task were obtained in studies by Frankel and Rollins (1985) and Schneider (1986).

While these findings demonstrate that a strong impact of the knowledge base on strategy use and memory performance can already be found in young school children, they do not give us sufficient information about how age differences in memory performance can be accounted for by differences in metamemory, knowledge base, or strategy use. As already noted, there is reason to assume that components of general world knowledge and specific content knowledge as well as strategic skills become more flexible and articulated with age. If so, the question is whether these age-related differences account for age differences in memory performance.

So far, basic memory processes like memory capacity or information processing speed have not been introduced as potentially influential predictors of memory performance. In fact, concepts like memory capacity have been usually neglected in attempts to explain the development of memory performance, mainly because it was assumed that memory capacity does not change with age. However, given the accumulating empirical evidence that facets of memory capacity like processing speed and working memory capacity have different effects on strategy use and memory performance in different age groups (see for detailed discussions Case, 1985; Dempster, 1985; Weinert, 1986; Weinert & Hasselhorn, 1986), indicators of memory capacity were included in some studies dealing with the explanation of age differences in memory performance.

The majority of these studies investigated the sort-recall paradigm. To assess the impact of memory capacity, metamemory, and strategy use on memory performance, different methodological procedures were used. Structural equation models (i.e., multiple regression analyses, causal modeling procedures) were appropriate when the focus was on the comparison of predictor constellations in different age groups. Analyses of covariance were used whenever the focus was on the explanation of age differences in memory performance. Further, comparisons of experts and novices represent an appropriate methodological approach to investigate the impact of the knowledge base. Results from studies using these three approaches are summarized next.

C. ANALYZING INDIVIDUAL DIFFERENCES IN MEMORY PERFORMANCE BY USING THE STRUCTURAL EQUATION APPROACH

Körkel et al. (1983) used multiple regression analyses to predict memory performance in different age groups (cf. Fig. 1). In addition to verbal and nonverbal IQ measures, memory strategies like sorting during study and clustering during recall as well as measures of general and task-specific metamemory were included in the predictor list. Structural patterns in results were similar in that most variables included in the structural equation predicted recall in all age groups (3rd to 8th graders). However, important differences were found in the roles of sorting during study and clustering during recall. Whereas the latter variable turned out to be an important predictor of 3rd graders' recall, its influence gradually diminished with age. Just the opposite trend was found for the sorting during study measure: It could be shown that the older the subjects, the better were the predictor qualities of this specific strategy measure. It should be noted however, that, taken together, predictor variables only explained a limited amount of variance in the dependent variable, with percentages of explained recall variance ranging from 20 to 40.

In a more recent study by Schneider (1986), multiple regression analyses were conducted to assess the relative impact of general and task-specific metamemory, sorting during study, clustering during recall, and measures of short-term and long-term memory capacity (i.e., digit span test, delayed recall of unrelated items) on 2nd and 4th graders' recall in a sort-recall task. As can be seen from Table I, different patterns of results were obtained for the two age groups. Memory capacity and clustering during recall were the best predictors of 2nd graders' recall, whereas metamemory and sorting behavior did not significantly contribute to the prediction. In contrast, sorting during study and task-related metamemory were the most important predictors of 4th graders' recall performance. Note that the developmental patterns obtained for the clustering during recall and sorting during study measures were quite similar in the Körkel et al. (1983) and Schneider (1986) studies. Additionally considering memory capacity, however, led to a considerably better overall prediction of the dependent variable in the latter study, with multiple R-Squares for 2nd and 4th graders of .49 and .63, respectively. From the two studies, it can be concluded that the importance of both memory strategies and task-specific metamemory for the prediction of memory performance increases with age. Probably as a consequence, memory capacity gradually loses its influence with age.

This overall impression was also confirmed in path analyses using latent variables instead of manifest indicators. In causal models using latent variables, the measurement model defines the relationship between observed variables and

TABLE I

Multiple Regression of Metamemory Measures, Organization Measures, and Memory Capacity Measures on Recall

Grade and task	Beta	*F*	*p*
Grade 2			
Task-related metamemory	.01	0.01	.93
General metamemory	.18	2.96	.09
Sorting during study	.13	1.43	.24
Clustering during recall	.22	3.94	.04
Nonverbal intelligence	.09	0.58	.45
Vocabulary	.14	1.53	.22
Short-term memory capacity	.33	10.13	.01
Long-term memory capacity	.42	14.48	.01
Grade 4			
Task-related metamemory	.22	5.68	.02
General metamemory	.10	1.29	.26
Sorting during study	.44	15.96	.01
Clustering during recall	.20	3.21	.08
Nonverbal intelligence	.14	2.23	.14
Vocabulary	.08	0.60	.44
Short-term memory capacity	.19	3.24	.08
Long-term memory capacity	.06	0.37	.54

Note: Data from Schneider, 1986.

the unmeasured hypothetical constructs, 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. Schneider, Körkel, and Weinert (1987a) used the structural equation modeling procedure (LISREL) to assess the impact of intelligence, metamemory, and strategy use on 3rd and 4th graders' memory performance in a sort-recall task. Although the data of the two age groups could not be fitted to one model, similar structural patterns across age groups were found in that metamemory directly affected strategy use, which in turn influenced memory performance. Again, the structural models explained high proportions of the variance in the criterion variable (memory performance), namely 64% and 78% for 3rd and 5th graders, respectively. In a similar type of analysis, Hasselhorn (1986) included measures of information processing speed, domain-specific knowledge, declarative and procedural metamemory (i.e., metacognitive knowledge and memory monitoring), and memory strategies in a latent variable structural equation model that aimed at predicting 4th graders' memory performance in a sort-recall task (cf. Fig. 2). Hasselhorn's model appears particularly interesting because it simultaneously integrates all variables considered relevant for the prediction of memory performance, namely, aspects of memory capacity, domain-specific knowledge, declarative and procedural metamemory, and strategy use. As a main result, metamemory, processing speed, the knowledge base, and strategy use (memory behavior) were shown to independently contribute to the prediction of memory performance. Moreover, in comparison with metamemory and processing speed, the knowledge base had by far the strongest impact on strategy use. The knowledge base, processing speed, and declarative metamemory were used as exogeneous variables in the model, that is, they were not further explained or interrelated. However, an inspection of the factor correlation matrix revealed that all three concepts were significantly intercorrelated, with coefficients ranging from .27 (metamemory and processing speed) to .57 (information processing speed and the knowledge base). A correlation of .50 between declarative metamemory and the knowledge base further indicated a considerable conceptual overlap for these two constructs.

Altogether, the findings from the regression and causal modeling analyses suggest that variations in memory capacity, the knowledge base, metamemory, and strategic behavior all predict and explain variance in elementary school children's memory performance. The results further show that, with increasing age, the combined effects of knowledge base, metamemory, and mnemonic strategies become increasingly important for the prediction of memory performance in laboratory tasks (cf. also Ornstein & Naus, 1985; Zembar & Naus, 1985).

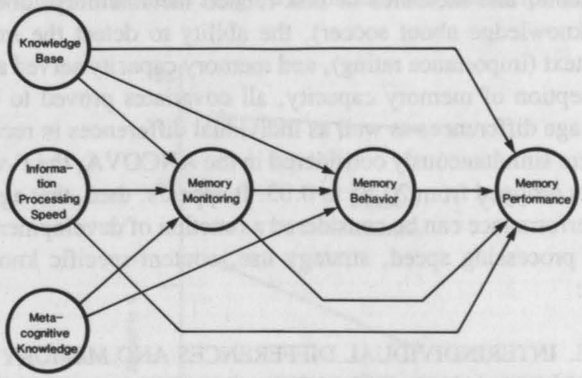

Fig. 2. The theoretical model of the metamemory-memory behavior relationship proposed by Hasselhorn (1986).

D. ANALYSIS OF AGE DIFFERENCES IN MEMORY PERFORMANCE: THE ANCOVA APPROACH

A slightly different methodological approach has been used to explain age differences in recall. Here, the problem is to identify those measures that are best suited to explain those differences. For example, Schneider (1986) conducted an analysis of covariance (ANCOVA) on recall with age group as the independent variable and short-term and long-term memory capacity, sorting during study, clustering during recall, and general and task-related metamemory as covariates to explore the importance of memory capacity, memory behavior (i.e., sorting during study), and metamemory in explaining age differences in recall. The main result was that the significant age differences in 2nd and 4th graders' recall were eliminated after adjustment was made for the linear effects of the covariates. With the exception of general metamemory, all covariates proved to be important predictors of age differences in recall.

In a related study by Knopf, Körkel, Schneider, and Weinert (in press), similar measures of metamemory, memory capacity, and memory behavior were included as covariates in an ANCOVA on 3rd, 5th, and 7th graders' performance in a sort-recall task. Again, it was demonstrated that the capacity measure, memory behavior, and metamemory were important predictors of age differences in recall. When all covariates were simultaneously considered, the drop in age effects was remarkable, although the attenuated F-values still remained significant. This could be due to the fact that the overall age differences in recall were considerably larger in the Knopf et al. study than in the study by Schneider. Results were even more impressive when memory for text was considered. In particular, memory for a story describing a soccer game was chosen as the criterion variable, and measures of task-related metamemory, domain-specific knowledge (knowledge about soccer), the ability to detect the important sentences of the text (importance rating), and memory capacity served as covariates. With the exception of memory capacity, all covariates proved to be important predictors of age differences as well as individual differences in recall. When all covariates were simultaneously considered in the ANCOVA, the F-value indicating age effects dropped from 20.55 to 0.03. It appears, then, that age differences in memory performance can be considered a function of developmental increases in children's processing speed, strategy use, content-specific knowledge, and metamemory.

E. INTERINDIVIDUAL DIFFERENCES AND MEMORY PERFORMANCE: THE EXPERT-NOVICES PARADIGM

Most studies presented so far have impressively illustrated the importance of children's knowledge for memory performance. Results from the structural modeling procedures (cf. Hasselhorn, 1986) did not only show direct effects of metamemory and the knowledge base on memory performance, but also demonstrated an indirect impact of these variables via strategy use.

Another way to illustrate the importance of the knowledge base for memory performance on the one hand and its interrelationship with strategy use on the other is to contrast the performance of experts and novices in a specific domain. As Ornstein and Naus (1985) pointed out, experts and novices likely differ in much the same way as children of different ages are usually thought to differ in laboratory-type memory tasks.

Strong evidence for the importance of the knowledge base for memory performance stems from a clever experiment conducted by Chi (1978; see also Voss et al., 1980). Chi investigated chess experts' and novices' memory for chess positions. Her twist was that knowledge was negatively correlated with age. The children were the experts, whereas the adults were the novices. The experts outperformed the novices both in terms of actual memory performance, and in predicting in advance how well they would perform. This untypical superiority of the younger subjects was explained by the special role of domain-specific knowledge in encoding and retrieval processes (Chi, 1984).

In a subsequent study based on Chi's findings and conducted in our laboratory (Körkel, 1987; Weinert et al., 1984), we investigated 3rd, 5th, and 7th graders' memory for the aforementioned story about a soccer game. The main reason for choosing soccer as a topic was that soccer is very popular in Germany. Accordingly, it is relatively easy to find many soccer experts, even among young children. And last but not least, soccer-related expertise is correlated neither to chronological age nor to the individual level of intelligence. At each age level, subgroups of soccer experts and novices were formed and compared according to various achievement outcomes. Figure 3 contains the results for an "easy," that

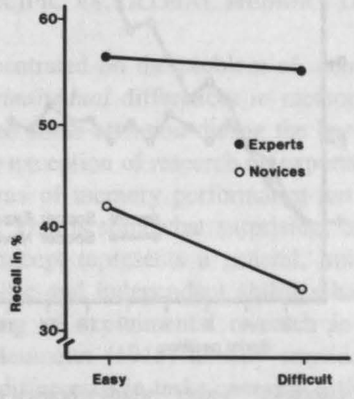

Fig. 3. Recall (percentage correct) for easy and difficult soccer stories.

is, standard text version, as compared to a "difficult" text including several contradictions and requiring many inferences. Not surprisingly, in all age groups (3rd, 5th, and 7th graders), experts showed better recall for text information than did novices. This is especially true in learning and recalling very difficult texts, as Fig. 3 shows. Moreover, experts were better in 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. Probably the most impressive finding was that younger experts outperformed older novices on all outcome measures, thus demonstrating the specific importance of a highly articulated knowledge base on text comprehension and recall.

Naus and Ornstein (see Ornstein & Naus, 1985) also compared (adult) soccer experts and novices, but chose a different memory paradigm to illustrate the effects of the knowledge base. That is, they assessed college-age soccer experts' and novices' rehearsal strategies when recalling a word list concerning soccer. As can be seen from Fig. 4, the highly articulated knowledge base of soccer experts led to maximally efficient active rehearsal strategies, whereas novices' rehearsal sets did not exceed two items, a size considered typical of passive rehearsal.

Recently, Brown, Bransford, Ferrara, and Campione (1983) have emphasized the problem that memory performance is highly dependent on access, that is, children's ability to access their knowledge and apply it appropriately. In line with that argumentation, Bransford, Stein, Shelton, and Owings (1981) demonstrated that academically unsuccessful learners showed poorer text comprehen-

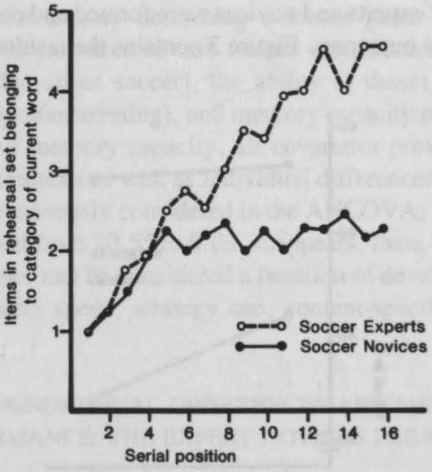

Fig. 4. Mean number of categorical "soccer" words rehearsed together by adult experts and novices, as a function of serial position (data from Ornstein & Naus, 1985).

sion and memory than successful learners, although the available background knowledge for the task was comparable across groups. This finding led us to reanalyze our soccer expert versus novice data (Schneider, Körkel, & Weinert, 1987b). The groups of experts and novices were further subdivided into groups of successful and unsuccessful learners to test the hypothesis that there are significant performance differences (i.e., text recall, detection of contradictions in the text, and drawing inferences from the text) between soccer experts classified as good and poor learners. The results only partially supported the assumption that access to the knowledge base is an important factor. The only significant difference between experts classified as academically successful versus unsuccessful learners concerned the detection of contradictions in the text. On the other hand, the samples did not differ with regard to text recall and the ability to draw correct inferences from the text. Further, in all three dependent measures, the poor learner experts scored significantly higher than those novices characterized as academically successful learners. Finally, it should be noted that no age by group interaction was obtained; that is, the same pattern of results was found in all age groups. This finding led us to conclude that a highly articulated knowledge base can obviously compensate for specific information processing deficiencies.

Taken together, the findings from various studies using the expert-novices paradigm unequivocally demonstrate the crucial role of domain-specific knowledge on strategy use and performance in different memory tasks. It has been repeatedly shown that its impact is particularly strong in experimental tasks that are closely related to everyday life experiences (e.g., memory for prose tasks). On the other hand, there is accumulating evidence that the knowledge base is almost equally important for the prediction of strategic behavior and performance in laboratory-type tasks (e.g., sort-recall tasks), especially in older children.

F. DOMAIN-SPECIFIC VS. GLOBAL MEMORY DEVELOPMENT

So far, we have concentrated on the problem of identifying factors that are causally related to *interindividual* differences in memory performance. While this problem has received some attention during the last decade, it is probably fair to state that with the exception of research on experts and novices, the topic of *intraindividual* patterns of memory performance has been consistently neglected for a long time. This is somewhat surprising, because the question of whether the memory concept represents a general, unitary human faculty or rather a variety of specific and independent abilities has been a controversial issue since the beginning of experimental research in human memory. Ebbinghaus (1885) and Meumann (1918) already considered the possibility of extreme intraindividual differences in tasks covering different memory contents (e.g., memory for prose vs. memory for numbers). This position was confirmed by a number of psychometric studies conducted in the 20s and 30s in that only low correlations were found among memory tests using different materials or assessment procedures (see for a review, Knopf et al., in press).

To our knowledge, there are only a few recent studies conducted within the information processing approach that addressed the issue to intraindividual consistency in performance across several memory tasks. Stevenson, Hale, Klein, and Miller (1968) compared 3rd to 7th graders' memory performances in different tasks. Although they reported intertask correlations higher than those obtained in the earlier investigations, the coefficients were not, in the absolute sense, of high magnitude. Kail (1979) investigated the hypothesis that interindividual differences in memory may reflect a general strategic factor. That is, some people may use memory strategies consistently and perform well, whereas others may use strategies poorly, and thus show low levels of recall. In Kail's study, 3rd and 6th graders' strategy use and memory performance were compared across three different memory tasks. Results of a factor analysis seemed to confirm the hypothesis of a general strategic factor, at least for the older subjects. However, a closer inspection of the intercorrelations among tasks and strategy measures revealed that they were generally small.

Probably the most convincing evidence in favor of a general strategic factor and high intertask correlations stems from a study by Cavanaugh and Borkowski (1980). In that study, kindergartners, 1st, 3rd, and 5th graders were presented with three different memory tasks (i.e., cognitive cuing, free sort, alphabet search), and degree of consistency across the three tasks was assessed by intercorrelations among measures of study strategy, and clustering during recall. Cavanaugh and Borkowski found significant developmental improvements for almost all sets of intercorrelations, with strategy measures showing particularly high intertask correlations within each age group. However, there may be some problems with the generalization of these findings because the three laboratory tasks used in this study (as well as those used by Kail) were very similar in structure.

Thus, in the remainder of this section, we focus on two studies conducted in our laboratory that assessed memory performance in different domains, namely memory for lists of objects and pictures, and memory for prose. As both are longitudinal studies of memory development, they not only allow us to compare intraindividual consistency across different memory tasks but also to assess the persistency of individuals across time when exactly the same items are presented.

The longitudinal study to be described started in 1985 with about 200 4-year-old children (cf. Weinert & Schneider, 1986). At the first measurement point, subjects' memory span, performance in a sort-recall task and memory for several scripted texts (i.e., a birthday party, playing with friends) were assessed. Table II shows the intercorrelation matrix for memory performance in the four different tasks based on n = 185 subjects.

TABLE II

Intercorrelations Among Various Memory Performance Measures Obtained for Four-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)			—

Given the large number of subjects, it is not surprising that all correlations shown in Table II are statistically significant. The data indicate that, with the exception of the interrelationship between recall for the two stories, intertask consistency of preschoolers' memory performance is reasonably low. For one of the two memory for prose tasks (playing with friends), retest data obtained about a year later were also available for analysis. In that task, the number of propositions correctly recalled was taken as one dependent variable, and the number of pictures correctly recognized as originally presented with the story was chosen as a second criterion variable. In addition, the number of wrong picture choices ("false alarms"), that is, the confusion of distractor items with originally presented pictures, was also used as a dependent variable.

Not surprisingly, the number of correctly recalled propositions increased significantly from the first to the second measurement point. Similarly, more pictures were correctly recognized, and the "false alarm" rate dropped significantly. The corresponding stability coefficients for the recall, correct recognition, and false recognition scores were .44, .20, and .36, respectively, indicating that rank-orderings of memory performance were not stable over time. In order to get more detailed information about "within-individual differences" varying among subjects, a more liberal criterion of within-task consistency was chosen. That is, subjects were classified as high (best 25%), medium (50%) or low (lowest 25%) achievers, and the consistency of classification was compared for the two measurement points. For the sake of brevity, only the recall data are reported. From a total of 165 children, 70 (= 42%) did not change their position in the group over time. Consequently, the majority of children changed their relative position in the group within 1 year. The degree of change could be better assessed when quartiles were used instead of the trichotomy. In total, 40 children (about 25%) moved from the upper quartile to the lower three-fourths of the distribution quartile and vice versa. This finding indicates that it is extremely difficult to predict memory performance changes during the preschool and kindergarten period.

A similar analysis covering the age range from 8- to 12-years was conducted by Knopf et al. (in press). Memory performance in sort-recall tasks with clusterable and nonclusterable stimulus lists, memory span, and the three performance measures on the soccer game text described earlier were used as the dependent measures. Intertask correlations based on a total of 578 children yielded the highest coefficients for the two sort-recall measures (ranging from .43 to .62), whereas intercorrelations among text variables were generally low (varying between .13 and .34). In addition, the subjects were classified as high, medium, and low achievers by using the procedure described above. Consistency of classification was compared for various combinations of memory measures as depicted in Table III. As can be seen from Table III, the highest stability coefficients were found for the two clusterable and nonclusterable word lists. When all three text variables were simultaneously considered, only 4% of the 3rd graders, 17% of the 5th graders, and 22% of the 7th graders were consistently classified as high, medium, or low achievers. Similarly, only very low intertask consistency coefficients were obtained when measures from memory tasks differing in contents and structure were combined.

Taken together, these findings shed doubt on the assumption that unitary lines of memory development can be assumed. In contrast, the general finding of low intraindividual consistency across different memory tasks supports the view first expressed by Ebbinghaus (1885) that we must question the existence of a "gen-

TABLE III

Percentage of Subjects Consistently Classified as High, Medium, or Low in Achievement for Various Combinations of Memory Tasks

Age groups	Children		
Measures	3rd-Graders	5th-Graders	7th-Graders
Nonclusterable and taxon. clusterable lists	50	56	64
Nonclusterable and episodic clusterable lists			
Two clusterable lists			
Word lists and memory span	24	21	24
Text inferences and text episodic memory	39	44	39
Text inferences and text contradictions	31	44	49
Text episodic memory and contradictions	19	31	39
All three text variables	4	17	22
All text variables and memory span	2	7	7
All word list variables and all text variables	0	4	7
All word list variables and all text variables and memory span	0	2	2

eral memory," and accept the notion of "task-specific memories" instead. Thus, while searching for general principles of memory development, we must be aware of the enormous variability across people and tasks. However, it seems that the problem is one of emphasis on either differences or similarities, and should be thought of as a natural dialectic rather than a dichotomy.

IV. Individual Differences in Memory Development in Elderly Adults

The development of different memory performances in elderly adults is less uniform than that observable in childhood. Whereas recognition memory is considered relatively stable across the life span, it is generally assumed that performance in free recall tasks declines (see Craik, 1977). To complicate the situation, memory performance in different free recall tasks does not show the same developmental pattern. Smaller declines are reported (see for example Craik, 1977; Poon, 1985) (1) when memory tasks require little strategy use (e.g., incidental learning), (2) when the instructions or the learning material give hints on optimal learning and remembering strategies (e.g., orienting tasks), or (3) when the learning material fits well with the cognitive prerequisites of elderly adults (e.g., close relationship of the learning material to everyday knowledge). Large declines in free recall tasks are observable (1) when the memory tasks require a high degree of spontaneous strategy use (e.g., learning and remembering nonclusterable word lists), (2) when knowledge is not especially helpful in learning and remembering (e.g., learning and recall of texts on an unfamilar topic), and (3) when no prompts or retrieval cues are given facilitating learning and remembering.

A. TYPICAL DEVELOPMENTAL PATTERNS IN MEMORY PERFORMANCE IN ELDERLY ADULTS

While these research findings on the variable development of different memory performances dominate the surveys, evidence is lacking that these patterns in fact can be confirmed in "within subject analyses." In a rather broad study with elderly adults who were in good health, we pursued this question (Knopf, 1987). Subjects were 124 volunteers of above average intelligence and educational status, ranging in age from 50 to 86 years ($\bar{x}$ = 63 years). Memory performance was assessed by using different word lists and texts as learning materials.

A cross-sectional design was used. The total sample was split in two subsamples by using the age mean. We thus investigated age differences rather than age changes. There was no reason to assume that the subjects in the two subsamples represented different populations.

One word list consisted of 24 nonclusterable words, and the other list of 24 clusterable words, which could be sorted into four categories of six words each. All words were highly familiar. No indication was given in the instruction that the words should be sorted. It was assumed that learning and remembering the clusterable words would be easier due to their inherent hierarchical structure. This should hold true, irrespective of age. It was further assumed, that the age-related decline should be smaller for the clusterable word list, because the inherent structure of the material cued subjects on how to handle the material. For this reason, higher age-correlated differences in memory performance were expected for the nonclusterable word list. No age-related differences were expected in the recognition text, given after the free recall test.

The results for the word list task confirmed our assumptions. As can be seen from Table IV, the nonclusterable word list was the most difficult to learn and remember, irrespective of age. This was also true for a sample of university students included in the study. For this memory task a significant age-related difference in memory performance was found, which, however, only reached statistical significance when subjects from the oldest subsample (over 63 years) were compared with university students. The age-related differences in the clusterable word list were smaller. Nevertheless, these differences again reached significance when subjects from the oldest subsample were compared with university students.

Results of the recognition test showed that the quality of recognition performance was high and equally accurate in both subsamples of elderly adults. Correct identification of items of the clusterable word list averaged 93% and 95%

TABLE IV

Mean Amount of Words Recalled as a Function of Age and Material Type

	University Students	Elderly adults		Wilcoxon-text		
	Mean age: 23 yrs (N = 60)	Mean age: 58 yrs (N = 74)	Mean age: 69 yrs (N = 50)	1 vs. 2	1 vs. 3	2 vs. 3
Recall nonclusterable words (max = 24)	15.35 (3.70)[a]	14.5 (4.2)	13.3 (2.9)	ns	$p < .01$	ns
Recall taxonomically clusterable words (max = 24)	18.9 (3.08)	18.2 (3.8)	17.2 (3.3)	ns	$p < .05$	ns

[a] Numbers in parentheses indicate standard deviations.

respectively, for the two subsamples of elderly adults. The false alarm rate was low for both age groups.

The development of memory for connected discourse was analyzed using six short texts on a very specific political topic. These texts were studied twice. In the first trial, only the gist of the texts was learned and recalled, whereas in the second trial the texts were learned and recalled in detail. In a final trial, memory performance was tested using a cued recall test. Two types of questions were used in the cued recall test. Whereas the first type referred to facts explicitly mentioned in the texts (text-related questions), the second type required inferences on the basis of the information given in the texts (inference questions).

Results from research on memory development in text learning and text recall reported in the literature are not very consistent. This is because there are many factors which determine memory performance in text learning. Hultsch & Dixon (1984) differentiate between person-related (e.g., abilities, interests, knowledge), material-related (e.g., sensory mode, organization, sequence), instruction- and learning-related (instructions, activities, apparatus) and criteria-related (recall, recognition, detailed recall versus recall of main ideas) determinants of text learning and memory. Meyer & Rice (1983) have expressed the same idea of multiple determinants of text learning and memory. They further demonstrated that the extent of age differences in learning and recalling a text is a function of the difficulty of the learning material. In particular, declines in text learning and memory were found for those elderly adults with low verbal abilities. Further, text memory proved to be poor when the texts to be learned were particularly difficult.

The texts we used in our study concerned a very specific event, so they were difficult to learn especially for people having no knowledge or little knowledge concerning this event. In fact, the great difficulty of learning the texts was expressed by most of the participants during the learning phase. Because of the difficulty of the learning material, age differences in free recall tests were expected.

Because a cued recall test is assumed to involve a smaller amount of retrieval processing than free recall, it was assumed that age-related differences obtained for this test would also be smaller. As can be seen from Table V, the results confirmed our expectations. Significantly poorer memory performance was found for the eldest subsample regardless if gist or detailed learning and remembering of texts was considered. This age-related difference in text learning and recall occurs, however, in the more limited age span of older adulthood. The age-related performance differences in text learning and recall again seem at least partly explainable by retrieval deficiency. This interpretation is supported by the results of the second text-related memory test, where the number of correctly answered questions was comparable for the two subgroups.

TABLE V

Mean Amount of Free and Cued Recall of Connected Discourse as a Function of Age

	Elderly adults		
	Mean age: 58 yrs (N = 74)	Mean age: 69 yrs (N = 50)	p
Propositions recalled in the gist learning task (max = 915)	232.41 (83.24)[a]	194.0 (74.63)	<0.5
Propositions recalled in the detail learning task (max = 915)	271.17 (103.78)	226.42 (84.32)	<.05
Text-related questions answered in the cued recall test (max = 7)	3.47 (2.17)	3.11 (2.13)	ns
Inference questions answered in the cued recall test (max = 14)	6.20 (1.86)	5.78 (3.60)	ns

[a] Numbers in parentheses indicate standard deviations.

Taken together, these broad analyses of memory development in elderly adults confirm the hypothesis that different developmental patterns can be assumed for different experimental tasks. While we found empirical evidence for a decline of free recall performance in different learning and memory tasks, cued recall and recognition performance in the same tasks remained at a high level. Thus, the retrieval deficits seem to be an important source of age-related differences in memory performance.

B. THE IMPACT OF STRATEGIC MEMORY PROCESSING ON MEMORY PERFORMANCE IN LATER ADULTHOOD

A major explanation of different memory performances in different age groups in later adulthood is that learning and remembering become less strategic with increasing age (summarized in Craik, 1977; Guttentag, 1985; Labouvie-Vief & Schell, 1982). Since strategic learning and remembering can be evoked through instruction, the strategy deficit of elderly people is considered to be a production deficiency.

In recent studies it has been assumed that changes of the knowledge base in old age may determine strategy deficiencies in word list tasks. In particular, it has been assumed that the taxonomic relations as preferred mode of conceptual organization (e.g., an orange is a fruit) lose their dominance in later adulthood, whereas episodic and action-oriented relations (e.g., one can eat an orange) become increasingly dominant (e.g., Denney, 1974; Nelson, 1983).

If this assumption is correct, the strategy deficit in elderly people should be less evident when they are learning and remembering episodically—as compared to taxonomically—clusterable material. We pursued this question in the aforementioned study (Knopf, 1987). Besides the two word lists already outlined, a third list of 24 words was used, which was clusterable into four episodes with 6 words each. The subjects (N = 124) were asked to learn as many words as possible and to recall them in any order. In addition to the amount recalled, recall organization was analyzed by using the adjusted-ratio-of-clustering (ARC) index (Roenker, Thompson, & Brown, 1971). The amount of organization in recall gave information on the extent to which the elderly adults used the organization principles inherent in the learning material.

Given the data, the strategy deficit-hypothesis can be rejected. The ARC scores indicated a high level of organization in free recall for both material types, irrespective of age. As can be seen from Fig. 5, the cluster index ARC for the episodically clusterable material (ECL) was slightly higher than the cluster index obtained for the taxonomically clusterable material (TCL). Because this is not only true for elderly adults but also for university students, it may be assumed that the episodically clusterable items were especially easy to organize.

When the relationship between the degree of clustering and recall was considered, it was found that its strength varied according to age and type of material. Overall, the interrelationship decreased with increasing age. This was true for both types of material. While the correlations between ARC-scores and recall

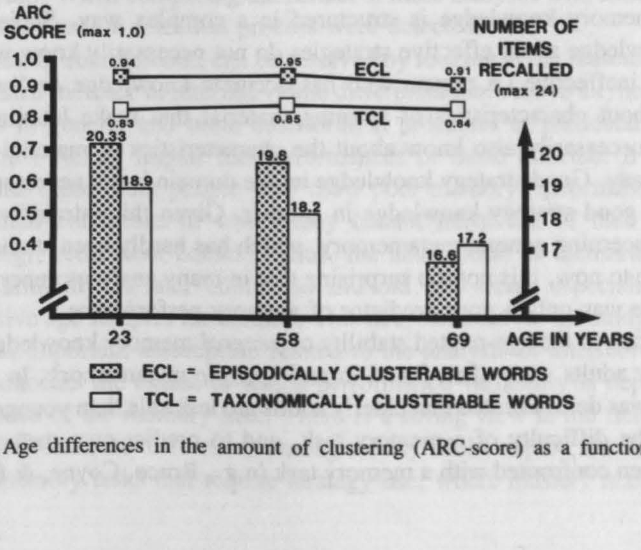

Fig. 5. Age differences in the amount of clustering (ARC-score) as a function of type of material.

were significant for the students (TCL: r = .41, $p < .001$; ECL: r = .32, $p < .05$) and remained high for the younger adult groups (TL: r = .35, $p < .05$; ECL: r = .30, $p < .05$), they were insignificant for the elderly adults (TCL: r = .19, n.s.; ECL: r = .04, n.s.). The older the subject, the less relevant is a high degree of clustering as a precondition of superior recall. This was especially true for the episodically clusterable material: Although it was generally highly structured by elderly adults, recall was far from perfect (cf. Fig. 5).

The results of this study demonstrate that age-related decline in free recall in strategy-intensive memory tasks does not always result from strategy deficiency. Rather, it seems that memory strategies have a different impact on learning and remembering in different age groups. While memory strategies seem to guarantee high rates of learning and high levels of memory performance in younger adults, use of the same strategies is not sufficient to reach the same good memory performance in old age. A second hypothesis frequently mentioned in the literature maintains that age-related differences in knowledge about learning and memory as well as the use of this knowledge (metamemory) represent important sources of age-related differences in memory performance on word list tasks as well as on text learning tasks.

Investigations into the development of metamemory in elderly adults uniformly demonstrate that general memory knowledge changes only minimally before old age (Lachman & Lachman, 1980; Lachman, Lachman, & Thronesbery, 1979; Perlmutter, 1978; Zivian & Darjes, 1983). Empirical support for this assumption was also provided in our investigation (Knopf, 1987), in which older adults evaluated which characteristics of texts and other verbal material make learning easy or difficult (task knowledge) and which strategies are especially well-suited or poorly suited to learning and remembering isolated verbal elements (e.g., names) and texts (strategy knowledge). Further, it was shown that general memory knowledge is structured in a complex way. Subjects having good knowledge about effective strategies do not necessarily know which strategies are ineffective. A person who has accurate knowledge or "who knows much" about characteristics of learning material that make learning difficult does not necessarily also know about the characteristics of material that make learning easy. Good strategy knowledge in one domain is not necessarily associated with good strategy knowledge in another. Given this intraindividual variability concerning general metamemory, which has hardly been studied systematically up to now, it is not too surprising that in many analyses general memory knowledge was only a poor predictor of memory performance.

In contrast to the age-related stability of *general* memory knowledge, deficits for elderly adults were often found in *task-specific* metamemory. In a series of studies it was demonstrated that elderly adults are less able than younger adults to evaluate the difficulty of a memory task, and to predict own memory performance when confronted with a memory task (e.g., Bruce, Coyne, & Botwinick, 1982; Coyne, 1985; Lovelace & Marsh, 1985; Rabinowitz, Ackerman, Craik, & Hinchley, 1982). However, the reported findings here are not consistent (see Murphy, Sanders, Gabriesheski, & Schmitt, 1981; Perlmutter, 1978). In our own study (Knopf, 1987) the developmental diversity of different aspects of task-specific metamemory was also demonstrated in an intraindividual analysis. While prediction accuracy was generally low for the total sample of elderly adults independent of type of material, these subjects were very well able, after recall, to retrospectively judge the quality of their own memory performance (accuracy of free recall judgments). Likewise, they were able to judge if the text-related questions could be answered based on the information given in the texts (feeling of knowing judgments). Different aspects of task-specific metamemory seem, therefore, to have completely different patterns of aging. The conditions which underlie age-related stability or variability of task-specific metamemory are not yet known.

C. INTERINDIVIDUAL DIFFERENCES IN MEMORY PERFORMANCE WITHIN DIFFERENT AGE GROUPS

A central assumption concerning interindividual differences in later adulthood and old age is that performance variability within an age group increases with age (e.g., see Botwinick, 1978; Krauss, 1980; Welford, 1985). However, considering the interindividual variability within the two age groups in our study, no age-related differences were found. This unexpected result could be due to a positive self-selection of the older participants in our study. To test this assumption we thoroughly analyzed the cognitive abilities of the participants of the two subgroups by using standardized test procedures (verbal and nonverbal intelligence; memory span). When comparing the results of these analyses with test norms, no indications for such a selection process were detected.

This seeming contradiction can be resolved by looking at the reasons given for the age-related increase in interindividual differentiation. Above all, health status differences in general and brain deterioration processes in particular are mentioned, which clearly impair the performances of those affected. It is further assumed that those older people who show poor memory performances live in environmental conditions in which they cannot make use of their cognitive abilities (e.g., retirement homes). Thus, the assumption of increasing interindividual variability in later adulthood and old age seems especially valid if representative age samples are studied. This does not hold for the study reported.

A further important assumption related to the analysis of interindividual differences concerns the extent to which performance variability is dependent on characteristics of the memory task. There is a strong view in the field of aging that large performance differences among elderly adults can be found especially for those memory tasks that require strategy use, where mastery is consciously directed, and where complex information processing is required (e.g., use of knowledge, use of different strategies). Conversely, it is assumed that interindividual differences are less pronounced in automatic as well as less strategy-bound-memory tasks (e.g., recognition performance, cued recall, memory scanning). Support for this dominant hypothesis on the preconditions of interindividual differences in memory performance comes from studies that contrast memory performance of normally developed persons and retarded persons. Here, memory tasks were used which afforded intensive use of strategies (rehearsal, labeling, clustering, organization) for successful recall (e.g., rote recall of lists of items). These studies showed that spontaneous strategy use was less common in retarded subjects (see e.g., Belmont & Butterfield, 1971; Evans & Bilsky, 1979; Smith, 1980). Further, interindividual memory differences appear to a lesser extent in those tasks which require less strategy use (e.g., Campione, Brown, & Bryant, 1985).

It is interesting to note that both the research on developmental and on interindividual differences in memory performance agree on this point. Thus it is assumed that developmental changes across age groups as well as interindividual differences within an age group can be found above all in strategy-intensive memory tasks. Consequently, the same factors are believed to be responsible for performance differences between age groups as for interindividual differences within age groups.

The role the knowledge base and metamemory play in explaining interindividual differences in memory performance in different age groups was analyzed in accordance with the hypothesis that the factors that have major impact on performance differences between age groups also are responsible for interindividual differences within age groups. As in the aforementioned study with children (see Körkel et al., 1983), a series of stepwise regression analyses was run for the samples of elderly adults to predict memory performance in the three word list tasks (free recall), as well as free and probed recall of texts. The predictor variables were domain-specific knowledge (amount of domain-specific knowledge in the text learning task), different indicators of general memory knowledge (six aspects of memory knowledge) and task-specific metamemory (prediction accuracy in the word list tasks). In addition, indicators of memory capacity (memory span), verbal and nonverbal intelligence, concentration, and quality of domain-specific knowledge were added to the predictor list. This procedure was thought appropriate to explore the impact of knowledge and metamemory on different measures of memory performance in different age groups, compared to more traditional cognitive indicators.

The variance explained for the two subsamples ranged from $R^2 = .40$ to $R^2 = .65$, and the pattern of results was comparable for the two subgroups. The explainable amounts of variance were similar for the two subgroups across different memory tasks. Surprisingly, the explainable amount of variance for the total sample of 124 elderly adults was lower than that of the subgroups ($R^2 = .29$ to $R^2 = .50$). The increase in explained variance within the homogeneous age groups, compared to the total sample, indicates that factors influencing memory performance across different age groups do not follow the same patterns.

Indicators of task-specific metamemory as well as indicators of verbal and nonverbal intelligence played a central role in predicting memory performance in the different age groups. As far as the age-related shift in the impact of predictor variables is concerned, it appears that general memory knowledge is an especially better predictor of performance differences in elderly adults than in younger ones. Further, domain-specific knowledge proved to be an important predictor of text learning and remembering. The memory span and the remaining variables had little impact on predicting memory performance in the different age groups. The role of memory span, however, may be underestimated because of restricted variance. To exclude persons from the study whose memory performance was possibly hindered by pathological brain deterioration processes, only elderly adults with a memory span of four or above ($\bar{x} = 6.1$, maximum = 9) were accepted.

D. KNOWLEDGE DIFFERENCES AS A SOURCE OF DEVELOPMENTAL CHANGES AND INTERINDIVIDUAL DIFFERENCES IN MEMORY PERFORMANCE IN ELDERLY ADULTS

Memory experts. The most impressive evidence for interindividual differences in memory performance are the (mostly anecdotal) reports on memory experts (see e.g., Binet, 1894; Müller, 1913; Neisser, 1982). These reports describe people who, for example, know the results of all multiplications of the numbers between 1 and 100, or who can name the correct day of the week corresponding to any date of this century or the last century, or who can memorize texts of entire books.

Traditionally, it was assumed that persons with such unusual memory performance have an exceptional memory. This seems true for certain memory experts (eidetics). On the other hand, Ericsson's (1985) systematic analysis of the characteristics of learning and remembering of several well-known memory experts, as well as of extremely good memory performances of people in their daily work (e.g., waiters) show that even very high memory achievements can be explained by the availability and use of knowledge and the availability and use of especially effective learning and memory strategies. The construction and functioning of such knowledge systems have been documented by Chase and Ericsson in training studies (e.g., Chase & Ericsson, 1981, 1982).

In the field of aging, these training studies have attained importance because they test the question if memory in old age, when optimally trained, can achieve the accomplishments of memory experts (testing-the-limits). Further, training studies can eliminate the often-mentioned problem that the performance deficits found in cross-sectional or longitudinal studies reflect the limited practice of elderly adults rather than a decrease in memory performance (see Welford, 1985).

A memory training study is currently being conducted by Baltes and his colleagues at the Max-Planck-Institute for Human Development and Education in Berlin (see e.g., Kliegl & Baltes, 1986; Kliegl, Smith, & Baltes, 1986). The goal of this intensive training program has been to establish expert knowledge in elderly adults, enabling them to transform meaningless triads of numbers into meaningful units and thus learn and remember a whole series of these number triads. History knowledge was chosen as the knowledge system to which the number triads could be related. The availability of this knowledge makes it possible for the participants of the training program to interpret the number triads as historical events. In the second part of the training program, a cognitive map was constructed which represented a route through the city of Berlin. This map was suited for a serial structuring of the elements to be learned in that each number triad was successively linked to the different stations on the map (method of loci).

The results of this training program first demonstrated that people approximately 70-years-old are capable of building up the immense knowledge which allows them to learn and reproduce more than 100 numbers in random order. Accordingly, young as well as elderly people can improve their memory for numbers so dramatically through training that they appear to be memory experts compared to nontrained persons. From a developmental point of view, the performance differences which arise between young and older trainees after longer use of the knowledge system are particularly interesting: Older people are not able to increase the speed of information processing through use of the knowledge system to the same degree as the younger people. The increment in the speed of processing is described as a result of an assimilation process, whereby the recently acquired knowledge is integrated into one's own existing knowledge, as well as the increased automatization of information processing. In elderly adults, the assimilation of acquired knowledge into their own knowledge systems has only been observed to a limited extent. In addition, large interindividual differences among elderly adults in using the acquired knowledge system have been demonstrated.

The knowledge system, as analyzed by Kliegl and Baltes (1986), is relatively artificial, extremely limited, and constructed for the optimal mastery of a memory task that is not a part of the daily learning and remembering routines. Kliegl and Baltes (1986) do not claim that knowledge systems of this type are representative of everyday life experiences. In the following paragraphs, we pursue the question of the importance of domain-specific knowledge for the emergence of interindividual differences in memory performances.

Domain-Specific Knowledge and Memory Performance. One type of knowledge concerns specific subject areas with which individuals occupy themselves at work or in their free time. Although some people have a lot of knowledge of this type (experts), others do not (novices). Examples concern the knowledge of chess, of natural sciences (physics, chemistry, mathematics), of computer programming, and of medicine. There is accumulated evidence that experts can learn and recall information from their domains of expertise more quickly and more accurately than novices can (Voss, Fincher-Kiefer, Greene, & Post, 1986).

However, studies on the effect of expertise have been mostly conducted with younger people. In the few studies with elderly adults, evidence for the expert effect was established for nonverbal material exclusively. Charness (1981a, 1981b, 1982, 1985b), for example, asked chess experts between 20- and 70-years-of-age to remember chess positions for games they had played before. It should be noted that because the participants in these studies were tournament players, their performance variance was reduced in comparison to a normal population of chess players and that age and skill level were uncorrelated. In a multiple regression analysis, it could be shown that the quality of recall was significantly related to both age (explaining 37% of the variance, see Charness, 1981a) and skill (explaining 22% of the variance). The older the player was, the worse his recall score. The more skilled the player was, the better the recall score.

It is interesting to note that the age-related decline in free recall for chess positions does not correspond to an age-related decline in the quality of the chess game. The mean outcome in a chess test, requiring that the best move be chosen, was significantly related only to skill level. The same is true for a second test, where an endgame position was evaluated. It is still an open question whether the knowledge effect in old age is similar for the acquisition of verbal material.

A study conducted in our laboratory has impressively documented the importance of domain-specific knowledge for text memory in elderly adults. In the aforementioned study by Knopf (1987), memory performance of elderly adults (age range: 50 to 86 years) who had domain-specific knowledge of the specific contents treated in the texts was compared with memory performance of those who had little or no domain-specific knowledge. Experts were separated from novices on the basis of a short test (domain-specific questions). The six short texts dealt with the campaign events and the U.S. presidential election of Ronald Reagan in 1980. Learning time was self-paced. For each text, a free recall test was conducted after study. In the first run, the gist of the six texts was to be learned and recalled; in the second run, the six texts were to be learned and

TABLE VI

Mean Amount of Recall in Text Learning as a Function of Domain-Specific Knowledge

	Domain-specific knowledge		
	Low and medium (N = 83)	High (N = 41)	Wilcoxon-test
Amount of learning time (sec) in the gist learning task	939.28 (441.66)[a]	785.26 (413.49)	ns
Amount of learning time (sec) in the detail learning task	745.07 (385.61)	653.54 (360.11)	ns
Number of propositions recalled in the gist learning task (max = 915)	193.3 (72.8)	251.6 (84.0)	p <.001
Number of propositions recalled in the detail learning task (max = 915)	232.5 (91.4)	294.0 (95.8)	p <.001
Number of text-related questions answered in the cued recall test (max = 7)	2.84 (2.10)	4.27 (1.94)	p <.001
Number of inference questions answered in the cued recall test (max = 14)	5.31 (3.47)	7.44 (3.15)	p <.001

[a] Numbers in parentheses indicate standard deviations.

recalled in detail. At the end of both runs, memory performance was globally tested by text-related and inference questions. Experts did not differ from novices in age or in relevant aspects of cognitive functioning (e.g., verbal intelligence, nonverbal intelligence, memory span).

As can be seen from Table VI, experts and novices took a similarly long time to learn the texts. In the memory tests, however, significantly better performance was found for the experts: This was true for both recall of the gist and for recall of the text details. In addition, experts were superior in answering both types of text-related questions.

Similiar to the findings by Charness with chess experts, our study showed that possessing expert knowledge is a favorable condition for the stability of memory performance in later adulthood and old age: Although an age-related decline in gist recall and free recall of details was found in the total sample of elderly adults (see Table V), these unfavorable age-related differences in memory performance disappeared when the data of the expert group were analyzed separately. Thus, these results demonstrate that older learners can compensate for age-related memory decline by using their elaborated knowledge base.

E. BASIC CHARACTERISTICS OF THE MEMORY SYSTEM AS SOURCES OF DEVELOPMENTAL AND INTERINDIVIDUAL DIFFERENCES IN MEMORY PERFORMANCE IN ELDERLY ADULTS

In an experimental approach to aging research (Kausler, 1982), the question is pursued if within or between group differences in memory performance can be traced back to basic characteristics of the memory system. Typical research problems concern the interindividual variability of structural characteristics of the memory system (e.g., short-term storage capacity; see Dempster, 1981), processing characteristics of short-term memory (e.g., rate of forgetting, speed of rehearsal; see Humphreys, Lynch, Revelle, & Hall, 1983; Salthouse & Kail, 1983), and basic long-term memory differences (e.g., priming effects; semantic verification latencies; see e.g., Gitomer & Pellegrino, 1985).

It should be noted that this approach has a long tradition. Interindividual differences in short-term memory capacity were postulated as a basic characteristic of cognitive functioning at the very beginning of research in human memory and intelligence (Galton, 1887). The digit-span test has been used to measure this capacity and to discriminate among individuals since the time of Binet (Binet & Simon, 1905). Almost 100 years later, memory span is still the most prominent indicator of a basic characteristic of the memory system. It was demonstrated in many developmental studies that memory span is relatively stable over the life span; the changes observed in advanced adulthood are rather small (see Craik, 1977 for a review). This result is supported by cross-sectional, as well as by longitudinal studies (e.g., Jarvik & Bank, 1983).

Drastic changes in memory span in old age could be found only for a small number of people and are probably due to pathological brain deterioration processes (Matarazzo, 1982). Short-term memory capacity is therefore used as an indicator of severe brain deterioration. As a consequence, it is assumed that not every level of memory span is equally suited for explaining memory performances in elderly adults. Rather, there appears to be a minimal capacity level which is sufficient for attaining good memory performances in a wide range of memory tasks. In our own study (Knopf, 1987) a memory span of four and above was not a good predictor of memory performance in different age groups of elderly adults. However, same-age subjects who had attained a memory span up to three in the pretests, (and thus not participated in the study) were unable to deal (especially) with the more difficult text learning task that was used in our investigation.

Memory span has lost some of its theoretical importance as a basic indicator of the memory system since it was shown that it can be traced back to still more basic properties of the memory system. Dempster (1981), for example, discusses strategic (such as rehearsal, chunking, retrieval strategies) as well as nonstrategic processes (such as item identification speed, search rate) as sources of developmental and interindividual differences in memory span.

Recent studies on basic memory characteristics and their change in old age have up to now not come up with consistent results (see for a summary, Kausler, 1982). The most uniform results concern the speed with which information can be identified in short-term memory (memory scanning time). The procedure involves presenting subjects with a short list of items to be remembered, and then presenting a probe item that is classified with respect to whether or not it was in the list (Sternberg paradigm). In a series of studies, it was demonstrated that older people scan memory more slowly than younger ones (e.g., Anders & Fozard, 1973; Anders, Fozard, & Lillyquist, 1972; Eriksen, Hamlin, & Daye, 1973; Lorsbach & Simpson, 1984; Salthouse & Somberg, 1982a, 1982b). On the other hand, no evidence was found for a qualitative change in memory search. Thus, for elderly adults as well as for young subjects, reaction time increases as memory set size increases, and reaction time is the same for positive and negative probe items. These results document that, regardless of age, information can be retained with similar quality in short-term memory, independent of processing speed, complexity of the information, and positions of the items in the presentation. With increasing age, however, speed of accessibility of this information decreases (for a summary, see Kausler, 1982). This is interpreted as evidence for changes in secondary-memory processes, which identify incoming information. In one of the few cross-sectional studies analyzing interindividual differences in memory scanning in elderly adults, Thomas, Waugh, and Fozard (1978) demonstrated that not only are reaction times poorer with increasing age, but that the interindividual differences in memory scanning in old age actually increase. The question of whether the scanning rate is really a basic memory characteristic has recently been discussed anew, after an increase in scanning rate due to practice effects was found in elderly adults in the Salthouse and Somberg (1982b) study.

The Role of Basic Memory Process in Tracing Complex Memory Performances. One of the aims in the analysis of basic memory processes is to break down complex memory performance (e.g., free recall) into components, and in doing so to explain the existence of interindividual performance differences in complex memory performance via differences in basic characteristics of the memory system. It is questionable if this goal will be reached in the future since studies that analyze complex memory performance as a result of more basic processes are still rare. Evidence (which points in the direction of not attaining this goal) can be found in the papers of Charness (1985a, 1985b) and Salthouse (1984). Charness (1985a, 1985b) investigated the performances of bridge players in bridge tasks and their cognitive ability in general (reaction time, different aspects of memory, problem-solving ability). The following pattern of results was consistent: On bridge-related tasks (full and partial bridge bidding tasks), speed and accuracy increased with skill level regardless of age, whereas speed declined with age only for the translation of card symbols to points.

However, bridge expertise was not related to performance on non-bridge tasks, and performance declined consistently with age regarding reaction time, memory span, and problem solving. It is argued that acquiring expertise provides efficient procedures for tapping an extensive, though domain-constrained knowledge base.

The same paradox, and the same type of results arose in a study of skilled typing (Salthouse, 1984). Salthouse studied typists, ranging in age from 19- to 72-years, with a typing speed of 17 to 104 wpm. He found the well-known age-related declines in the simple skills that presumably underlie typing, namely choice reaction time, rate of tapping, and digit-symbol substitution rate. Nevertheless, the slower performances on these tasks were accompanied by nearly stable performances across the adult life span in the rate of typing. Individuals could differ between 80 and 150 ms in choice reaction time between the ages 20 to 60, and yet the average interkey interval in typing was found to be nearly identical for the 20- to 60-year-old typists. It is suggested that older people compensate for their general slowing down by being more sensitive to characters ahead of the character just being typed. The question of why younger typists are not able to type in this effective way has not yet been answered.

As a number of memory performance decreases in elderly adults have been well established, it is certain that compensatory mechanisms in the memory system are limited. Just where these limits are, however, is not known. It has not been clarified, for example, if too severe of a deficit in one area of memory is principally not compensable, if cognitive resources available to older people are insufficient to compensate for arising deficiencies, or if the compensatory mechanism of the memory system might decline with increasing age. Above all, it has not been clarified if the interindividual differences in memory performance in old age can be seen as a result of differences in such compensatory mechanisms.

V. Concluding Remarks

In a recent chapter on memory development, Salthouse and Kausler (1985) discuss some of the methodological problems of research in this field, in particular problems in generalizing from empirical findings and in deriving theoretical conclusions on this basis. The question raised here refers to the great variability of memory phenomena, to their countless attributes, modalities, and contents, different retention intervals, as well as to the issue of the internal validity of particular studies and the ecological validity of the experimental settings. An implicit assumption when dealing with this broad reference system is that the results reported in this chapter are generalizable only within relatively narrow limits. The studies considered in this chapter mostly used different word lists and texts as learning materials, short retention intervals, and free recall tests to analyze the memory performance of elementary school children and older adults. The question then is whether generalizable conclusions concerning individual differences in memory development across the life span can be derived on the basis of these studies. The answer will be in the negative if we are considering in what individuals within different age groups and within different social settings actually learn, represent, and are able to retrieve, and how much information, under variable conditions, they are able to access and to use. However, our answer will be less skeptical if our prime concern is the role of specific factors as sources of individual differences in memory development. Mook (1983) has correctly emphasized the importance of the theoretical basis of the external validity of research results:

> Ultimately, what makes research findings of interest is that they help us understand everyday life. That understanding, however, comes from theory or the analysis of mechanism; it is not a matter of generalizing the findings themselves . . . The validity of these generalizations is tested by their success at prediction and has nothing to do with the naturalness, representativeness, or even noncreativity of the investigations on which they rest. (p. 386)

A second restriction concerns the analysis of individual differences in memory *development*. Data from longitudinal studies are rare in the literature. Our own projects comprise a span of only 2 years. It is not possible, therefore, to directly investigate whether individuals take the same route of memory development but differ only in their rate of change, or whether there are different routes in memory development. The description and explanation of individual differences in this chapter has been guided by the transfer of explanatory variables for the analysis of developmental differences: That is, we assumed that the explanatory variables for memory development are also relevant for the explanation of individual differences. Accordingly, the analyses comprised interindividual performance differences of subjects within the same age group, intraindividual differences across various memory tasks, and the possibility of age-related deficits being compensated by the individual's availability of specific competences (such as an elaborate knowledge base or the use of effective memory strategies).

From this perspective, and on the basis of the research findings concerning individual differences in memory development, only a small part of which are, however, reported here, three generalizations appear justifiable:

First generalization: Individual differences in the knowledge base are a major source of intra- and interindividual differences in memory performance, irrespective of chronological age. The major role of the knowledge base in explaining individual differences in memory performance has been impressively demonstrated by experimental evidence both from studies of elementary school children and elderly adults. Moreover, when one subsumes under the individual knowledge base such aspects of knowledge as general world knowledge, domain-specific knowledge, declarative and procedural knowledge, then the individual differences reported will explain a great deal of the variance found in memory performance.

The crucial factor seems to be that the construction of a mental representation of the information to be learned and later to be retrieved is largely determined by available knowledge (Hesse, 1985). The knowledge base comprises not only facts, concepts, and rules but also explanations, inferences, and operations, which regulate the conceptual behavior of the individual in the mastery of a learning and memory task (Wattenmaker, Dewey, Murphy, & Medin, 1986). Resnick and Neches (1984) "have been able to show the role of particular schemata in both inducing and resolving the cognitive conflicts that appears to be at the heart of some forms of learning" (p. 319).

Second generalization: The role of domain-specific knowledge is increasingly important for memory performance as a function of complexity of the to-be-learned information, and the difficulty of the criteria for the use of such information. Conversely, the more general the memory-related knowledge and memory strategies, the less effective they are in resolving difficult tasks with a domain-specific content. For easy tasks or tasks of medium difficulty, there is a wide range of compensatory mechanisms between domain-specific and memory-related knowledge.

Two broadly defined classes of knowledge have been typically distinguished in recent research on memory development: Domain-specific knowledge relates to the domain from which specific information must be acquired and/or retrieved to master a given task; memory-related knowledge (i.e., metamemory) relates to all aspects of the cognitive system and of cognitive activities, which facilitated the acquisition and use of knowledge. The second category thus refers to knowledge (e.g., knowledge about goals of memory tasks), metamemory knowledge (e.g., concerning the difficulty level of the task and by what behavior means it can best be mastered), memory strategies (e.g., rehearsal) and metastrategies (e.g., monitoring). Research findings have amply demonstrated a great amount of functional compensation between domain-specific and memory-related knowledge whenever relatively easy tasks were used. However, the limits of such compensations are not yet known, and assumptions concerning them can only be made on the basis of plausible threshold values. It appears that the compensatory functions are drastically reduced when difficult memory tasks are used (Kintsch, 1986; Schmalhofer, 1982). In such instances domain-specific knowledge and its automatized use are a necessary condition for good memory performance. Apparently, general learning and retrieval strategies are not very effective here (Siegler, 1983).

Both domain-specific and memory-related knowledge grow in quantity and quality throughout childhood. Here formal schooling plays an important role (Weinert & Treiber, 1982). Whereas we know only little about the distributional pattern of domain-specific knowledge in various cultures, in different populations, and in various age groups (in particular adolescents and adults), some indicators reveal that memory-related knowledge is stabilized at a relatively high level during adolescence and remains relatively constant until old age (Weinert et al., 1984). It is, however, still an open question whether the compensation mechanisms remain invariant across the life span or whether the range of functional compensations between content-related and memory-related knowledge is reduced in old age.

Third generalization: To explain individual differences in memory performance, relatively stable differences in memory capacities must be assumed, in addition to variations in the knowledge base. Predictions of individual differences in memory performance (within and between age groups) made on the basis of indicators relating to the knowledge base are comparably reliable but by far not perfect. The opinion that the hardware of the memory system has capacity limitations appears frequently in the research literature. An additional factor to be considered in this context is that the role of the knowledge base in explaining memory performance is most probably overestimated within the developmental perspective because the acquisition of knowledge and the individual differences observable here are not considered within the novice-expert paradigm. Estes (1982) has recently emphasized this aspect:

> Presumably, individual differences in the structural aspects of memory (referring to aspects that are independent of experience and that impose limits on the capacity and efficiency of operations of the system) would be set by individual anatomical and physiological characteristics innately determined to some major extent. Control processes refer to aspects of the system that do result from training and individual experience and are presumably under voluntary control—for example, the use of mnemonic strategies . . . Because both structural and control processes must be implicated in every test used to assess memory or memory abilities, it follows that all of the results on individual differences . . . must have utilized measures of abilities in which structural and control processes are confounded. Consequently, no conclusion can be drawn from that body of work regarding individual differences in aspects of memory that should be relatively persistent over time. (p. 205)

In recent years, several experiments were conducted to assess basic capacities of memory separately. Various cognitive processing parameters, like the speed of processing or speed-accuracy tradeoff indicators (Salthouse & Kail, 1983), working memory capacity (Case, 1985), associative acquisition capacity (Langley, Neches, Neves, & Anzai, 1981), retention/retrieval capacities (Brainerd, Kingma, & Howe, 1985; Burke & Light, 1981), and abstract thinking capacities (Piaget & Inhelder, 1968) were all considered. Notwithstanding these efforts, the present status of the research is not satisfying. One reason for this could be that relatively complex memory tasks have been used predominantly in experimental studies where memory performance is determined by multiple factors which overlap with the effects of specific capacity limits and thus to some extent do have compensatory effects. Therefore, one important task of future research should be to make the development of individual differences in memory capacities measurable. Currently, several interesting new approaches (Dillon, 1985; Dillon & Schmeck, 1983) provide a more than adequate basis for assessment in future longitudinal studies of the combined effect of the knowledge base and capacity measures on memory *development* and on individual differences.

References

Anders, T. R., & Fozard, J. L. (1973). Effects of age upon retrieval from primary and secondary memory. *Developmental Psychology, 9,* 411–416.

Anders, T. R., Fozard, J. L., & Lillyquist, T. D. (1972). Effects of age upon retrieval from short-term memory. *Developmental Psychology, 6,* 214–217.

Baker-Ward, L., Ornstein, P. A., & Holden, D. J. (1984). The expression of memorization in early childhood. *Journal of Experimental Child Psychology, 37,* 555–575.

Belmont, J. M., & Butterfield, E. C. (1971). What the development of short-term memory is. *Human Development, 14,* 236–248.

Binet, A. (1894). *Psychologie des grands calculateurs et joueurs d'echecs.* Paris: Hachette.

Binet, A., & Henri, V. (1894). La memoire des phrases (memoire des idees). *L'Annee Psychologique, 1,* 24–59.

Binet, A., & Simon, T. (1905). Methodes nouvelles pour le diagnostique du niveau intellectuel des anormaux. *L'Annee Psychologique, 11,* 191–244.

Bjorklund, D. F. (1985). The role of conceptual knowledge in the development of organization in children's memory. In C. J. Brainerd & M. Pressley (Eds.), *Basic processes in memory development: Progress in cognitive development research* (pp. 103–142). New York: Springer.

Bjorklund, D. F., & Bjorklund, B. R. (1985). Organization versus item effects of an elaborated knowledge base on children's memory. *Developmental Psychology, 21,* 1120–1131.

Bjorklund, D. F., & Zeman, B. R. (1982). Children's organization and metamemory awareness in their recall of familiar information. *Child Development, 53,* 799–810.

Botwinick, J. (1978). *Aging and behavior* (2nd ed.). New York: Springer.

Brainerd, C. J., Kingma, J., & Howe, M. L. (1985). On the development of forgetting. *Child Development, 56,* 1103–1119.

Bransford, J. D., Stein, B. S., Shelton, T. S., & Owings, R. (1981). Cognition and adaptation. The importance of learning to learn. In J. H. Harvey (Ed.), *Cognition, social behavior, and the environment.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Brown, A. L., Bransford, J. D., Ferrara, R. A., & Campione, J. C. (1983). Learning, remembering and understanding. In J. H. Flavell & E. M. Markman (Eds.), *Handbook of child psychology: Vol. 3. Cognitive development* (4th ed., pp. 77–166). New York: Wiley.

Bruce, P., Coyne, A. C., & Botwinick, J. (1982). Adult age differences in metamemory. *Journal of Gerontology, 37,* 354–357.

Burke, D. M., & Light, L. L. (1981). Memory and aging: The role of retrieval processes. *Psychological Bulletin, 90,* 513–546.

Campione, J. C., Brown, A. L., & Bryant, N. C. (1985). Individual differences in learning and memory. In R. J. Sternberg (Ed.), *Human abilities: An information processing approach* (pp. 103–126). New York: Freeman.

Carey, S. (1985). *Conceptual change in childhood.* Cambridge: MIT Press.

Case, R. (1985). *Intellectual development: Birth to adulthood.* New York: Academic Press.

Cavanaugh, J. C., & Borkowski, J. G. (1980). Searching for metamemory—memory connections: A developmental study. *Developmental Psychology, 16,* 441–453.

Charness, N. (1981a). Aging and skilled problem solving. *Journal of Experimental Psychology: General, 110,* 21–38.

Charness, N. (1981b). Visual short-term memory and aging in chess players. *Journal of Gerontology, 36,* 615–619.

Charness, N. (1982). Problem-solving and aging: Evidence from semantically rich domains. *Canadian Journal on Aging, 1,* 21–28.

Charness, N. (1985a). Aging and problem-solving performance. In N. Charness (Ed.), *Aging and human performance* (pp. 225–254). New York: Wiley.

Charness, N. (1985b, July). Age and expertise: The hardware/software trade off. Paper given at the 13th International Congress on Gerontology, New York.

Chase, W. G., & Ericsson, K. A. (1981). Skilled memory. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition* (pp. 141–189). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chase, W. G., & Ericsson, K. A. (1982). Skill and working memory. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 16, pp. 1–58). New York: Academic Press.

Chi, M. T. H. (1978). Knowledge structures and memory development. In R. Siegler (Ed.), *Children's thinking: What develops?* (pp. 73–96). Hillsdale, NJ: Lawrence Erlbaum Associates.

Chi, M. T. H. (1984). Bereichsspezifisches Wissen und Metakognition. In F. E. Weinert & R. H. Kluwe (Eds.), *Metakognition, Motivation und Lernen* (pp. 211–232). Stuttgart: Kohlhammer.

Chi, M. T. H. (1985). Changing conceptions of sources of memory development. *Human Development, 28,* 50–56.

Coyne, A. C. (1985). Adult age, presentation time, and memory performance. *Experimental Aging Research, 11,* 147–149.

Craik, F. I. M. (1977). Age differences in human memory. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (pp. 384–420). New York: Van Nostrand.

DeLoache, J. S., Cassidy, D. J., & Brown, A. L. (1985). Precursors of mnemonic strategies in very young children's memory. *Child Development, 56,* 125–137.

Dempster, F. N. (1981). Memory span: Sources of individual and developmental differences. *Psychological Bulletin, 89,* 63–100.

Dempster, F. N. (1985). Short-term memory development in childhood and adolescence. In C. J. Brainerd & M. Pressley (Eds.), *Basic processes in memory development. Progress in cognitive development research* (pp. 209–248). New York: Springer.

Denney, N. W. (1974). Classification abilities in the elderly. *Journal of Gerontology, 29,* 309–314.

Denney, N. W. (1982). Aging and cognitive changes. In B. B. Wolman (Ed.), *Handbook of developmental psychology.* Englewood Cliffs, NJ: Prentice-Hall.

Dillon, R. F. (Ed.). (1985). *Individual differences in cognition.* (Vol. 2). New York: Academic Press.

Dillon, R. F., & Schmeck, R. R. (Eds.). (1983). *Individual differences in cognition.* (Vol. 1). New York: Academic Press.

Ebbinghaus, H. (1885). *Über das Gedächtnis*. Darmstadt: Wissenschaftliche Buchgesellschaft.

Ebbinghaus, H. (1983). *Urmanuskript "Über das Gedächtnis" 1880*. Passau: Passavia Universitätsverlag.

Ericsson, K. A. (1985). Memory skill. *Canadian Journal of Psychology, 39*, 188–231.

Eriksen, C. W., Hamlin, R. M., & Daye, C. (1973). Aging adults and rate of memory scan. *Bulletin of the Psychonomic Society, 1*, 259–260.

Estes, W. K. (1982). Learning, memory, and intelligence. In R. J. Sternberg (Ed.), *Handbook of human intelligence* (pp. 170–224). Cambridge, England: Cambridge University Press.

Evans, R. A., & Bilsky, L. H. (1979). Clustering and categorical list retention in the mentally retarded. In N. R. Ellis (Ed.), *Handbook of mental deficiency. Psychological theory and research* (2nd ed., pp. 533–567). Hillsdale, NJ: Lawrence Erlbaum Associates.

Flavell, J. H. (1971). First discussant's comments: What is memory development the development of? *Human Development, 14*, 272–278.

Flavell, J. H., & Wellman, H. M. (1977). Metamemory. In R. V. Kail & J. W. Hagen (Eds.), *Perspectives on the development of memory and cognition* (pp. 3–33). Hillsdale, NJ: Lawrence Erlbaum Associates.

Frankel, M. T., & Rollins, H. A. (1985). Associative and categorical hypotheses of organization in free recall of adults and children. *Journal of Experimental Child Psychology, 40*, 304–318.

Galton, F. (1887). Notes on prehension in idiots. *Mind, 12*, 79–82.

Gitomer, D. H., & Pellegrino, J. W. (1985). Developmental and individual differences in long-term memory retrieval. In R. F. Dillon (Ed.), *Individual differences in cognition* (Vol. 2, pp. 1–34). New York: Academic Press.

Guttentag, R. E. (1985). Memory and aging: Implications for theories of memory development during childhood. *Developmental Review, 5*, 56–82.

Hasselhorn, M. (1986). *Differentielle Bedingungsanalyse verbaler Gedächtnisleistungen bei Schulkindern*. Frankfurt: Peter Lang.

Hesse, F. W. (1985). Vergleichende Analyse kognitiver Prozesse bei semantisch unterschiedlichen Problemeinbettungen. *Sprache & Kognition, 3*, 139–153.

Hollingworth, L. S. (1920). *The psychology of subnormal children*. New York: Macmillan.

Hultsch, D. F., & Dixon, R. A. (1984). Memory for text materials in adulthood. In P. B. Baltes & O. G. Brim, Jr. (Eds.), *Life-span development and behavior* (Vol. 6, pp. 78–108). New York: Academic Press.

Humphreys, M. S., Lynch, M. J., Revelle, W., & Hall, J. W. (1983). Individual differences in short-term memory. In R. F. Dillon & R. R. Schmeck (Eds.), *Individual differences in cognition* (Vol. 1., pp. 35–64). New York: Academic Press.

James, W. (1890). *The principles of psychology* (Vol. 1). New York: Dover.

Jarvik, L. F., & Bank, L. (1983). Aging twins: Longitudinal psychometric data. In W. K. Schaie (Ed.), *Longitudinal studies of adult psychological development* (pp. 40–63). New York: Guilford Press.

Johnson, G. D., & Blake, K. A. (1960). *Learning performance of retarded and normal children*. New York: Syracuse University Press.

Kail, R. V. (1979). Use of strategies and individual differences in children's memory. *Developmental Psychology, 15*, 251–255.

Kausler, D. H. (1982). *Experimental psychology and human aging*. New York: Wiley.

Keeney, T. J., Cannizzo, S. R., & Flavell, J. H. (1967). Spontaneous and induced verbal rehearsal in a recall task. *Child Development, 38*, 953–966.

Kintsch, W. (1986). Memory for prose. In F. Klix & H. Hagendorf (Eds.), *In memoriam Hermann Ebbinghaus. Symposium on Structures and Functions of Human Memory* (pp. 841–850). Amsterdam: Elsevier.

Kliegl, R., & Baltes, P. B. (1986). Theory-guided analysis of mechanisms of development and aging through testing-the-limits and research on expertise. In C. Schooler & K. W. Schaie (Eds.), *Social structure and individual aging processes* (pp. 95–119). Norwood, NJ: Ablex.

Kliegl, R., Smith, J., & Baltes, P. B. (1986). Testing-the-limits, expertise, and memory in adulthood and old age. In F. Klix & H. Hagendorf (Eds.), *In memoriam Hermann Ebbinghaus. Symposium on Structures and Functions of Human Memory* (pp. 395–407). Amsterdam: Elsevier.

Knopf, M. (1987). Gedächtnis im Alter. Berlin, Heidelberg, New York: Springer Verlag.

Knopf, M., Körkel, J., Schneider, W., & Weinert, F. E. (in press). Human memory as a faculty versus human memory as a set of specific abilities: Evidence from a life-span approach. In F. E. Weinert & M. Perlmutter (Eds.), *Memory development: Universal changes and individual development*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Körkel, J. (1987). *Die Entwicklung von Gedächtnis- und Metagedächtnisleistungen in Abhängigkeit von bereichsspezifischen Vorkenntnissen*. Frankfurt: Peter Lang.

Körkel, J., Schneider, W., Vogel, K., & Weinert, F. E. (1983, August). Developmental changes in the metamemory-memory behavior relationship. *Poster presented at the Seventh Biennial Meetings of the ISSBD*, München.

Krauss, J. K. (1980). Between- and within-group comparisons in aging research. In L. W. Poon (Ed.), *Aging in the 1980s* (pp. 542–551). Washington, D.C.: APA.

Labouvie-Vief, G., & Schell, D. A. (1982). Learning and memory in later life. In B. B. Wolman (Ed.), *Handbook of developmental psychology* (pp. 828–846). Englewood Cliffs, NJ: Prentice Hall.

Lachman, J. L., & Lachman, R. (1980). Age and the actualization of world knowledge. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging* (pp. 285–311). Hillsdale, NJ: Erlbaum.

Lachman, J. L., Lachman, R., & Thronesbery, C. (1979). Metamemory through the adult life span. *Developmental Psychology, 15*, 543–551.

Lange, G. (1978). Organization-related processes in children's recall. In P. A. Ornstein (Ed.), *Memory development in children* (pp. 101–128). Hillsdale, NJ: Erlbaum.

Langley, P., Neches, R., Neves, D., & Anzai, J. (1981). A domain-independent framework for procedural learning. *Policy Analysis and Information Systems. Special Issue on Knowledge Acquisition and Induction, 4*, 163–197.

Lorsbach, T. C., & Simpson, G. B. (1984). Age differences in the rate of processing in short-term memory. *Journal of Gerontology, 39*, 315–321.

Lovelace, E. A., & Marsh, G. R. (1985). Prediction and evaluation of memory performance by young and old adults. *Journal of Gerontology, 40*, 192–197.

Matarazzo, J. D. (1982). *Die Messung und Bewertung der Intelligenz Erwachsener nach Wechsler*. Bern: Huber.

McGeoch, J. A., & Irion, A. L. (1952). *The psychology of human learning* (2nd ed.). New York: Longmans, Green & Co.

Meumann, E. (1918). *Ökonomie und Technik des Gedächtnisses* (Vol. 1). Leipzig: Klinkhardt.

Meyer, B. J. F., & Rice, G. E. (1983). Learning and memory from text across the adult life span. In J. Fine & R. O. Freedle (Eds.), *Developmental studies in discourse* (pp. 291–306). Norwood, NJ: Ablex.

Moely, B. E. (1977). Organizational factors in the development of memory. In R. V. Kail & J. W. Hagen (Eds.), *Perspectives on the development of memory and cognition* (pp. 203–236). Hillsdale, NJ: Erlbaum.

Moely, B. E., Olson, F. A., Halwes, T. G., & Flavell, J. H. (1969). Production deficiency in young children's clustered recall. *Developmental Psychology, 1*, 26–34.

Mook, D. A. (1983). In defense of external invalidity. *American Psychologist, 3,* 379–387.

Müller, G. E. (1913). Neue Versuche mit Rückle. *Zeitschrift für Psychologie und Physiologie der Sinnesorgane, 67,* 193–213.

Murphy, M. D., Sanders, R. E., Gabriesheski, A. S., & Schmitt, F. A. (1981). Metamemory in the aged. *Journal of Gerontology, 36,* 185–193.

Naus, M. J., & Halasz, F. G. (1979). Developmental perspectives on cognitive processing and semantic memory structures. In L. S. Cermak & F. I. M. Craik (Eds.), *Levels of processing in human memory* (pp. 259–288). Hillsdale: Lawrence Erlbaum Associates.

Neisser, U. (1932). *Memory observed: Remembering in natural contexts.* San Francisco: Freeman.

Nelson, K. (1983). The derivation of concepts and categories from event representations. In E. K. Scholnick (Ed.), *New trends in conceptual representation* (pp. 129–149). Hillsdale, NJ: Lawrence Erlbaum Associates.

Ornstein, P. A., & Naus, M. J. (1985). Effects of the knowledge base on children's memory strategies. In H. W. Reese (Ed.), *Advances in child development and behavior* (Vol. 19, pp. 113–148). New York: Academic Press.

Perlmutter, M. (1978). What is memory aging the aging of? *Developmental Psychology, 14,* 330–345.

Piaget, J., & Inhelder, B. (1968). Memoire et intelligence. Paris: Presses Universitaires de France.

Poon, L. W. (1985). Differences in human memory with aging: Nature, causes and clinical implications. In J. E. Birren & K. W. Schaie (Eds.), *Handbook of the psychology of aging* (2nd ed., pp. 427–462). New York: Van Nostrand Reinhold.

Pressley, M., Forrest-Pressley, D. L., Elliott-Faust, D., & Miller, G. (1985). Children's use of cognitive strategies, how to teach strategies, and what to do if they can't be taught. In M. Pressley & C. J. Brainerd (Eds.), *Cognitive learning and memory in children* (pp. 1–47). New York: Springer.

Rabbitt, P. (1981). Cognitive psychology needs models for changes in performance with old age. In J. Long & A. Baddeley (Eds.), *Attention and performance IX* (pp. 555–573). Hillsdale, NJ: Lawrence Erlbaum Associates.

Rabinowitz, J. C., Ackerman, B. P., Craik, F. I. M., & Hinchley, J. L. (1982). Aging and metamemory: The roles of relatedness and imagery. *Journal of Gerontology, 37,* 688–695.

Rabinowitz, M. (1984). The use of categorical organization: Not an all-or-none situation. *Journal of Experimental Child Psychology, 38,* 338–351.

Resnick, C. B., & Neches, R. (1984). Factors affecting individual differences in learning ability. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 2, pp. 275–323). Hillsdale, NJ: Erlbaum.

Roenker, D. L., Thompson, C. P., & Brown, S. C. (1971). Comparison of measures for the estimation of clustering in free recall. *Psychological Bulletin, 76,* 45–48.

Salthouse, T. A. (1984). Effects of age and skill in typing. *Journal of Experimental Psychology: General, 113,* 345–371.

Salthouse, T. A., & Kail, R. (1983). Memory development throughout the life span: The role of processing rate. In P. B. Baltes & O. G. Brim, Jr. (Eds.), *Life-span development and behavior* (Vol. 5, pp. 89–116). New York: Academic Press.

Salthouse, T. A., & Kausler, D. H. (1985). Memory methodology in maturity. In C. J. Brainerd & M. Pressley (Eds.), *Basic processes in memory development* (pp. 279–311). New York: Springer.

Salthouse, T. A., & Somberg, B. L. (1982a). Isolating the age deficit in speeded performance. *Journal of Gerontology, 37,* 59–63.

Salthouse, T. A., & Somberg, B. L. (1982b). Skilled performance: The effects of adult age and experience on elementary processes. *Journal of Experimental Psychology: General, 111*, 176–207.

Schmalhofer, F. J. (1982). *Comprehension of a technical text as a function of expertise*. Unpublished doctoral dissertation, University of Colorado, Boulder.

Schneider, W. (1985). Developmental trends in the metamemory-memory behavior relationship: An integrative review. In D. L. Forrest-Pressley, G. E. MacKinnon, & T. G. Waller (Eds.), *Cognition, metacognition, and human performance* (Vol. 1, pp. 57–109). New York: Academic Press.

Schneider, W. (1986). The role of conceptual knowledge and metamemory in the development of organizational processes in memory. *Journal of Experimental Child Psychology, 42*, 218–236.

Schneider, W., Körkel, J., & Weinert, F. E. (1987a). The effects of intelligence, self-concept, and attributional style on metamemory and memory behavior. *International Journal of Behavioral Development, 10*, 281–299.

Schneider, W., Körkel, J., & Weinert, F. E. (1987b, April). Knowledge base and memory performance: A comparison of academically successful and unsuccessful learners. *Paper presented at the annual meetings of the American Educational Research Association*, Washington, DC.

Siegler, R. S. (1983). Five generalizations about cognitive development. *American Psychologist, 38*, 263–277.

Smith, A. D. (1980). Age differences in encoding, storage, and retrieval. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging* (pp. 23–45). Hillsdale, NJ: Erlbaum.

Sodian, B., Schneider, W., & Perlmutter, M. (1986). Recall, clustering, and metamemory in young children. *Journal of Experimental Child Psychology, 41*, 395–410.

Sophian, L. (1984). Developing search skills in infancy and early childhood. In C. Sophian (Ed.), *Origins of cognitive skill* (pp. 27–56). Hillsdale, NJ: Lawrence Erlbaum Associates.

Stevenson, H. W. (1972). *Children's learning*. New York: Appleton Century Crofts.

Stevenson, H. W., Hale, G. A., Klein, R. F., & Miller, L. K. (1968). Interrelations and correlates in children's learning and problem solving. *Monographs of the Society for Research in Child Development, 33* (7, Serial No. 123).

Thomas, J. C., Waugh, N. C., & Fozard, J. L. (1978). Age and familiarity in memory scanning. *Journal of Gerontology, 33*, 528–533.

Voss, J. F., Fincher-Kiefer, R. H., Greene, T. R., & Post, T. A. (1986). Individual differences in performance: The contrastive approach to knowledge. In R. J. Sternberg (Ed.), *Advances in the psychology of human intelligence* (Vol. 3, pp. 297–334). Hillsdale, NJ: Lawrence Erlbaum Associates.

Voss, J. F., Vesonder, G. T., & Spilich, G. J. (1980). Text generation and recall by high-knowledge and low-knowledge individuals. *Journal of Verbal Learning and Verbal Behavior, 19*, 651–667.

Wattenmaker, W. D., Dewey, G. J., Murphy, T. D., & Medin, D. L. (1986). Linear separability and concept learning: Context, relational properties, and conceptual naturalness. *Cognitive Psychology, 18*, 158–194.

Weinert, F. E. (1986). Developmental variations of memory performance and memory-related knowledge across the life-span. In A. Sørensen, F. E. Weinert, & L. R. Sherrod (Eds.), *Human development: Multidisciplinary perspectives* (pp. 535–554). Hillsdale, NJ: Lawrence Erlbaum Associates.

Weinert, F. E., & Hasselhorn, M. (1986). Memory development: Universal changes and individual differences. In F. Klix & H. Hagendorf (Eds.), *In memoriam Hermann Ebbinghaus. Symposium on Structures and Functions of Human Memory* (pp. 423–435). Amsterdam: Elsevier.

Weinert, F. E., Knopf, M., Körkel, J., Schneider, W., Vogel, K., & Wetzel, M. (1984). Die Entwicklung einiger Gedächtnisleistungen bei Kindern und älteren Erwachsenen in Abhängigkeit von kognitiven, metakognitiven und motivationalen Einflußfaktoren. In K. E. Grossmann & P. Lütkenhaus (Eds.), *Bericht über die 6. Tagung Entwicklungspsychologie* (pp. 313–326). Regensburg: Universitätsdruckerei.

Weinert, F. E., & Schneider, W. (Eds.). (1986). *First report on the Munich Longitudinal Study on the Genesis of Individual Competencies (LOGIC).* Max-Planck-Institute for Psychological Research, Munich.

Weinert, F. E., & Treiber, B. (1982). School socialization and cognitive development. In W. W. Hartup (Ed.), *Review of Child Development Research* (Vol. 6, pp. 704–758). Chicago: The University of Chicago Press.

Welford, A. T. (1985). Changes of performance with age: An overview. In N. Charness (Ed.), *Aging and human performance* (pp. 333–365). New York: Wiley.

Wellman, H. M. (1985). The origins of metacognition. In D. L. Forrest-Pressley, G. E. MacKinnon, & T. G. Waller (Eds.), *Metacognition, cognition and human performance* (Vol. 1, pp. 1–31). New York: Academic Press.

Yussen, S. R. (1985). The role of metacognition in contemporary studies of cognitive development. In D. L. Forrest-Pressley, G. E. MacKinnon, & G. T. Waller (Eds.), *Metacognition, cognition, and human performance* (pp. 253–283). New York: Academic Press.

Zembar, M. J., & Naus, M. J. (1985). The combined effects of knowledge base and mnemonic strategies on children's memory. *Paper presented at the biennial meeting of the Society for Research in Child Development,* Toronto.

Zivian, M. T., & Darjes, R. W. (1983). Free recall by in-school and out-of-school adults: Performance and metamemory. *Developmental Psychology, 19,* 513–520.